ON THE POSSIBILITY OF ESTIMATING YEAR-CLASS STRENGTH BY MEASURING ECHO-ABUNDANCE OF 0-GROUP FISH

By

Olav Dragesund and Steinar Olsen

Fiskeridirektoratets Havforskningsinstitutt

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 leveling off. Various authors have suggested that critical periods exist during early life when mass mortality may occur. 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 (Russel 1935, Knudsen 1954, Saville 1956), and as a working hypothesis for the present investigation it is assumed that such a relation does exist.

During late summer and autumn, fish fry of many species occur pelagically off the Norwegian coast and in the Barents Sea, and their distribution and abundance may be estimated by a combination of echo surveying and fishing experiments with pelagic trawl and purse seine.

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

1. a fairly complete and accurate charting of the vertical and horizontal distribution of the sound scatterers (*echo-abundance*),
2. easy and reliable identification of the sound scatterers,
3. exact measurements 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

Scattering layers have been detected by echo sounding over broad reaches of the oceans (HERSEY and MOORE 1948, JOHNSON 1948, TUCKER 1951, PARRISH and CRAIG 1951). Sometimes observations made by different investigators in the same part of the ocean did not conform, but later investigations showed that these discrepancies were mainly due to differences in echo sounding equipment, especially the operating frequency.

HERSEY and BACKUS (1962) distinguished between "scattering groups" and "scattering layers", and by their definition the scattering groups are discontinuous 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 schooling fishes.

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

The question has often arisen if density discontinuities themselves may give echoes to be recorded as scattering layers. In the North Sea this problem was carefully investigated by WESTON (1958), who demonstrated that the sharp density gradient, usually present 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.

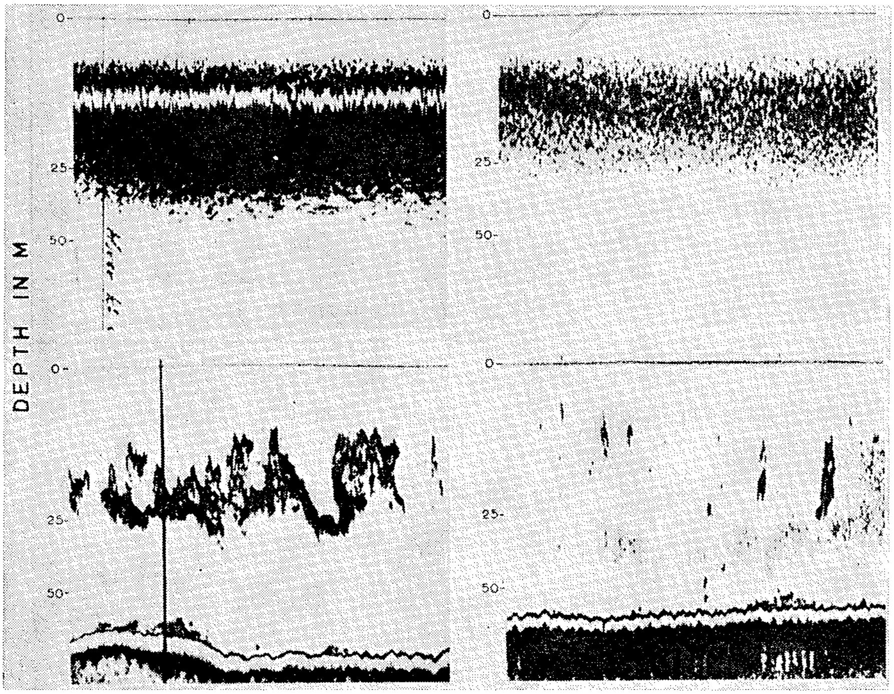

Fig. 1. Echo-recordings of sound scatterers identified as 0-group herring at night (above) and during daytime (below).

The sound scatterers referred to in the present paper are generally distributed in the top layers of water, comprising scattering layers as well as scattering groups according to the terminology of HERSEY and BACKUS. The vertical extension may reach 50—100 m during daytime, but at night the scatterers 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 sound scatterers were frequently recorded in the top layers of water in the Barents Sea and some success was made in identifying their cause by U.W.-photography (MIDTTUN and SÆTERSDAL 1959). However, until 1959 no systematic routine programme of identification was developed. For the present investigation 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 different 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). Further developments of this technique have been applied by Soviet investigators (FEDOROV, TRUSKANOV and YUDANOV 1963) who 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. 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 SYSTEM OF WATER CURRENTS

During the last decade herring in Norwegian waters have spawned from the end of February to the middle of March, and mass hatching of larvae has been completed approximately three weeks later. During the following weeks the distribution of the larvae is determined by the current running along the coast of western and 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 somewhat later than that of the herring (March to April). When the herring larvae pass the Lofoten area they are mixed with cod larvae, and further northwards the pattern of the drift is nearly the same for the two species.

In most years the main spawning of the Arctic haddock takes place south of the Lofoten area, probably south of 65°N (SÆTERSDAL 1952), and the spawning period overlaps that of the cod. The haddock larvae are also distributed in the surface layers, and consequently have a drift pattern similar to that of the cod and herring (WIBORG 1960).

In the areas north of Lofoten, the Barents Sea and the eastern part of the Norwegian Sea, the distribution of the larvae is largely determined by the system of water currents (Fig. 2, modified from TANTSURA 1959).

From the shelf off the Lofoten islands the larvae are transported northwards by the coastal current. Passing the banks off Troms, the drift

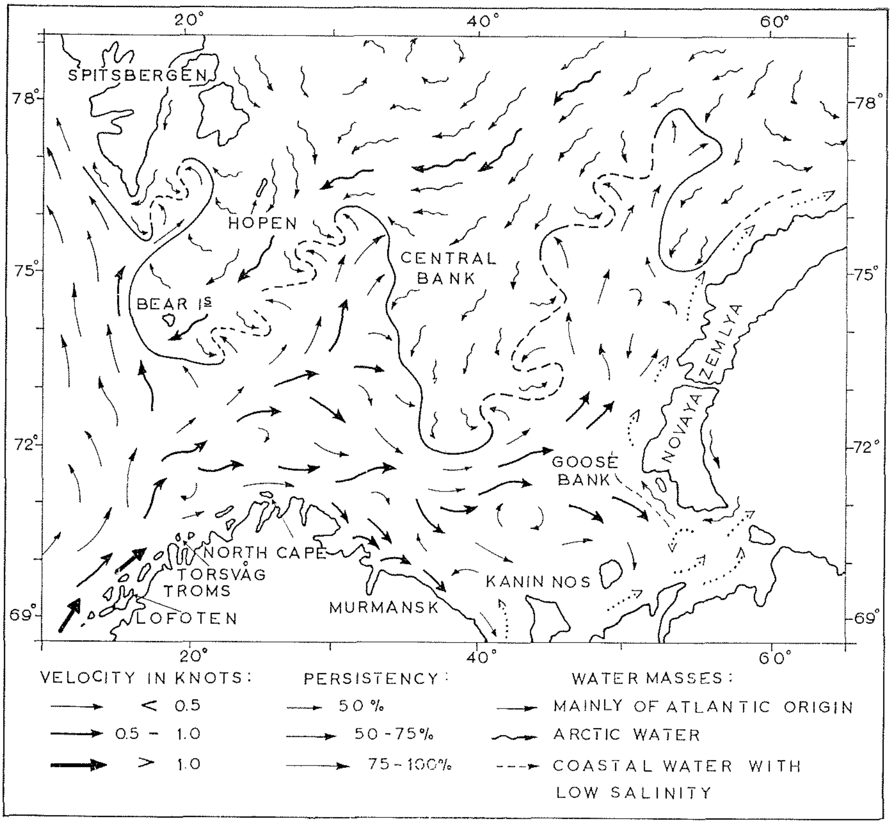

Fig. 2. The general current systems off northern Norway and in the Barents Sea (modified from Tantsura 1959).

becomes more influenced by the Atlantic current, which in this area is intensively mixed with coastal waters (Ljøen 1962). Before reaching the entrance of the Barents Sea, the water masses split into several branches, one proceeding northwards, forming the Spitsbergen current. Off Torsvåg (70°30'N), where a large shelf is located, two east-going branches separate. One of these flows along the coast of West Finnmark (The North Cape Current), the other continues into the northern Barents Sea. The North Cape Current again splits into two branches, one along the southern and the northern slopes of the Goose Bank, the other passing near the Murman coast.

Considering this current system the most extreme distribution of larvae hatched during the same year, and being passively transported by currents, would be off the western shore of Spitsbergen (Hornsund Bank), the southwestern area of the Central Bank, the Novaya Zemlya

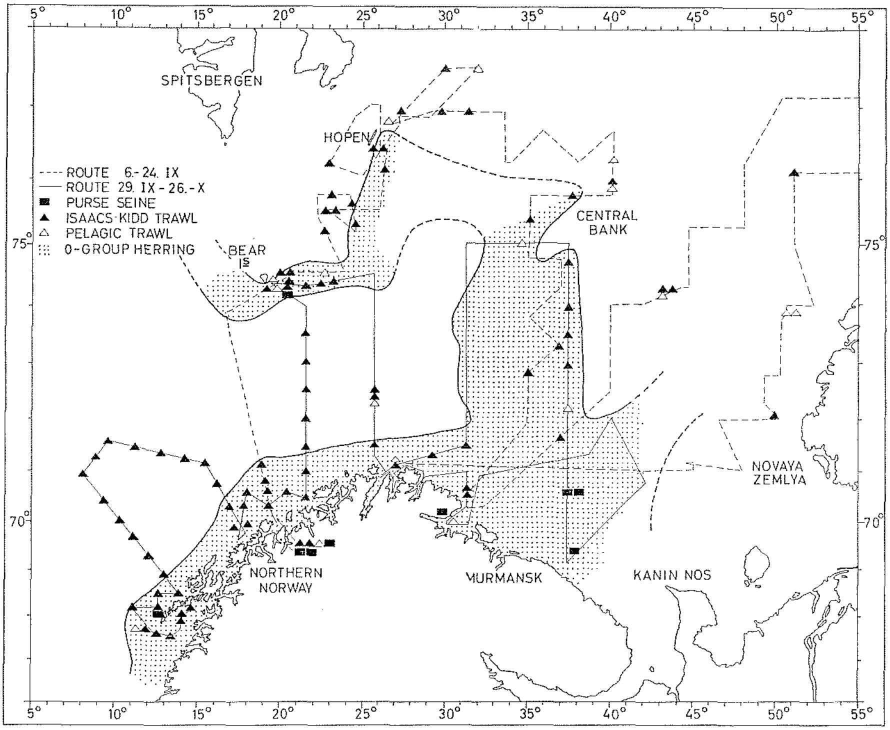

Fig. 3. The distribution of 0-group herring (mainly) in late September and October 1960.

shelf, the southern slope of the Goose Bank, Kanin Nos and the inlet of 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 off the coast of northern Norway and in the Barents Sea, (DRAGESUND and HOGNESTAD 1959, 1962, OLSEN 1960). At the end of the autumn the fry are concentrated 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 in the central and southeastern part of the Barents Sea (Fig. 3). A concentration also takes place along the coast, especially at the entrance of the fjords, whereas between the coast of northern Norway and Bear Island the larvae are less numerous. In late autumn the 0-group of cod, haddock, and to some extent also herring and capelin, descend and settle near bottom, and during the winter months fish fry are more rare in the surface layers.

THE RELATION BETWEEN ECHO SIGNALS AND SCATTERING AGENTS

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

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

when the duration of the pulse is $t_2 - t_1$.
When a target passes through the beam of an echo sounder, echoes may be received for several successive transmissions, and the total sum of voltages of all signal pulses derived from the target is:

$$S_v = b\bar{V} \qquad (2)$$

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

The strength and duration of the individual echoes are affected by the size of the target, and the maximum strength for fish of the same species is found to be a function of the size of the fish (MIDTTUN and HOFF 1961, RICHARDSON *et al.* 1959).

Scatterers distributed at a constant depth

The simple case is considered that fish of the same kind and size are sparsely and evenly distributed in a layer of constant depth, so that there is no overlapping of echoes from individual fish. Further, it is assumed 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 sum of voltages of all signals received is n times that received from one single fish. Thus, the sum of 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.

A school or a layer will always have a vertical as well as a horizontal range, and the echo signals received are therefore produced both by direct reflections of the transmitted sound pulses and by reflections derived from multiple scattering of the sound. On the other hand the strength of the signal received from a school is also affected by interference, and by the fact that part of the transmitted sound energy is absorbed by the school itself. Cushing (in Richardson *et al.* 1959) and Mitson and Wood (1961) found that a square root relationship between catch per effort (square root of baskets/hr) and the amount of signals received existed under certain conditions; whereas Shishkova (1963) found it necessary to add a term referring to the effects 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 signal voltage from an individual target is reduced proportionally to the square of the depth of the target:

$$V_d \propto d^{-2} \qquad (3)$$

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 2^{nd} power of time, the signal voltage produced by the receiver is adjusted for the reduction with depth.

On the other hand the area covered by the beam increases with depth, and consequently also the number of reflecting targets when the target density is constant. Thus, the sum of signal voltages produced by a receiver in which the signals are amplified proportional to the 2^{nd} power of time will tend to give an overestimate of the target density.

This is a particular problem when there is a considerable variation in depth distribution of scatterers. When the vertical range of distribution is small, but the mean depth of the scatterers varies with the locality (i.e. horizontally), this problem may be overcome by estimating the corresponding sum of signal voltages in a chosen standard depth. However, in the case of a large vertical range and/or considerable vertical density gradients, 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 to work in conjunction with the research sonar equipment onboard the R/V "G. O. Sars". This instrument is summing all signal

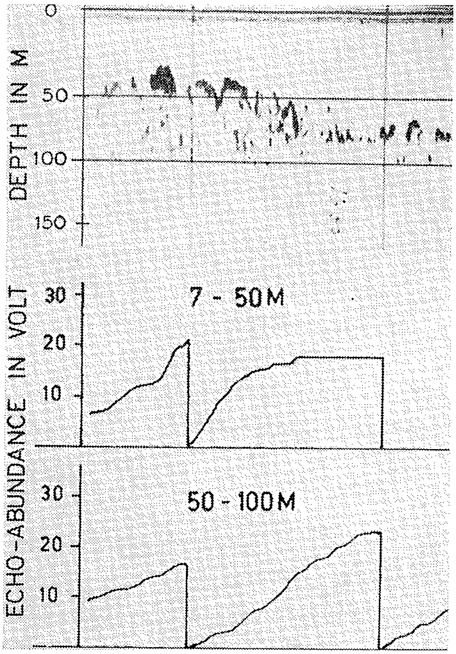

Fig. 4. Echo sounder recordings of a fish fry layer (top) and the corresponding echo abundance in volt from 7 to 50 m (middle) and 50 to 100 m (bottom) depth.

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 at present a duo-channel system is used. This allows integration over two different depth ranges at the same time, or over two different signal amplitude levels (Fig. 4).

This apparatus 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 courses steered. On the charts are plotted the sum of signal voltages per five nautical miles, and iso-lines for equal leve ls 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, longitudes 28°E and 33°E; whereas the survey from 15 September to 6 October indicated that a displacement towards the east had occurred, the main concentration being then between longitudes 33°E and 37°E.

Numerous fishing experiments with 10-foot Isaacs-Kidd midwater trawl (I.K.M.T.) and a pelagic trawl (P.T.) were carried out, and the catches obtained indicated that the sound scattering agents in these areas were mainly 0-group herring, cod and haddock mixed with some invertebrates (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 51°E). These were indentified as being mainly fry of polar cod, capelin and various other cold water fish.

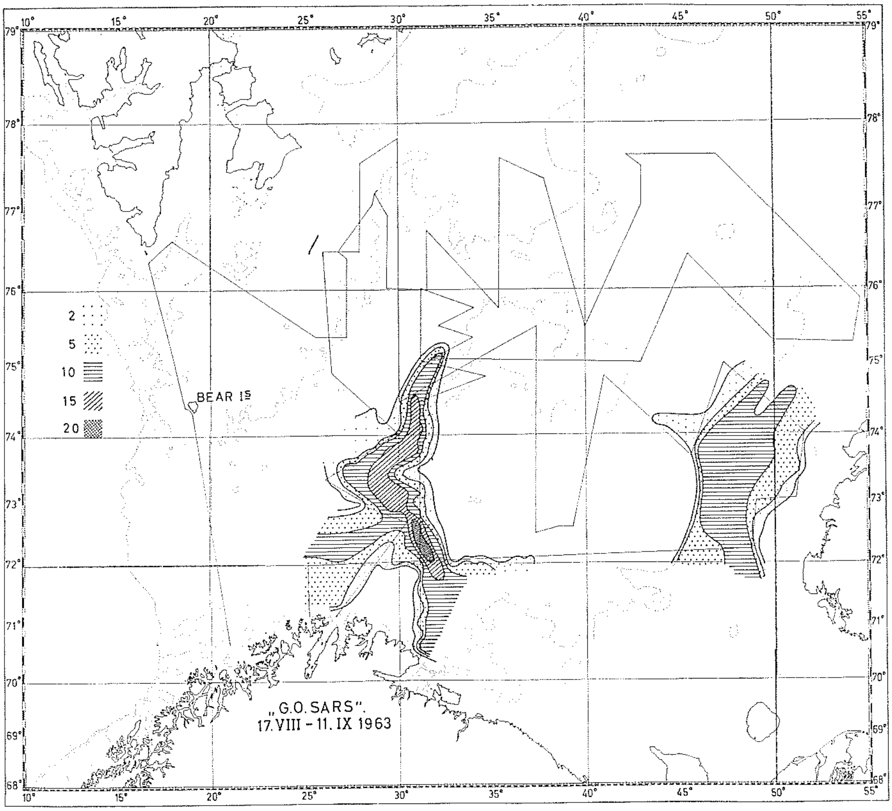

Fig. 5. Echo-abundance distribution as determined by the echo-integrator during the survey from 17 August to 11 September 1963. Equal levels of abundance are indicated by isolines.

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 this concentration was probably the southernmost part of 0-group fish being transported northwards by the Spitsbergen current.

Along the Norwegian coast aggregations of sound scatterers, identified as 0-group herring were found at the entrance of the fjords, whereas on the banks off northern Norway (71°N to 72°N and 15°E to 25°E) sound scatterers were scarce. This distribution conforms with the observations made in previous years (see Fig. 3).

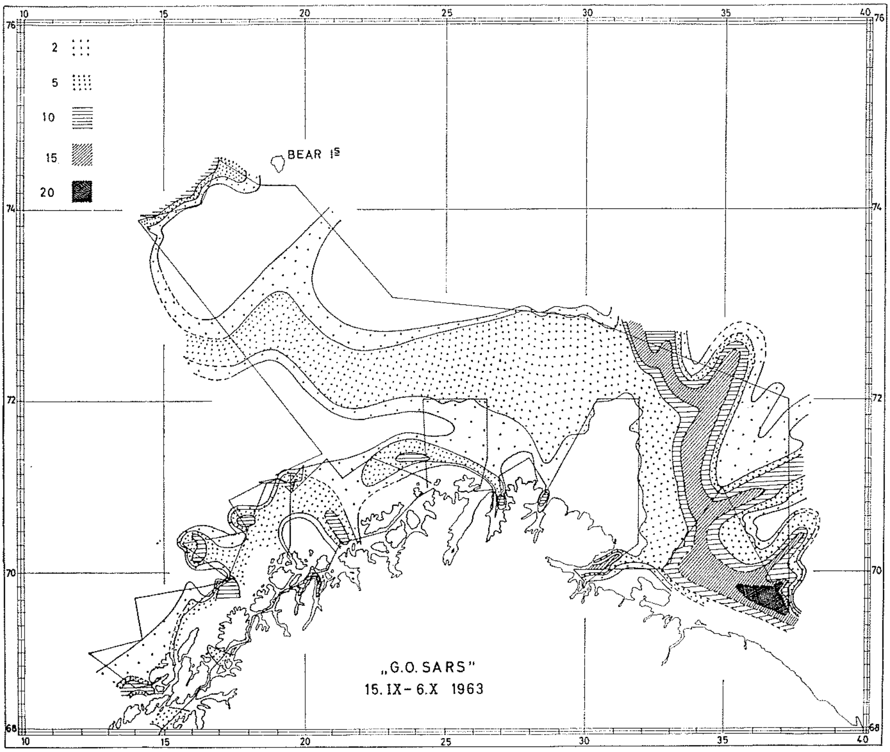

Fig. 6. Echo-abundance distribution as determined during the survey from 15. September to 6. October 1963.

During these surveys a pelagic trawl gave catches of fish fry and/or invertebrates whenever it was used at the exact depth where sound scatterers were recorded. This experience indicates that the pelagic trawl used is quite suitable for the purpose of identifying and sampling the 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 with respect to species and size composition.

From 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, it might be assumed that precise measurements of the *echo-abundance* are feasible. The problem of charting the echo-abundance distribution in 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. 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 completely 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 at present the target strength of the various kinds of fish fry and its variation with size are insufficiently known.

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 may be determined experimentally. Such models would necessarily contain several variables, and be rather complex, especially in cases when various degrees of schooling occur. It is, therefore, suggested to avoid variability in schooling as far as possible by surveying areas abundant with fish fry during night time when the fish are more evenly distributed in continuous layers.

For this type of distribution, it is suggested to establish directly, by

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°58′ E20°10′	27.9.63 1940—2100	600	—	10— 120	8.0	69.0
Ullsfjord N69°58′ E20°06′	28.9.63 0200—0300	500	9 1 of Scyphomedusae	10— 120	7.5	68.5
Ullsfjord N69°43′ E19°43′	30.9.63 1912—2000	8520	—	10— 80	35.5	128.8
Lyngenfjord N69°50′ E20°25′	1.10.63 0255—0400	5322	—	10— 60	26.0	—
Hadselfjord N68°28′ E14°30′	4.10.63 0213—0330	13424	—	10— 25	28.9	28.9

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 experiment for this purpose was 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

The possibility 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 is discussed.

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 autumn in this area consist mainly of 0-group fish of which herring, cod and haddock are most important.

The transport of the larvae from the spawning places in relation to the current systems is 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 south-eastern parts of the Barents Sea.

The relation between echo signals received from scattering agents distributed at a constant depth and the amount of scatterers is discussed, as well as the effect of variations in depth distribution. Special attention is paid to the signal strength received from targets uniformly distributed in a layer or school of wide horizontal distribution.

The needs for theoretical as well as empirical studies of the relationship between the amount of echo signals received and the abundance of sound scatterers are stressed.

The first results of charting the echo-abundance distribution are presented. For this purpose an electronic 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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APPENDIX I

Short Description of the Echo-Integrator

The authors are greatly indebted to Mr. INGVAR HOFF, who has been responsible for the developement of the echo-integrator, and the description given below.

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 the case that the integrator is not desired to start at the time of transmission (i.e. from the surface), the start of the pulse generator has to be delayed 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 regulation of the delay time between the moment the waveform generator is triggered and the moment the pulse generator excites the gate pulse.

Suppose that integration of the signal voltages between 75 and 150 m (t_2-t_1) is wanted and at the same time the sum of these voltages over one nautical mile should be added. At the moment the stylus of the echo-

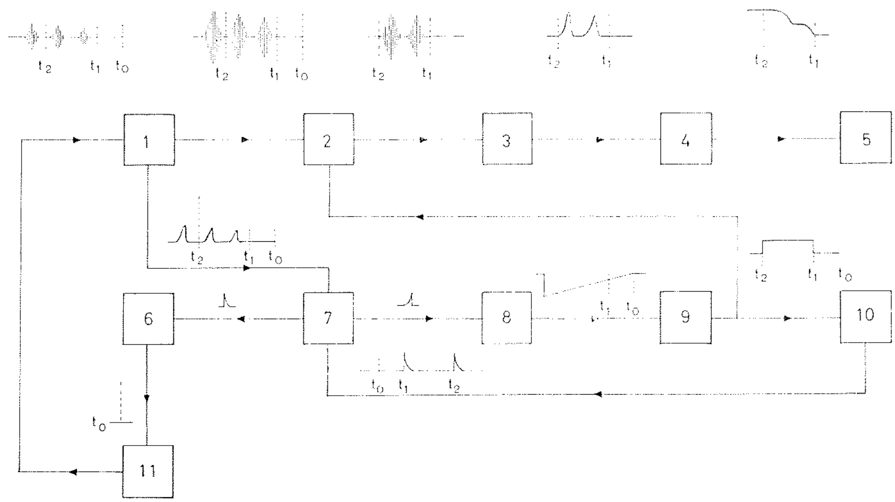

Fig. 1. Block diagram of the echo-integrator set-up:

1. Amplifier (Simrad)
2. Signal selector (gated amplifier)
3. Signal rectifier
4. Integrator (Tektronix, type 0)
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).

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 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 I

"G. O. Sars" 17 August to 4 October 1963. Record

Note: Echo-abundance indices are for 38 kc/s visual classifi

St. No. Position	Date Hour	Gear	Dist. towed	Catch in numbers			
				Her-ring	Cod	Had-dock	Other fish
49 N71°30′ E20°30′	17.8.63 1730	I.K.M.T.	1.5	—	—	2	—
50 N72°00′ E20°20′	17.8.63 2110	I.K.M.T.	1.0	—	6	—	—
51 N73°00′E19°52′	18.8.63 0320	I.K.M.T.	1.0	—	—	—	—
52 N73°30′ E19°37′	18.8.63 0650	I.K.M.T.	1.0	—	1	—	5 redfish 3 long rough dab
54 N75°53′ E27°15′	20.8.63 0413	I.K.M.T.	1.2	—	—	—	4 long rough dab 1 *Leptagonus decagonus*
55 N76°00′ E31°30′	21.8.63 0222	I.K.M.T.	1.2	—	—	—	—
57 N76°10′ E53°40′	24.8.63 0945	I.K.M.T.	0.8	—	—	—	7 polar cod 2 long rough dab
58 N76°03′ E54°10′	24.8.63 1053	I.K.M.T.	—	—	—	—	ca. 100 polar coc
59 N75°18′ E52°20′	24.8.63 2007	I.K.M.T.	—	—	—	—	ca. 50 polar coc 1 sea scorpion
60 N75°05′ E32°27′	26.8.63 1845	I.K.M.T.	1.0	—	—	—	4 long rough dab 1 sea scorpion
61 N75°09′ E32°25′	26.8.63 2050	P.T.	3.0	—	752	59	100 capelin
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*
63 N74°16′ E31°13′	28.8.63 1230	I.K.M.T.	0.6	—	7	—	—
64 N74°05′ E31°13′	28.8.63 1339	P.T.	2.0	—	887	21	2 capelin
65 N73°00′ E31°13′	28.8.63 2205	I.K.M.T.	1.0	—	76	1	14 redfish

›f fishing experiments for identification of echo traces.
ations of the echograms, and for 30 kc/s integrator readings.

Evertebrates	No. of fish per n. mile	Echo-abund. index 38 kc/s	30 kc/s	Remarks
—	1.3	1	—	Integrator out of function
—	6.0	1	—	Integrator out of function
—	—	1	—	Integrator out of function
—	9.0	1	—	Integrator out of function
).5 1 of euphausiids	4.2	0	—	Integrator out of function
!0 specimens of diff. medusae, :a. 200 euphausiids, ›0 amphipods	—	0	7.4	
Some *Clione*	11.3	1	—	
Some amphipods	ca. 100	1	—	
—	ca. 50	1	—	
Some *Clione*, ctenophores and amphipods	5.0	1	—	
4 cephalopods, some *Clione*, 1 scyhpomedusa	304.0	1	—	
Some *Clione*, ctenophores	15.0	1	—	
—	11.7	2	—	
—	455.0	2	—	
—	91.0	2	—	

APPENDIX I

St. No. Position	Date Hour	Gear	Dist. towed	Catch in numbers: Herring	Cod	Haddock	Other fish
66 N72°04′ E31°13′	29.8.63 0636	I.K.M.T.	1.0	—	—	—	—
67 N70°49′ E31°13′	30.8.63 —	I.K.M.T.	1.1	15	51	2	—
68 N70°59′ E30°28′	30.8.63 0430	I.K.M.T.	0.7	—	1	—	—
70 N72°02′ E33°20′	3.9.63 0203	I.K.M.T.	1.0	—	3	—	—
71 N72°03′ E35°35′	3.9.63 0610	I.K.M.T.	1.0	—	—	—	—
72 N72°04′ E40°20′	3.9.63 1553	P.T.	2.1	—	—	—	712 polar cod
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.
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
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.
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*
77 N73°00′ E51°20′	4.9.63 1755	I.K.M.T.	1.0	3	—	—	3 *Gymnocanthus tricuspis* 2 *Artediellus uncinatus europeus*

(continued)

Evertebrates	No. of fish per n. mile	Echo-abund. index		Remarks
		38 kc/s	30 kc/s	
—	—	1	48.8	Echo-trace at 100 m, trawl did not catch representatively
Some euphausiids	61.8	2	9.4	
Some Scyphomedusae	1.4	2	10.9	
Some euphausiids	3.0	1	10.7	
—	—	0	—	
Some euphausiids	339.0	0	—	
—	16.0	1	—	
Some *Clione*	21.0	1	15.4	Integrator reading 5 n.m. before station
Some *Clione*	14.0	2	—	Integrator out of function
Some *Clione*	2.1	1	8.8	
Some *Clione*	5.0	1	4.5	

St. No. Position	Date Hour	Gear	Dist. towed	Catch in numbers Her- ring	Cod	Had- dock	Other fish
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.
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*
80 N74°40′ E48°52′	5.9.63 0655	I.K.M.T.	0.5	—	—	—	52 polar cod
81 N74°08′ E46°20′	5.9.63 1515	I.K.M.T.	1.0	—	—	—	61 polar cod 1 *Artediellus uncinatus europeus*
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
83 N73°38′ E45°40′	5.9.63 1904	I.K.M.T.	2.1	—	—	—	23 polar cod 12 *Leptagonus decagonus*
84 N74°46′ E41°05′	6.9.63 0525	I.K.M.T.	1.3	1	—	—	1 polar cod 1 *Leptagonus decagonus*
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*

(continued)

Evertebrates	No. of fish per n. mile	Echo-abund. index		Remarks
		38 kc/s	30 kc/s	
Some Scyphomedusae	27.0	1	4.3	
Some *Clione*	58.0	2	11.6	
Some ctenophores and *Clione*	104.0	1	15.4	
Some *Clione*	62.0	1	7.1	
Some *Clione*	100.0	1	13.1	Trawl depth 43—44 m
Some *Clione* and euphausiids, 1 *Sagitta* sp. 1 ctenophore	16.7	1	13.1	Trawl depth 55—65 m
Some euphausiids and *Clione*	2.3	1	—	
Some euphausiids and *Clione*	52.5	1	—	

APPENDIX II

St. No. Position	Date Hour	Gear	Dist. towed	Catch in numbers Her-ring	Cod	Had-dock	Other fish
86 N74°37′ E31°15′	8.9.63 0931	P.T.	3.0	—	720	7	3 *Leptagonus decagonus* 2 long rough dab
87 N74°32′ E30°50′	8.9.63 1110	I.K.M.T.	1.3	—	—	—	—
88 N74°30′ E30°00′	8.9.63 1522	P.T.	1.9	—	1240	7	1 *Leptagonus decagonus* 1 long rough dab
89 N74°53′ E26°30′	10.9.63 0914	I.K.M.T.	1.1	—	—	—	14 long rough dab
90 N73°48′ E28°40′	10.9.63 2330	I.K.M.T.	1.0	18	33	—	—
91 N73°36′ E27°27′	11.9.63 0202	I.K.M.T.	1.0	8	11	—	—
92 N73°29′ E26°47′	11.9.63 0340	I.K.M.T.	0.6	—	—	—	—
93 N73°19′ E26°10′	11.9.63 0620	I.K.M.T.	1.0	—	—	—	—
94 N72°56′ E28°30′	11.9.63 1148	P.T.	2.8	—	1200	18	—
96 N71°50′ E28°20′	12.9.63 0003	I.K.M.T.	0.9	—	10	—	—
97 N71°20′ E24°16′	16.9.63 2223	I.K.M.T.	0.9	—	—	—	—
98 N72°00′ E24°12′	17.9.63 0324	I.K.M.T.	0.8	—	—	—	—
99 N71°56′ E26°34′	17.9.63 0930	P.T.	1.1	—	220	4	—
100 N70°51′ E27°02′	17.9.63 2230	I.K.M.T.	1.2	10	—	—	—
101 N70°51′ E27°02′	18.9.63 0150	I.K.M.T.	0.6	4	—	—	—
102 N70°51′ E27°02′	18.9.63 0217	I.K.M.T.	1.2	2	1	—	—
103 N70°53′ E28°35′	18.9.63 1145	P.T.	5.3	239	1	1	—
104 N71°40′ E29°55′	18.9.63 1940	I.K.M.T.	—	—	16	—	—

(continued)

Evertebrates	No. of fish per n. mile	Echo-abund. index 38 kc/s	Echo-abund. index 30 kc/s	Remarks
Some *Clione*	244.0	1	44.	
—	—	1	21.0	Trawl did not catc h
—	657.4	1	29.6	
—	12.7	1	3.5	
10 euphausiids	51.0	1	16.3	
Some euphausiids	19.0	1	10.7	
Some Scyphomedusae	—	1	16.0	Trawl did not catch
Some Scyphomedusae	—	2	3.6	
—	435.0	1	10.4	
—	11.1	1	7.9	
Some euphausiids	—	1	8.8	
—	—	1	3.8	Trawl towed above top of echo-trace
2 Scyphomedusae	204.0	1	9.0	
Some euphausiids and Scyphomedusae	8.3	2	—	Integrator out of function
Some euphausiids and Scyphomedusae	6.7	2	—	Trawl towed at greater depth than previous haul
Some euphausiids and Scyphomedusae	2.5	2	—	Trawl towed at greater depth than previous haul
A few Scyphomedusae	45.5	1	2.0	
1 cephalopod	16.0	1	9.0	

St. No. Position	Date Hour	Gear	Dist. towed	Catch in numbers			
				Her-ring	Cod	Had-dock	Other fish
105 N70°02′ E30°39′	20.9.63 0438	P.T.	1.6	3564	175	78	8 blue whiting
106 N70°45′ E34°26′	20.9.63 1950	I.K.M.T.	0.5	3	36	—	—
107 N70°53′ E35°13′	20.9.63 2300	P.T.	2.0	76	800	3	4 blue whiting
108 N69°50′ E36°50′	21.9.63 0840	P.T.	1.5	—	196	3	—
109 N70°30′ E37°20′	21.9.63 1950	I.K.M.T.	0.6	1	12	—	—
111 N72°42′ E31°30′	23.9.63 0512	P.T.	1.7	—	—	3	—
112 N74°18′ E17°47′	24.9.63 1835	P.T.	1.0	126	4	—	A few long rough dab
113 N73°22′ E16°50′	24.9.63 2220	P.T.	1.0	—	20	7	1 *Triglops pingeli*
116 N69°42′ E19°44′	30.9.63 2122	P.T.	1.0	240	12	11	—
117 N70°44′ E17°37′	2.10.63 1033	P.T.	1.5	—	—	—	—
118 N70°11′ E16°15′	2.10.63 1955	I.K.M.T.	2.0	1	—	—	69 *Myctophum glaciale* 1 blue whiting
119 N68°32′ E14°00′	3.10.63 1955	I.K.M.T.	2.6	1	1	—	—
120 N69°55′ E17°10′	4.10.63 1908	P.T.	2.1	448	—	—	—

continued)

Evertebrates	No. of fish per n. mile	Echo-abund. index 38 kc/s	Echo-abund. index 30 kc/s	Remarks
cephalopods, some cyphomedusae	2391.0	3	21.7	
Scyphomedusa	78.0	1	—	Integrator out of function
—	442.0	1	14.8	
ome Scyphomedusae	132.7	1	32.5	
—	21.7	2	15.8	
—	1.8	1	30.2	Trawl towed above most dense echo-trace
—	130.0	3	11.4	
ome euphausiids	28.0	1	11.1	
litres of euphausiids, 3 Scyphomedusae	263.0	2	14.4	
—	—	1	11.8	Likely trawl did not catch representativly
Some euphausiids and 1 Scyphomedusa 1 cephalopod	35.5	0	16.3	
1 Scyphomedusa	0.8	1	4.5	
—	213.3	1	19.3	