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CLUSTERING
ITS EFFECT ON
TRAWL AND ACOUSTIC
ABUNDANCE ESTIMATION

By

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INTRODUCTION

It has for some time been in mind that each trawl station on a survey should be squeezed for more information than has been the case in the past. The function of trawl stations has been, to give the species selection so that echo integrator values in the surrounding area could be subdivided, to give the length frequency distributions and so abundance indices by length group, to provide conversion factors for the echo integrator values so that these could be turned into local abundance estimates plus various detailed biological data from the fish catch.

Recently bottom locked channels have been used to investigate the vertical fish profile as it appeared below the ship during trawl hauls. It was felt that the horizontal distribution, and whether or not it was found to be clustered, could also be interesting. Studies on cod gillnets had shown changes in horizontal distribution to be no less important than changes in the vertical for the catching process. For the active method of trawling, changes in horizontal distribution may not have the same prime importance, but may, nevertheless, have an effect.

This report considers only a very limited number of case studies and all in the same place on the shelf west of Bear Island. It is meant mostly as a discussion of methods and possibilities.

EQUIPMENT AND METHODS

The echosounder equipment is the Simrad EK400, used with an 8° x 8° full angle ceramic transducer. The echo integrator was used with a 0.5 m backstep to try to make as much use of the 0-2 m bottom locked channel as possible. Other bottom locked channels, 2-4, 4-8, 8-14 and 14-20 m above bottom, were also used. Trawling was with the C 1800 survey trawl rigged as is now the standard with 40 m sweeps and rockhopper ground gear.

The method was to measure distances between individual fish echoes and between clusters along the trawl track, using the echograms. This was later repeated in an 11 knot survey, using integration over 0.1 nm intervals for a 5 nm stretch. Attempts are then made to turn the information into probable horizontal distribution pattern or patterns.

RESULTS

The location of the 3 trawl stations and the 0.1 nm interval echo survey are shown in Figure 1. In some ways fortunately, fish abundance was low, at best only about one third of a commercially worthwhile level. The fish was mostly cod, 30-60 cm long, with a very few haddock in the middle of that range. The low abundance made counting the echoes possible, which was just as well because with the fish close to bottom and the low backstep value, the integration from the bottom channel was sometimes erratic. At the first two trawl stations the fish was all seen as within 4 m of bottom, at the third it sometimes went as high as 8 m, but no higher. All stations were by day in August 1989.

Taking the last station with the most fish, the encounters as seen on the echosounder were counted off into the number of echoes in each of the 30 cables (0.1 nm) in the 3 nm tow. Not more than 8 echoes were seen in any 0.1 nm, sometimes none, thus:

x_i	0	1	2	3	4	5	6	7	8	number/0.1 nm
F_i	3	2	6	3	5	3	3	1	4	frequency

From this the average number per 0.1 nm is 3.83 and the variance 6.21. According to Zar (1974), when variance > average, the tendency is toward clustering, when average = variance, the distribution is random, and when the average > variance, the distribution tends towards being even. There is a farther test which determines whether the variance is significantly different from the mean to reject the Ho condition of randomness. In this case Chi square $\chi^2 = 25.4$, whereas $\chi^2(0.05)(7)$ is 14.1, so that the clustering of the distribution along the line of tow is convincing enough. To pass from a clustered distribution towards an even one or vice versa, it seems the distribution has to pass through a random stage. For different purposes a clustered or a more even distribution have tactical advantages. Since a random distribution lacks apparent advantage, it may be an unstable state.

To find whether the clusters were themselves clustered, one may try counting 3 or more contacts as forming part of a cluster, and consider the number of clusters over 0.3 nm intervals. The size of the cluster will almost certainly be greater than the number of contacts passing through it (see later). Now

x_i	0	1	2	3	$\bar{x} = 1.9$ clusters in 0.3 nm
F_i	1	3	2	4	$s^2 = 1.2$

Though there is a tendency toward even distribution of the clusters, the random distribution of the clusters cannot be rejected. Counting 4 or more contacts as forming a cluster leads to a similar conclusion. The distance of 3 nm is too short for this test.

In both the other tows of 1.4 nm and 3.4 nm, respectively, there was even less abundance, and the distance between contacts was close to random, $\bar{x} = 1.3$/cable, $s^2 = 1.3$, and $\bar{x} = 2.4$/cable, $s^2 = 2.5$.

For the 3 hauls count abundance, trawl abundance, and integrator abundance are as follows:

Haul	Count	Distance n.m.	Count abundance No/(0.1nm)^2	Trawl abundance No/(0.1nm)^2	Integrator abundance No/(0.1nm)^2
452	18	1.4	14	14	56 (0-2m) 0 (2-4m)
453	83	3.5	25	21	47 (0-4m) 1 (2-4m)
454	115	3.0	41	38	46 (2-4m) 21 (4-8m)

The depth was all about 100 m. The count abundance is based on a cut off angle of 5° rather than semi beam angle of 4° at -3 dB. No increase for dead zone has been added to the count abundance, but it could be increased by about 14%. Trawl abundance is based on the catch, the distance towed, and the 25 m effective spread commonly assumed. The echo integrator abundance is extrapolated for dead zone + backstep, and is counted in the bottom 4 m. In the last haul it gave no sensible value in the bottom 0-2 m. The values in the next two channels above are given as guidance. With the fish as close to bottom as this and the low abundance, the integrator values would seem less reliable than counting or the trawl estimate.

In the 5 nm night survey at 11 knots and by 0.1 nm intervals, the speed was too fast to give good counting. The abundance now was even lower. The integrator level as plotted from values given for the (0-2m) on the video display are shown on Figure 2. The computer makes corrections for jumps (probably ground breakthrough) at the end of the 5 mile distance, and the integrator value of 6.1 is printed out. Watching the display by 0.1 nm intervals, one can see the jumps. The integration per 0.1 nm is printed out at 10 times the scale for the bottom BAR (QD) channel (0-2 m), the other bottom channel, and the two channels above that. The integrator values 0-8 m from bottom and extrapolated for dead zone and backstep give M = 1.8/(nm)^2 or only 10 fish/(0.1 nm)^2. These are 21 of the 0.1 nm intervals that look as if they contained a fish contact, but that on a count basis only amounts to 4/(0.1 nm)^2. It would take all the signals greater than zero in the 0-2, the 2-4, and the 4-8 m channels, to give a count equivalent to 10 fish/(0.1 nm)^2. Just taking the 21 signals (contacts) marked with a bar staff and counting the number in each 5 cables, then:

x	0	1	2	3	4	x = 2.1
f_i	0	4	2	3	1	s^2 = 1.2

There is thus a tendency towards an even distribution, but it is hardly enough to reject Ho the random condition.

The attempt was made in the case of Haul 454 to simulate an area distribution from the linear distribution, and to do this some idealization of the situation is required as set out in Table 1.

Table 1.

Linear contacts	Frequency	Total encounters	Chord mean m	Chord range m	Area density No/(0.1nm)^2	Probable No. in groups	Encounter chance	No.of groups	Probable No. in 3(nm)^2
1	6	6				1	1/106	636	636
2	6	12	18	13-33	217	3 (2.6)	1/31	486	1264
3	5	15	40	30-50	147	9 (8.6)	1/37	185	1591
4	3	12	56	39-84	140	16	1/26	78	1248
5	4	20	74	57-88	132	27	1/20	80	2160
6	2	12	100	80-120	117	43	1/15	29	1247
7	2	14	104	102-105	132	52	1/14	28	1456
8	3	24	137	119-150	114	79	1/11	33	2607
		115							12209 4070/(nm)^2 41/(0.1nm)^2

Abundance = 115(185/(30*200tan5°)) = 41/(0.1nm)^2

To obtain the probable diameter of the group, divide the mean chord by $\pi/4$. The area density is worked out encounters/((mean chord/185)(200tan5°/185)) in the usual way. The propable number in the group follows from the density * area of the circle occupied. The chance of encounter is probable diameter/1852. The last column follows from the probable number in the group * probable number of groups. The sum of the last column when turned into number abundance/(nm)^2 or number/sq.cb. must be the same as derived the normal way as the lower left of Table 1.

From Table 1 attempts can now be made at simulating the area distribution 3 nm long and 1 nm wide. The idealized linear condition with the 115 encounters is set along the middle. In Figure 3 the clusters are set out more or less evenly. In Figure 4 the clusters are themselves somewhat clustered. By lines, their end positions chosen by random numbers, and equivalent to 3 nm long, one can find how repeatable the original abundance is, thus,

Clusters not clustered	39, 47, 43, 43, 42, 38, 50
	Mean 43.1/sq.cb.Variance 17.8
Clusters more clustered	51, 38, 55, 50, 58, 46, 40, 46, 41
	Mean 47.1/sq.cb.Variance 47.3

For what it is worth, Figure 5 shows a picture of how the individual fish might be distributed in about $1(nm)^2$ area. In the groups they would be 12-17 m apart, while if spread out would be some 29 m apart.

DISCUSSION

Conditions are encountered where there appears to be clustered random and fairly even distribution, all within a few miles and at the same depth. Strongly clustered distribution was found at one day trawl station, nearly random at two others by day, and a tendency to even distribution on a night survey, all at low to very low abundance. Reasons for clustering could be feeding, at other times of year spawning, and could sometimes be related to topography. A reason for more even distribution could be search. Both clustered and even distribution require some degree of organization, random would appear to be degenerate or transitory. For purposes like understanding or simulating, a bottom gillnet fishery, how and when the transition is made and the degree of evenness or clustering, is important because from these a measure of movement can be derived.

Clustering must make replicate trawl hauls, and replicate acoustic legs have greater variance. This is important in comparative fishing betweeen gears. It would be interesting to note whether long sweeps reduce variance. In comparing trawl abundance with acoustic abundance there is usually great variance and little enough information on where to allocate this variance. For the trawl there is different vertical availability, change in trawl efficiency, variance in the horizontal distribution (as here). Because of different amounts hidden in the dead zone, some ground breakthrough, and possible other reasons, the acoustic abundance may also not accurately reflect the true abundance. Any information which will help to subdivide the sources of variance is important.

It is too early to draw definate conclusions. Suffice to say that for many purposes information on the nature of the horizontal distribution will be useful.

REFERENCE

Zar, J.H. 1974. *Biostatistical Analysis*, pp. 409-411. Prentice-Hall, Inc. 1974.

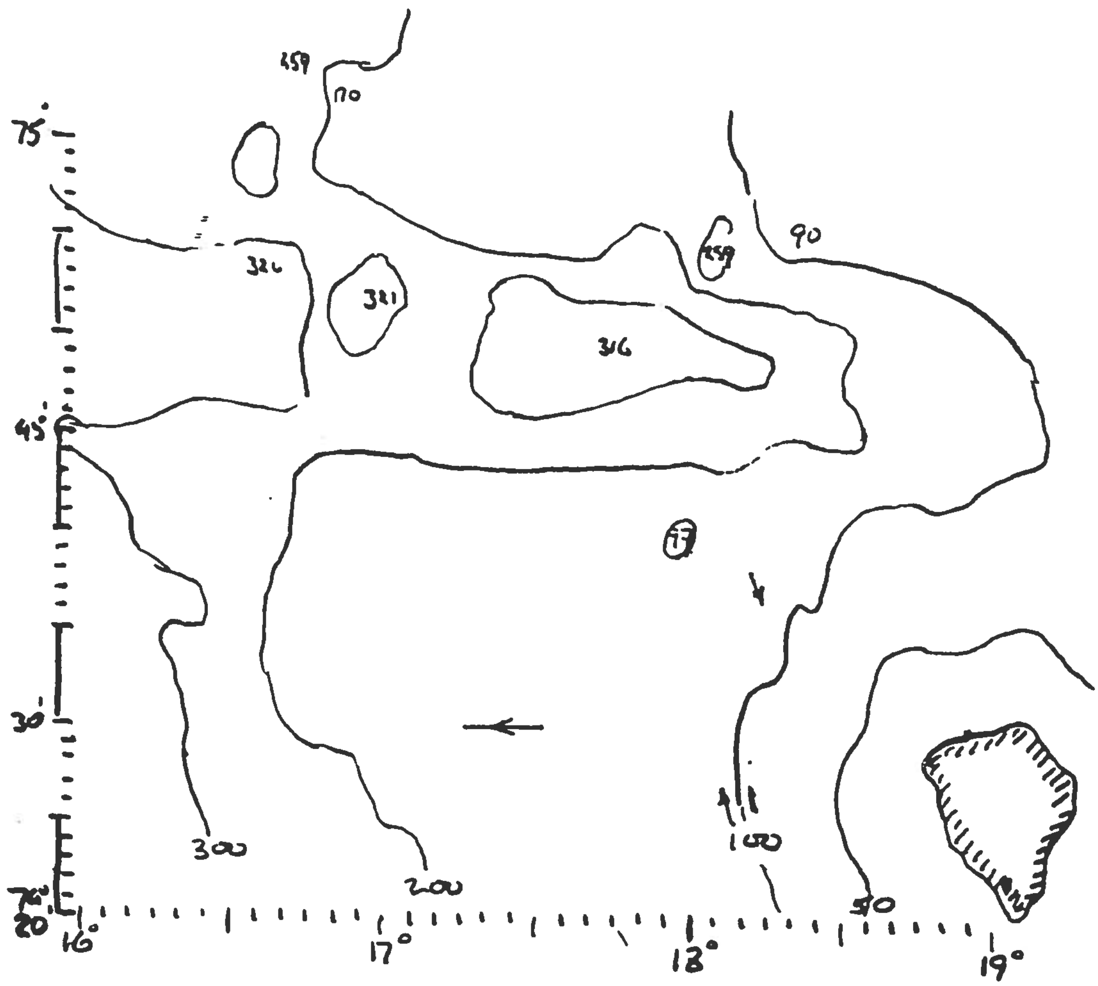

Figure 1. Bear Island, August 1983, trawl stations 452, 453, 454, and 5 nm survey at 11 knots.

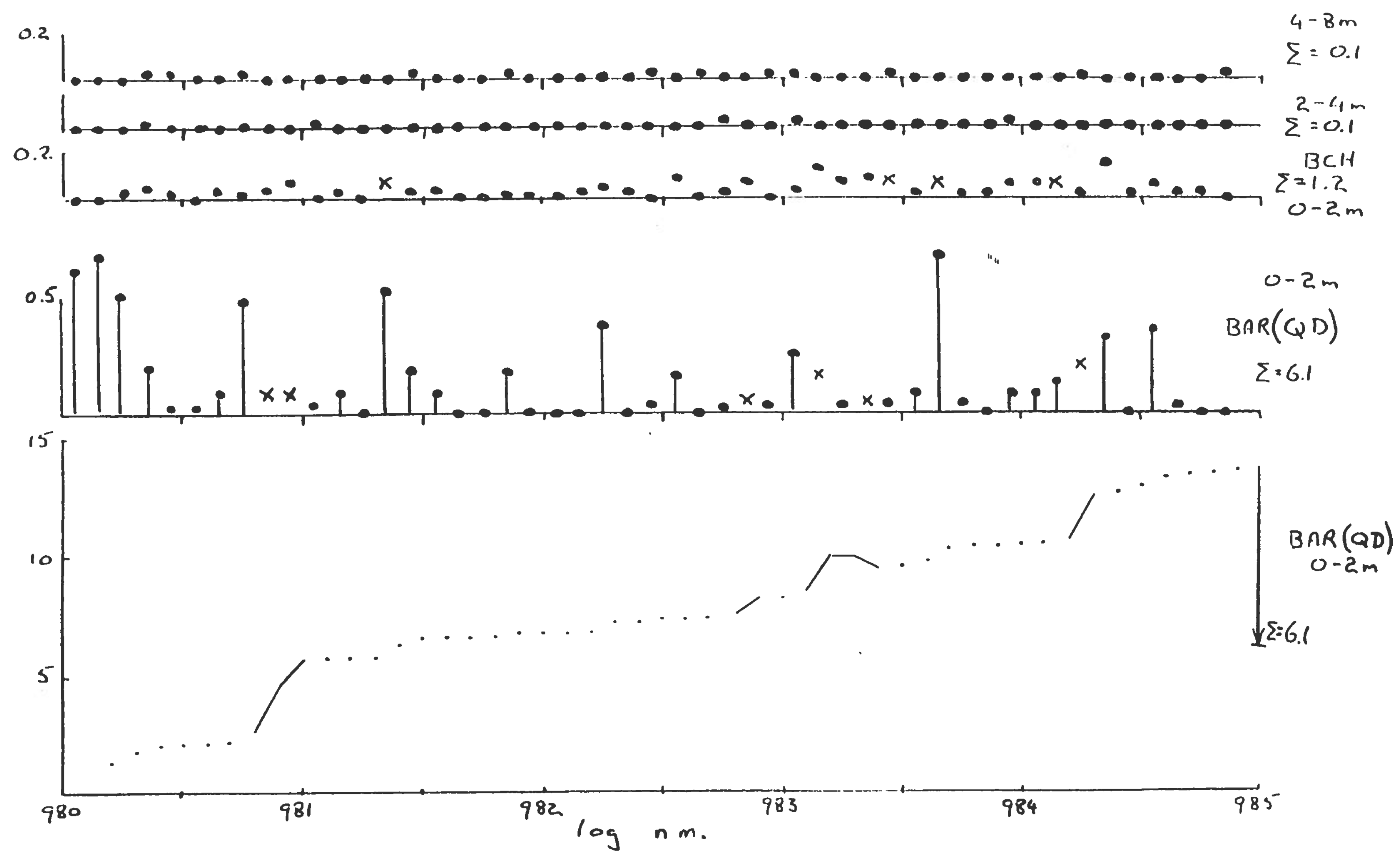

Figure 2. Integrator values over 5 nm by 0.1 nm intervals, bottom locked channels, 0-2 m (0.5 m backstep), also another channel 0-2 m integrating from first time signal drops below threshold, counting backwards from the bottom up, then channels 2-4 m and 4-8 m from bottom.

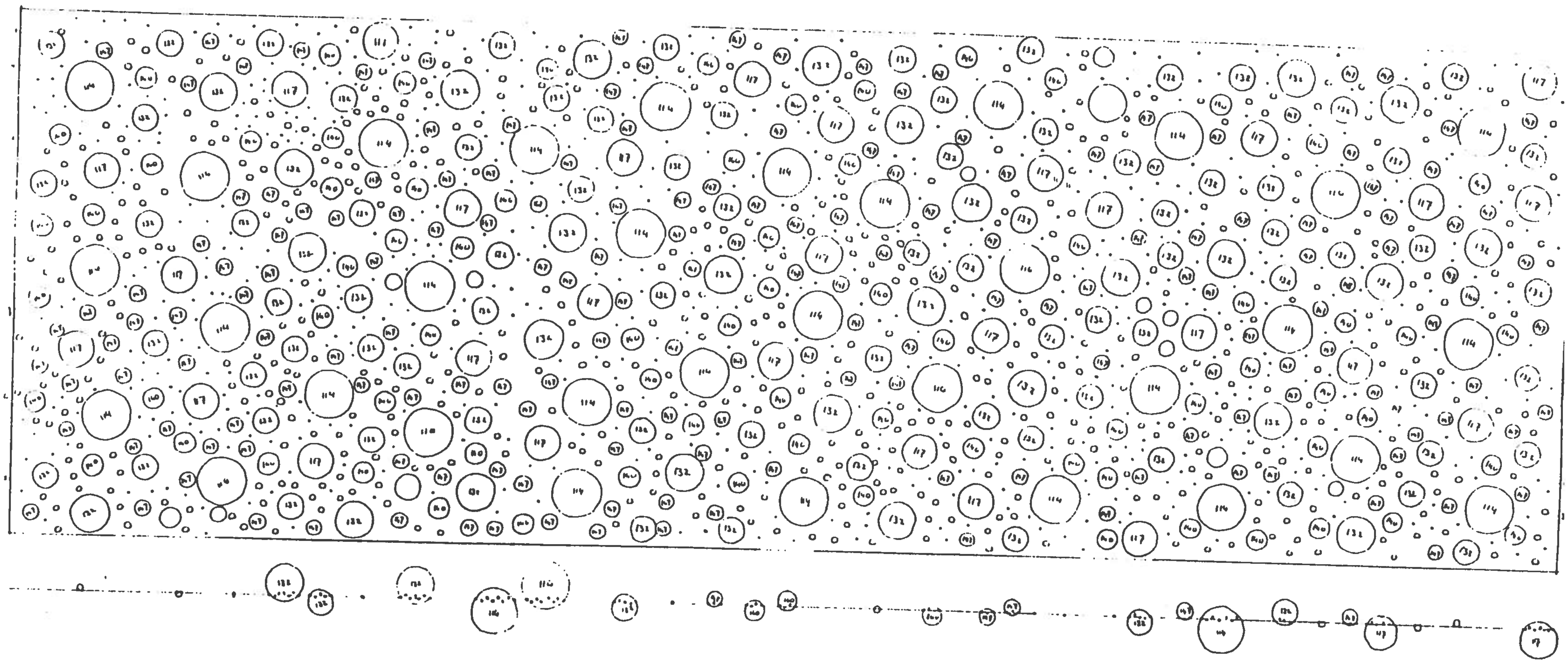

Figure 3. At bottom, idealised configuration of 115 cod echoes in a 3 nm trawl tow. Above, impression of distribution in 3 nm * 1 nm area at 4100 fish/(nm)^2, clusters fairly evenly spread out. Repeat 3 nm "line runs" randomly chosen are made across the area.

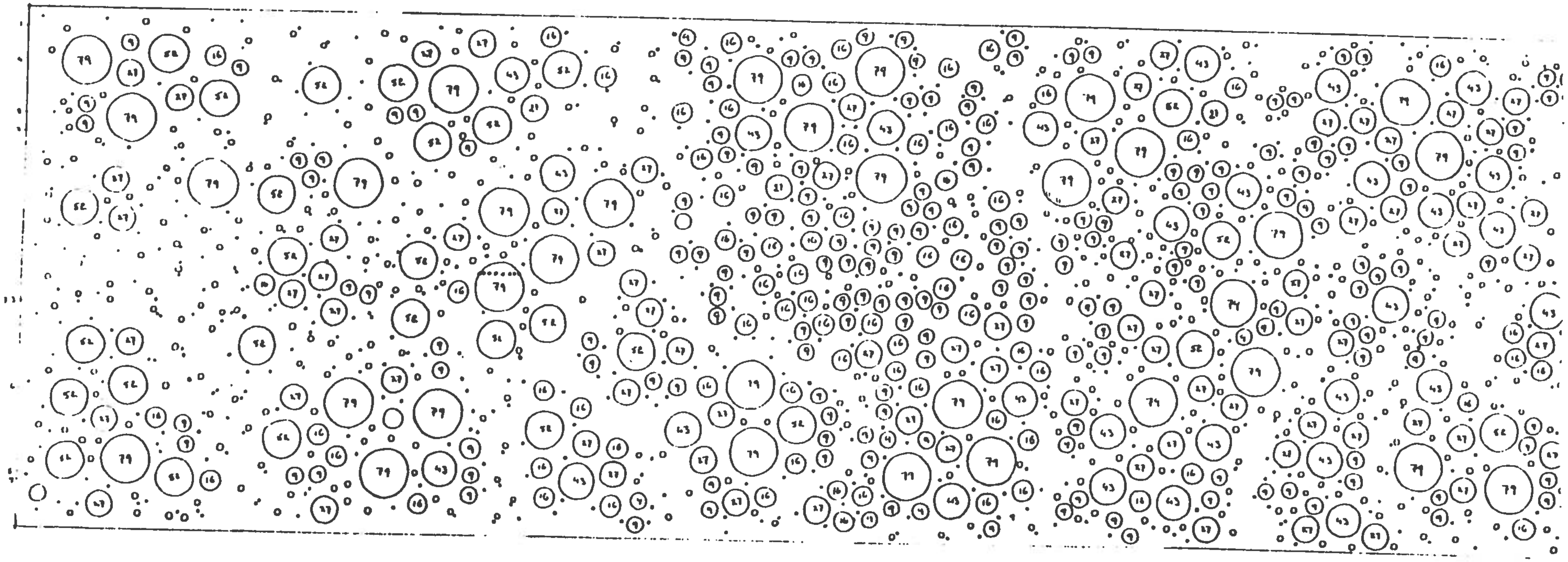

Figure 4. Impression of the same abundance 4100 fish/(nm)^2 in 3 nm * 1 nm area, clusters now themselves clustered. Repeat "line runs" randomly chosen are again made across the area.

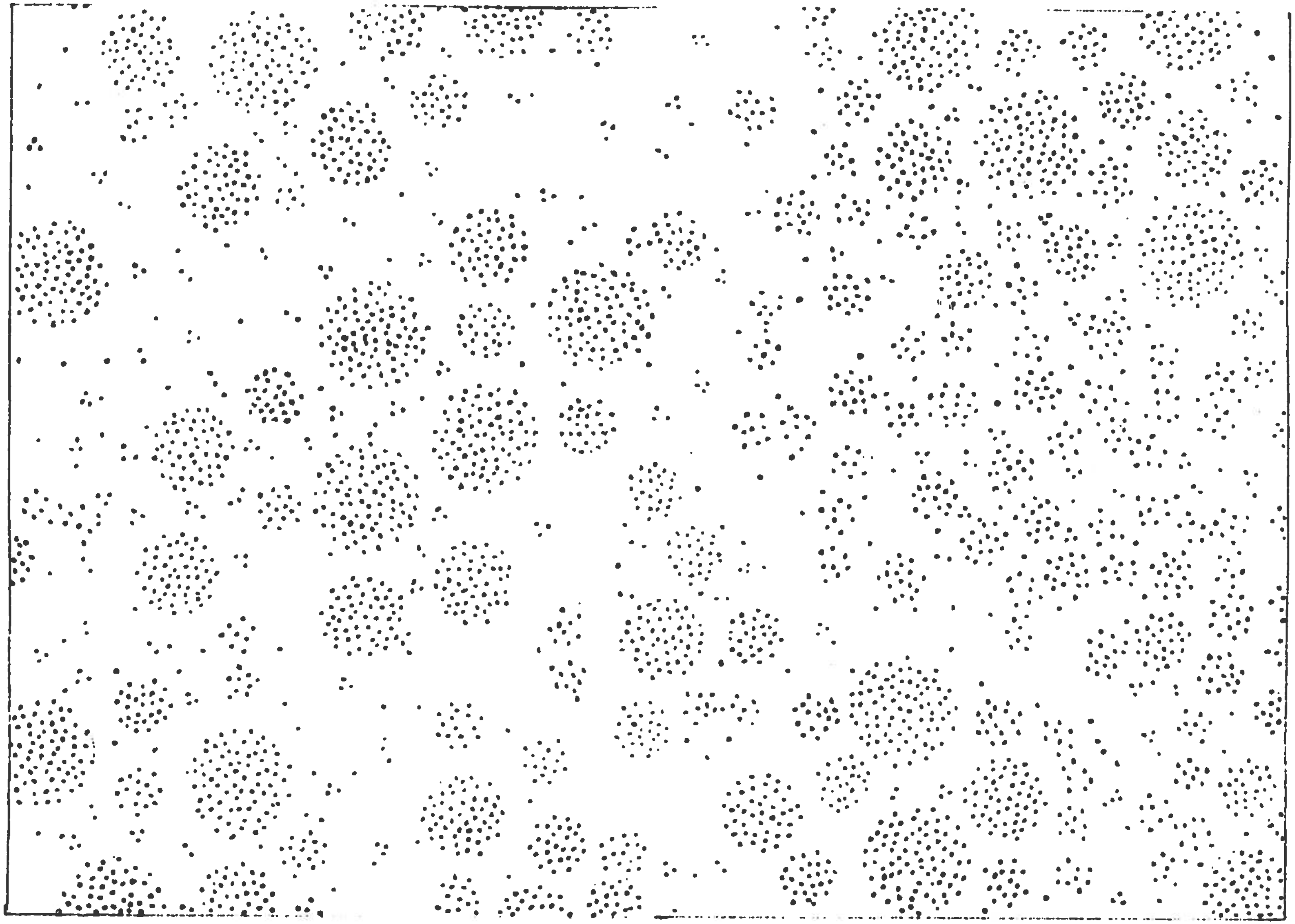

Figure 5. Impression of individual cod distribution in approximately $1(nm)^2$ taken from left centre of Figure 4. Cod in clusters are 12-17 m apart.