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Abundance Estimates in the East Anglian Herring Fishery

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I. Introduction

Since the publication by Hodgson (1939) of the method of obtaining the estimates of abundance of each age group of herring in the East Anglian fishery, considerable changes have taken place in the magnitude of this fishery. Basically Hodgson's method is still used, but certain modifications have had to be made in the method of collection of length data and in recent years in the manner of obtaining the annual catch per effort.

In brief, Hodgson obtained length measurements of herring bought by processers. These measurements, in units of a cran (5.5 crans = 1 ton) were grouped by three-day periods and then raised to the total catch of the port. Using an age/length key, obtained from laboratory biological samples, the raised length distribution was split up by ages to give an estimate of the total number of fish in each age group of the catch. The index of abundance was then obtained by dividing by the total number of landings made in the three-day period. Finally, the annual age distribution was arrived at by taking a mean of the three-day period catches per landing.

The method of obtaining the length measurements was the first modification necessary. Hodgson obtained most of his measurements at various curing or kippering yards. This technique was used, in the main, up to 1955, but by this time, the quantity of fish being processed in these methods was considerably reduced. In 1948 60% of the catch went to these processers but it had dropped in 1955 to only 28%. Burd (1958) analysed the market measuring programme and showed that considerable bias could be introduced if care was not taken in the source of the measurements. The bias could arise in two ways, by measuring in kipper yards where fish had been bought selectively for size or by the difference in the areas of distribution of large and small fish in the fishery. All measurements from 1955 onwards have been made when the fish are unloaded from the vessels on to the quay. In this way it can be ensured that all areas fished are sampled for length.

At the time that the analysis of the market measuring scheme was taking place, the second cause for alteration of the Hodgson method had not yet become so important. However, in 1955 it was already apparent that the reduction in fleet size which had already taken place, might be impairing the search for the areas of highest herring density. The full magnitude in the reduction in fleet size is very evident from inspection of Table 1 which gives the number of boats taking part in the fishery each year. (See page 2).

In taking the annual estimate of abundance as a mean of the three-day period abundance indices low catches per effort in search periods would reduce the estimate of abundance obtained when contact had been made with the main herring concentrations. The abundance index as catch per landing would tend to include an increasing component of 'inefficiency', and underestimate of stock abundance would result.

The use of the statistic 'landing' as the effort estimate also increasingly tended to underestimate the true effort. More and more vessels tended to remain at sea for two nights or even three. In the immediate post-war years, and in the pre-war period, a landing was in most cases one night's fishing. As the ultimate use of the catch per effort is in the calculation of mortality rates, it was essential that for their long-term analysis as little bias as possible need be accepted. For this reason effort has, since 1955, been collected as shots. The catch made by each drifter on each night of shooting is recorded on the quay when the vessels land.

Table 1. Number of English and Scottish drifters operating in the East Anglian fishery

Year	English		Scottish		Total
	Steam	Motor	Steam	Motor	
1947	111	4	211	84	41o
1948	115	12	191	112	43o
1949	122	13	187	151	473
195o	97	14	1o5	15o	366
1951	1oo	12	71	181	373
1952	96	14	54	189	353
1953	82	15	34	18o	311
1954	59	16	11	182	268
1955	42	2o	5	174	241
1956	23	22	1	143	189
1957	16	29	-	128	173
1958	11	28	-	133	172
1959	8	28	-	119	155
196o	5	22	-	77	1o4
1961	1	22	-	96	119
1962	-	22	-	65	87

Despite the reduction in fleet size resulting in search being limited, Cushing (1961) has produced evidence to suggest that the efficiency in the period 1946-54 was somewhat higher than that in 1936. In the post-war period between 1946 and 195o an increase in the efficiency factor of about 4o% took place. After this date a sharp decline took place, followed (especially after 1955) by increased variability. Catch data in East Anglia are summarised by grouping into statistical areas 1° of longitude by 1° of latitude. Using these areas Cushing calculated fishing intensities, $\tilde{f}$, in the manner of Beverton and Holt (1957), for

$$\tilde{f} = \frac{C_{ij}}{C/_{gij}}$$

where C_{ij} is the catch in the i^{th} square in the j^{th} period and $C/_{gij}$ is the catch per shot in the i^{th} square in the j^{th} period. Using the efficiency intensity the estimate of efficiency used by Cushing was:-

$$\text{Efficiency factor} = \tilde{f} x \frac{\text{number of squares}}{\text{number of shots}}$$

This was further corrected for the reduction in the number of squares fished over the period 1935-57. The increased variability in the efficiency factors observed after 1955 could be reflecting true changes in efficiency in techniques or only increased variability in catch per effort in a period of declining stock. The question of the reliability of the catches per effort as good abundance indices firstly of the catch and secondly of the stock was particularly important. It was in this context, and to a lesser extent to give information to the fleets, that echo-surveys were begun in 1956 covering the Southern Bight during the migration of herring to the spawning grounds. Some of the results of these surveys have already been reported by Tungate (1958), Burd (1959), Veldez and Cushing (1961) and Burd (1961).

The distinction between the abundance indices of the fish in the fishery and that in the stock is not an unimportant one. Ideally with an adequate market sampling programme and with the fishery exploiting the whole stock there should be no distinction between the two indices. However, while it is relatively easy to obtain abundance indices of the age distribution in the catch, proper stock estimates may be more difficult. For example, mesh selection may produce a bias in that too few large, or small, fish are caught; this will cause the stock to be under- or overestimated. Burd (1963) has shown that in a period of sudden increase in length, such as happened in East Anglia in 195o/51, the abundance of the older fish was underestimated. Bias could not be detected in any of the subsequent years. Again Bolster (1962) has shown a relation between the size of the average catch under different wind and tide conditions. As few seasons are alike in weather condition the mean catch per effort may be biassed by this factor, so affecting the stock estimate. These effects, while always having been present in the drifter fishery, may quite easily be enhanced with the low stock and low effort now involved.

In the succeeding sections, the present method used to obtain the annual age distribution will be described and some comments will be made on the improvements which could lead to better estimates of stock size.

II. East Anglian Annual Age Distributions

During October and November, English and Dutch drift-net vessels are fishing widely over the Southern Bight; the English tend to the western side and the Dutch to the eastern half. To eliminate or at least minimize some of the biasses in catch per effort due to limited search it was thought worthwhile to try to combine the Dutch and English abundance data. In collaboration with our Dutch colleagues, J. J. Zijlstra and K. H. Postuma, in 1958 the first age distributions using the combined data for the 1956-58 seasons were published in the Fish Stock Record.

Weekly abundance indices per age group, expressed as number of fish per net per shot were obtained for Dutch, English and Scottish vessels. Some idea of the initial variability of the data can be obtained by inspection of Table 2, which gives two weeks in the 1957 season.

Table 2. Abundance indices from English, Scottish and Dutch vessels as numbers of fish per loo nets per shot

1957 Week 43	Age in years									
	2	3	4	5	6	7	8	9	lo	lo+
English	8.o	364.o	188.o	24.o	9.o	5.o	o.3	o.6	1.6	1.o
Scottish	lo.2	495.o	215.o	18.o	8.o	5.o	o.3	o.3	o.6	o.3
Dutch	-	165.o	172.o	5o.o	36.6	12.7	7.6	4.2	-	3.6
1957 Week 44										
English	o.5	224.o	lo2.o	28.o	25.o	14.o	9.o	2.o	2.5	1.5
Scottish	o.5	136.o	53.o	11.o	8.o	4.o	3.o	o.o	o.5	o.5
Dutch	-	299.o	228.o	75.o	8o.o	32.o	13.7	5.5	5.4	6.6

In both weeks the Dutch vessels tended to catch more older fish. The British vessels tended to catch the recruits. The annual abundance estimate for each age was obtained by taking a grand mean of all the weekly estimates. This method was giving satisfactory results up to 196o. However, in this year there was a remarkable example of inefficient search on the part of the English based drifter fleet. During the first two weeks of October only about 45o crans were caught. The Dutch drifters worked further east during this period and landed some 6,ooo crans. It was not till the third week in October that real contact with the shoals was made. Taking a straight mean of the weekly abundances the English and Scottish values are biassed downwards by the weeks of low catch when there was inefficient search. It has been observed from the echo-surveys that the first two weeks is the critical period when effort can be expended fruitlessly. Once contact is established the fishing tends to stabilize, though again at the end of the season vessels tend to remain too long in the Smith's Knoll area before breaking away to the southern grounds. Again ineffective effort may give low catches per shot, which do not represent the stock which has, by now, passed through the fishery area. In order to minimize the effects of ineffective fishing, a further modification was made in the method of obtaining an annual abundance index.

If the British and Dutch vessels are working on the same stock of herring then it would seem reasonable to suppose that similar estimates of abundance of the age groups in the two fisheries would be obtained. This criterion was used for assessment of any improvement in the age data.

Weekly raised age distributions were calculated for the English and Scottish vessels and the Dutch luggers. For each country a seasonal mean was obtained by weighting each week's abundance index by the catch using the following relation:

$$\text{seasonal mean} = \frac{\bar{x}_a \times A + \bar{x}_b \times B + \ldots.}{A + B + \ldots\ldots}$$

where $\bar{x}_{a,b\ldots}$ is the abundance of an age group as number per net per shot in week a, b, c, etc. and A, B, C ..... is the catch in the same period. A simple mean is taken of the Dutch and British raised age distributions so obtained. The effects of weighting may be appreciated with reference to the 196o data, Table 3.

Table 3. Number per net per shot in 196o

	English and Scottish		Dutch	Age
Unweighted	199.3		169.8	3
Weighted	249.2		221.7	
Mean		235.4		
Unweighted	68.4		114.8	4
Weighted	85.2		133.2	
Mean		1o9.2		
Unweighted	9.9		16.8	5
Weighted	12.5		19.1	
Mean				
Unweighted	2.7		5.6	6
Weighted	3.2		6.5	
Mean		4.8		

The effect of weighting is less, in this particular case, in the Dutch data than it is in the English and Scottish data. The weighted English and Scottish data are closer in number to the Ducth data.

The combined age distributions for the drift-net fishery in the Southern Bight are given in Table 4 below:-

Table 4. Number per net per shot for the Southern Bight British and Dutch drift-net fisheries

Year	Age in Years										
	2	3	4	5	6	7	8	9	1o	1o+	
1956	2.5	227.3	72.2	43.6	24.9	8.5	4.3	3.6	2.2	2.8	391.9
1957	2.8	183.o	79.o	17.1	13.1	6.5	2.9	1.3	1.o	1.4	3o8.1
1958	o.5	11o.8	76.2	22.o	8.o	2.9	1.3	o.7	o.4	o.2	223.o
1959	1.o	156.7	42.5	26.4	9.4	2.2	1.2	o.8	o.2	o.2	24o.6
196o	13.o	235.4	1o9.2	15.8	4.8	o.9	o.2	-	-	-	379.3
1961	2.4	482.o	68.8	3o.o	3.5	o.3	-	o.o	-	-	587.o
1962	6.6	38.9	191.3	22.3	1o.9	o.5	o.2	-	-	-	27o.7

These values are considered the best estimates of the composition of the drift-net catch. For the individual country's fisheries the weighted mean abundance index is preferable to a simple mean.

The extent of the improvement made may be seen in the mortality rates. Comparing those derived from the above data with those from the English data only, it is seen that a great amount of the variability is removed, see Table 5 (page 5).

Table 5. Mean instantaneous mortality rates, Z, for age groups 3-7 in 1956-1962

Year	Combined	English alone
1956/57	1.26	1.6o
1957/58	1.12	1.19
1958/59	1.o2	o.92
1959/6o	1.35	2.23
196o/61	1.7o	o.88
1961/62	1.15	1.o2

III. Drifter Catch per Effort as a Stock Index

Using the technique of echo-survey (Cushing, 1952) the distributions in space and time of pelagic fish traces during the East Anglian fishery have been recorded in recent years. Though individual traces may not be herring, a general identification of the contoured echo-densities with herring has been made. The echo-patches move south at the same rate as the fishery for herring and concentrate in the areas of the herring spawning grounds in the southern North Sea and eastern English Channel. More critically, when drifter catches have been distributed over areas of varying echo-concentration correlations, as in Figure 1, of herring catch on echo-level have been obtained. The distribution and abundance of these echo-traces have been used to give and independent estimate of abundance, against which the observed drifter catches per effort may be compared.

While long-term changes in efficiency can be detected by such techniques as that of Cushing, the initial variability in the catches per effort cannot so be examined. One might expect that an abundance index of stock derived from the effort of some 4oo vessels, as in the immediate post-war period to be more reliable than that derived in recent years from a fleet of loo drifters. Use of radio- and echo-sounders in recent years and coupled with the fact that only the most expert skippers and the best ships have survived the decline might counter any decline in efficiency. Any numerical enumeration of this type of effect is intangible.

One factor, which in recent years, has had a considerable effect on the size of a drifter's catch has been the effect of westerly winds. Bolster (1962) analysed the average catches made on nights when the wind lay across and in line with the tide. As the tidal stream in the Smith's Knoll region runs roughly north/south, winds from westerly quarters will hold the drift net across the tidal flow and present the biggest area of nets to fish moving south. Bolster showed that in the period 1952-6 the average catches 'in line' were between 5o% and 7o% of those on nights when the nets lay across the tide. He also showed that on 'across' nights bigger catches were taken on spring than on neap tides and that the ratio of these was of the same order as the ratio of the distances over which the nets would theoretically travel. Under periods of low abundance of herring, as in recent years, these factors might become important in biassing the stock estimates from the drifter's catch per effort.

In the period 195o-62 the percentage of fish nights with westerly components has varied between 11% and 78% with an average of 49%.

The echo-surveys have shown clearly that with the reduced fleet, location of the areas of high fish density is slow at the commencement of the season. An example of this limit in search may be taken from the 1957 season. High density echo-patches were recorded in the first two weeks of October; these areas were not exploited until 16/17th October. The catch, effort and catch per effort within and outside the patches are given below:-

Date October 1957	In			Out		
	Catch	Effort	Catch/Effort	Catch	Effort	Catch/Effort
7-9	96	2	48.o	1,174	2o1	5.8
11-13		-		1,433	216	6.6
16-17	4,889	242	2o.3	8.5	1	8.5
18-2o	1,913	247	7.7			
21-22	6,14o	174	35.4			

The drifters evidently 'discovered' the patch between 13th and 16th and subsequently concentrated on it.

An extreme example of the degree of dissociation between British drifters and the echo-patches occurred in 1960. In this year the main density of fish traces moved down the eastern side of the Southern Bight. It was only late in October that the British fleet moved east and south of the Brown Ridges into the area of high echo-density. This could account for the bias in the 1960 stock estimate referred to in the previous section.

Using the echo-surveys Burd (1959 and 1961) calculated stock indices using a relation between the echo-density of the patches and the corresponding catch per effort of the English drifters. The regression, Figure 1, of catch on echo-level for 1957 has been taken as standard as the echo-sounders used have been Kelvin Hughes MS 29 recorders since this date. Echo-traces expressed as mm per mile on the ships' course are contoured at four levels: 0, <5, $\leqslant 9$ and >9 mm per mile. For each survey echo-level 1 is taken as the minimum echo-level in which catches are recorded. The area of each contoured echo-level is measured for each cruise and raised by the mean catch from the regression in Figure 1. The weighted mean catch per shot, i.e. $\frac{\Sigma \text{ catch/shot x area}}{\text{Total area}}$ was called the Stock Density Index. The values obtained for the last eight years compared with the drifter catch per shot appear below:-

Year	Stock Density Index as crans/shot		Drifter Catch Crans/shot
1956	41.9		24.8
1957	22.2		22.1
1958	18.2		17.8
1959	17.8		15.0
1960	24.0		18.7
1961(Oct.)	29.4	(Oct.)	23.2
1962(Oct.)	23.0	(Oct.)	13.7

The drifter catch per shot is seen in most years to be rather similar to the independent estimate of stock obtained from the echo-surveys. Two notable exceptions are those of the 1962, 1960 and 1956 seasons, when it is evident that either the drifter search was relatively poor, or some other effect was reducing the catch per shot, or again that the echo-survey was misleading.

If the magnitude of the drifter catch each year is as dependent on westerly winds as Bolster has indicated, then for the study of annual fluctuations in abundance the seasonal catch per effort must be a biassed one. The only comparable data from year to year are the catches on nights of westerly winds. These nights should in general also give the highest abundance estimate, as the fleet's efficiency is highest under these conditions. For this reason Burd (1961) called this index the 'Most Efficient Drifters' catch per shot and when correlated with the Stock Density Index gave a highly significant regression (Figure 2a). Comparable data to the 'Most Efficient Drifters' catch per shot is unfortunately not available for the combined East Anglian abundance index. One would hope, however, that such refinement of the catch data might not be necessary with the increased weight of data available. These data expressed in number per net per shot are not directly comparable with the Stock Density Index which is in crans, a volume measure. In plotting the regression of the combined East Anglian abundance index on Stock Density Index in Figure 2b, the former has been converted to crans using the number of fish per cran from the Lowestoft and Yarmouth landings. While there would appear to be an even better correlation between the 1957-62 observations than that in Figure 2a, 1956 is far out, resulting in a non-significant correlation for the data as a whole. In 1956 there was a difference of 1.79 times in the magnitude of the British catch per effort for the whole season and that based on the 'Most Efficient Drifter' catch/shot, the latter being the greater. If such an effect is observed in the catches of one country it is likely that a similar effect would be noticed in the Dutch data. Ratios of the seasonal 'Most Efficient Drifter' catch per shot to the total drifter catch per shot have been calculated for the British data and are shown below:-

Year	Ratio	Year	Ratio
1956	1.79	1960	1.23
1957	1.27	1961	1.09
1958	1.27	1962	1.45
1959	1.24		

These ratios have been used to raise the combined East Anglian abundance indices for each year and these data have been plotted on the Stock Density Index in Figure 2c. A highly significant correlation results, $p > .001$.

It would appear that the use of the combined East Anglian abundance index does not wholly eliminate bias due to westerly wind effects. This is not surprising as both drifter fleets are likely to be affected in the same way by wind. In the main, however, it would seem that this combined index is a better one than either the British weighted index or the 'Most Efficient Drifter' index.

The Stock Density Index is derived from the total echo-traces recorded on the surveys. In this way it will include a certain number of echoes derived from fish other than herring. The Index will therefore be to some extent an over-estimate of the herring stock. The correlation between echo-level and observed drifter catch, Figure 1, includes a variance on catch due to inclusion of non-herring traces in the echo-levels. Dependent upon how important this proportion was, the average catch per echo-level would be biassed up or down from the true herring abundance. The Stock Density Index will be to a greater or lesser extent an overestimate of the stock available, if other species form an important part of the echo-traces. The correlations (Figures 2a and c) of 'Most Efficient Drifter' and the combined East Anglian indices both have intercepts not significantly different from zero. This would suggest that the Stock Density Index is a good measure of the abundance of herring and that either of the two catch indices are giving reliable stock estimates.

Summary

In recent years there has been a dramatic decline in the drifter fleet working from the East Anglian ports in October and November. There has also been a reduction in numbers of the Dutch lugger fleet.

With the reduction in quantity of herring being landed at Lowestoft and Yarmouth and the change in marketing, it became necessary to revise the Hodgson method of estimating the abundance of each year-class of herring in the catches. As reduction in area of search was a major cause of inefficiency in the drifter fleet the first modification was a combination of the catch and age data from Dutch and English sources. A second modification was introduced in 1960 when the seasonal abundances were obtained by using the weekly mean abundances weighted by the catch. A considerable reduction in the variability between the annual mortality estimates resulted.

From the echo-surveys made during the fishery it could be seen that poor cover of the high echo-densities by the drifters often took place early in the season. The surveys also afforded a method of assessing abundance. This Stock Density Index was found to be highly correlated with the catches on nights of westerly winds when the drifters were working at their most efficient level.

References

Beverton, R. J. H. & Holt, S. J. 1957 "On the dynamics of exploited fish populations". Fish.Invest.Lond., Ser.II, 19.

Bolster, G. C. 1962 "The influence of wind and tide on the catch by drift nets in the East Anglian herring fishery, 1952-6". J.Cons.int.Explor.Mer, XXVII(2).

Burd, A. C. 1958 "On the relation between the echo-survey and the drifter catches in the East Anglian herring fishery". ICES, Herring Cttee. Paper No.47.

Burd, A. C. 1959 "An analysis of the method of sampling the East Anglian herring catches". J.Cons.int.Explor.Mer, XXIV, pp.80-94.

Burd, A. C. 1961 "Echo-survey as an independent estimate of abundance". ICES Herring Symposium, Paper No.26.

Burd, A. C. 1963 "On selection by the drifter fleets in the East Anglian herring fishery". J.Cons.int.Explor.Mer, XXVIII, pp.91-120.

Cushing, D. H.	1952	"Echo-surveys for fish". J.Cons.int.Explor.Mer, XVIII, pp.45-6o.
Cushing, D. H.	1961	"The effect of fishing on the Downs stock of herring in the North Sea". ICES Herring Symposium, Paper No. 25.
Min.Agr.,Fish. & Food, Scottish Home Dept.		"Fish Stock Record" - Published annually.
Hodgson, W. C.	1939	"An improved method of sampling herring shoals". Rapp.Proc.-Verb., 11o, pp.31-38.
Tungate, D. S.	1958	"Echo-sounder surveys in the autumn of 1956". Fish. Invest. Lond., Ser.II, 22(2).
Valdez, V. & Cushing, D. H.	1961	"The effect of tidal streams on the presence of an extensive layer of mid-water echo-traces". J.Cons. int.Explor.Mer, XXVII(3).

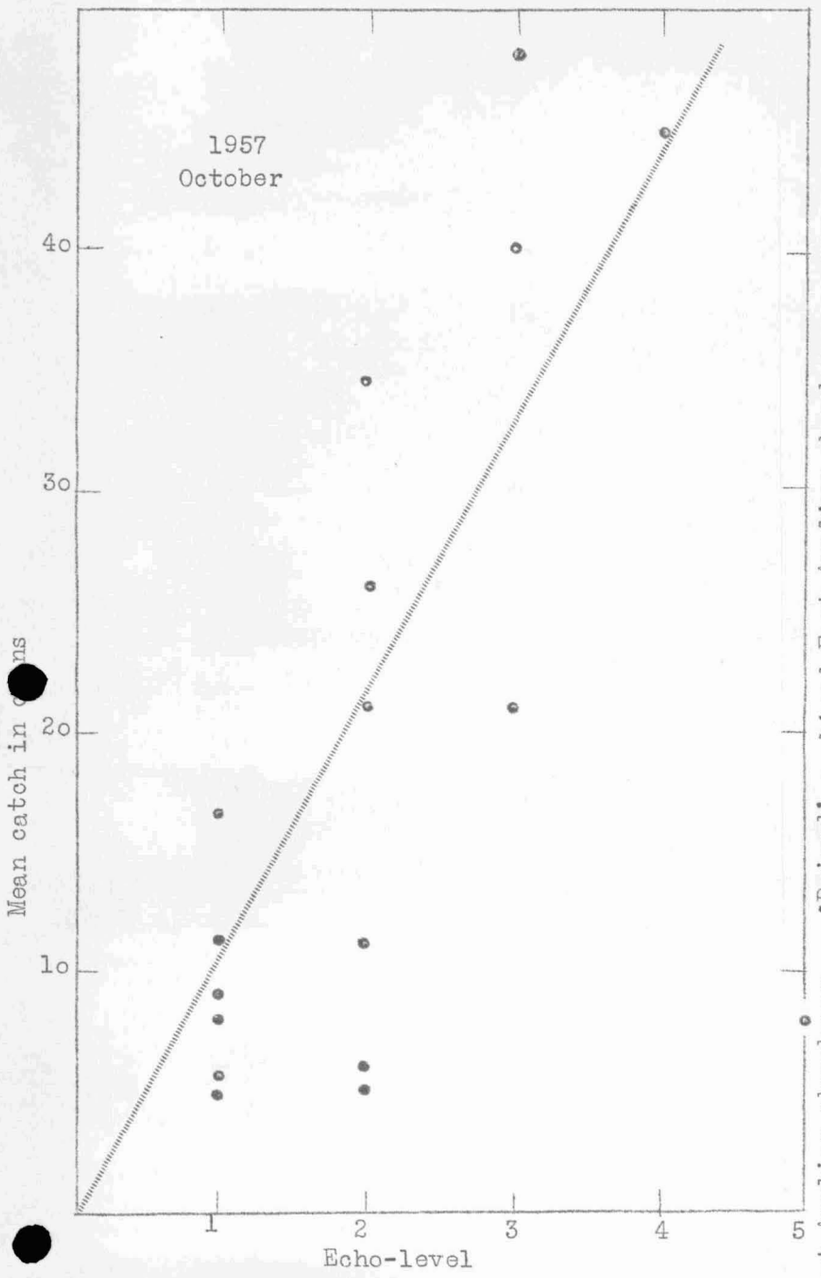
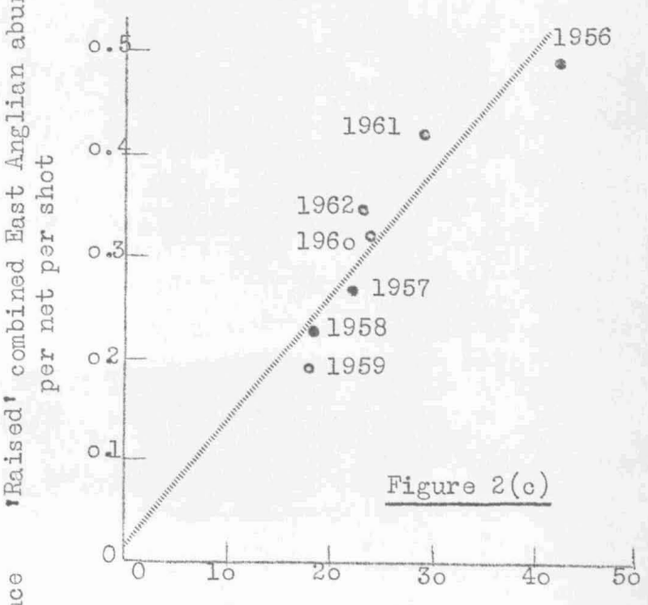
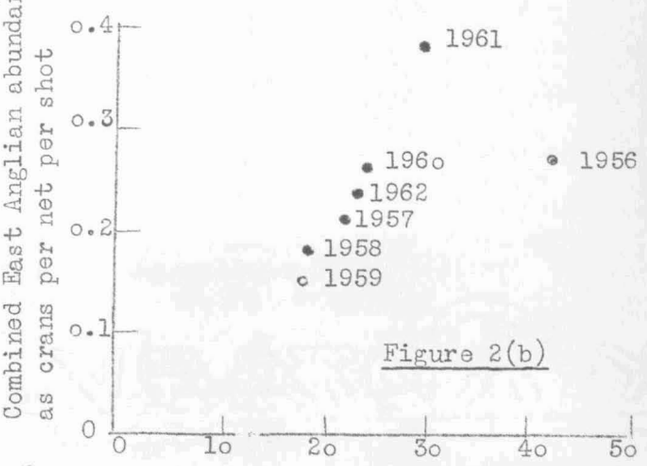


Figure 1. The relation between echo-level and mean drifter catch of herring.





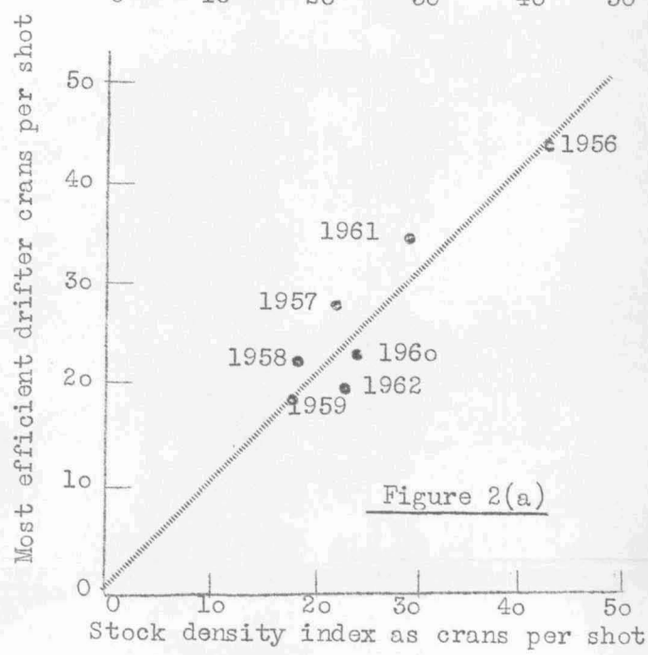


Figure 2(a), (b), (c). Relationship between the stock density index and various estimates of abundance from catch data.