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Haddock Recruitment Predictions from Bottom-trawl Catches of 0-Group Fish in Subarea 5 and Division 4X

by

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INTRODUCTION

The ability to predict future recruitment to exploited fish stocks contributes to the operational efficiency of a fishery and it provides for more precise management. This is particularly important in heavily exploited fisheries which are dependent on relatively few year classes, and where optimum management ultimately will require annual catch quotas. In the Georges Bank haddock fishery, the earliest U.S. commercial index of the strength of incoming year classes is in the form of fisherman reports of small haddock, usually about 1-1/2 years old, discarded at sea. These reports do not provide a satisfactory basis for prediction partly because it is difficult to obtain an accurate record of the quantity or composition of these discards, and partly because the discard reports give a lead time of only one year. Georges Bank haddock make their first significant contribution to landings by the U.S. fleet when they are about 2-1/2 years old (at which time they reach the 50 percent selection point for 4-1/2" mesh). A more precise basis for predictions as well as increased lead time are desirable, and we have been able to achieve such improvements by means of research vessel surveys.

Otter trawl surveys in New England waters by the U.S. Bureau of Commercial Fisheries Laboratory at Woods Hole, have been conducted since 1948. An attempt to provide better predictions of year class strength as well as further insight into the recruitment processes of fish in general, were among the objectives of these surveys. Consequently, a fine mesh liner was used routinely in the cod end of survey trawls. Emphasis has been given to Georges Bank haddock and the abundance of 0-group (young-of-the-year) haddock on our surveys has been correlated with the relative abundance of the same year classes in U.S. haddock landings two and three years later (see U.S. Research Reports for 1964, 1966, 1967 in Redbook). In addition to the obvious predictive value, this correlation suggests that major factors controlling brood success probably have operated by the time the young become available to bottom trawls, and implies that natural mortality for the remainder of the pre-recruit phase is not highly variable. A similar correlation has been found for Brown Bank (Division 4X) except that year classes normally enter that fishery about two years later than Georges Bank because of slower growth.

The purpose of this document is to describe the 0-group index used to date. The index must still be considered preliminary because we are still evaluating factors which may affect its accuracy. The most important potential sources of error are temporal variations in availability of 0-group fish to the bottom trawl, and fluctuations in pre-recruit mortality. Study of these factors and others, involves inter alia comparisons of 0-group indices with abundance of the same year classes at successively older ages in both commercial and research vessel catches. A definitive analysis is scheduled for completion in 1969.

DEVELOPMENT OF HADDOCK 0-GROUP INDEX

U.S. Groundfish Surveys.

A research vessel survey on Georges Bank in the summer of 1948 demonstrated among other things that juvenile haddock could be caught in large numbers with a bottom trawl (#1-1/2 Iceland trawl) as early as July (Colton, 1955). Peak spawning on Georges Bank usually occurs during February, March and April. Therefore by July, 0-group haddock normally are about four months old, and those available to bottom trawls form a distinct modal length class within a range of about 6-10 cm. Subsequent surveys in summers of 1949 and 1950 also yielded 0-group haddock on Georges Bank as well as in the Gulf of Maine, but there were noticeably fewer 0-group haddock in 1949 than in 1948 and 1950 (Figure 1). By 1952, U.S. landings statistics showed the 1949 year class to be substantially weaker than the other two year classes, and then the prediction possibilities of the surveys became apparent (Colton, 1955).

In September 1953, a new series of autumn groundfish surveys was begun employing the smaller and easier to handle #36 Yankee trawl (see trawl description in Res. Doc. 68/87 by Grosslein). Except for 1954 and 1957 there has been a survey each subsequent autumn using basically the same #36 trawl, and this autumn series has formed the basis for the 0-group index. Before describing the index however, it is necessary to describe the several sampling designs used, one of whose geographical strata were used in constructing the index.

Survey sampling designs.

I first became involved with discussions on sampling design for the surveys when I arrived at Woods Hole in the summer of 1961. Four of the surveys had employed a systematic or grid sampling pattern and two had used a subjective pattern, concentrating stations in places where the biologists expected to find 0-group haddock. The latter plan was obviously inferior to the grid pattern, and the grid pattern was not ideal for either the general purposes of the surveys or for an 0-group census. At the low sampling intensity used, it was inevitable that with a grid pattern there would be large gaps in sampling the various depth zones within any one geographic section of the survey area.

Clearly some form of stratified sampling was needed and the entire area from Hudson Canyon to Western Nova Scotia was provisionally subdivided into nine sampling areas (Figure 2). These areas were selected on the basis of the biologists' concensus as to approximate ecological boundaries particularly with respect to adult haddock populations, but taking into account other important species and hydrographic factors as well. Selection of stations within areas was arbitrary except that stations were distributed more or less evenly throughout each area and all depths out to about 200 fathoms were represented. This sampling plan was used for the 1961 fall survey and thereafter, until 1964 when the stratified random design in current use was adopted (see U.S. Res., Redbook 1966, Pt. II).

Selection of 0-group index areas.

The 0-group index was first constructed in 1963 after examining the distribution of sampling and the 0-group haddock catches for the surveys from 1953 to 1963. During this period there was an obvious tendency for 0-group haddock to be concentrated in the autumn along the northern edge and northwest corner of Georges Bank, and to be much less abundant on the southern parts of the Bank (Figures 3, 4). This distribution pattern plus the fact that some trawling had been done in every survey on these same parts of Georges Bank (including 1959 and 1960) let naturally to the choice of area V and the northern half of VII combined, as the index area for Georges Bank (see shaded area in Figure 2). Areas III and IV combined were chosen to represent western Nova Scotia and Areas I and II represented the Gulf of Maine.

Despite the change in 1964 to a more precise stratification scheme, these same six areas have been used to date for computing the 0-group indices. Geographic distribution of 0-group haddock has remained essentially the same in fall surveys subsequent to 1963 except that by comparison, 0-group fish have been rather consistently scarce (Figure 4, 5). Occurrence of 0-group haddock west of Georges Bank, outside the current index area and as far west as Long Island, seems to be correlated with 0-group abundance within the index area (Figure 4). However, since adult haddock are not consistently found in abundance in this area, and since there is a tendency for the 0-group fish to be present there in the summer and then disappear in the fall, there is some question whether the 0-group abundance in this area will be very meaningful in relation to subsequent recruitment to principal fishing grounds (Figure 4). The distribution pattern does raise interesting questions about the origin and fate of these fish, and eventually this pattern may contribute to a better understanding of the role of dispersion and other factors affecting survival of larval haddock.

The correlation between summer and autumn abundance in the same year is obvious for the Albatross IV surveys shown in figure 4, and adds to the evidence obtained from the 1948-50 summer surveys, that the year class strength is determined for the most part at least by age 6 months.

Calculation of the index.

Our initial objective was simply to find a relative abundance index. That is for predictive purposes it would suffice to be able to measure the size of one year class as a proportion or multiple of another year class regardless of the absolute abundance of 0-group fish.

Since distributions of 0-group catches are highly skewed, I transformed catches to logarithms in an attempt to improve efficiency of estimation and simplify analysis by normalizing distribution functions and stabilizing variances. The transformation was only partly successful. The distribution of transformed catches was still positively skewed, and so far a better transformation has not been found. However this is considered a relatively minor problem in comparison with the potential variability from factors affecting availability of 0-group fish to a bottom trawl.

Depth and time of day were two factors which might be expected to affect availability and these were accounted for by classifying trawl hauls according to two depth zones ($\leq$ 60 fathoms and $>$60 fathoms) and three time periods (full daylight, 0800-1600; full darkness, 2000-0400; and "twilight and dawn", 1600-2000 and 0400-0800). A simple mean of the transformed catches, common log of the number of 0-group haddock plus 1, was calculated for each of the six depth-time combinations in each pair of sampling areas noted above. Note that each pair of areas (V and VII, I, II, III and IV) was treated only in combination, i.e. as a single area. Finally the six depth-time means were averaged to provide a single index for each of the three regions, Georges Bank (V, VII), Gulf of Maine (I, II), and western Nova Scotia (III, IV), and the anti-log of the compound mean was used as the numerical index, in terms of mean numbers of fish per haul.

Analysis of variance of the transformed catches for four surveys with the highest 0-group abundance (1955, 1958, 1959, and 1963) showed no significant effects due to depth or time of day, nor any significant interactions involving these factors. That is, 0-group catches showed no consistent relation with depth-time categories used.

0-GROUP INDEX FOR GEORGES BANK (DIV. 5Z)

Haddock are first recruited to the Georges Bank fishery in the latter part of their third year of life, at age 2, and recruitment is essentially complete by the end of the fourth year of life, at age 3.

The 0-group index described above was plotted against the average U.S. landings per day for the same year class at ages 2 and 3 years (Figure 6, Table 1). Clearly there is a positive correlation between the two abundance indices, but the scatter of points is wide, particularly at the lower values of the 0-group index. A curve would fit the entire array of points better than a straight line but we have not fit a line because as noted earlier, factors affecting the accuracy of the two sets of indices are still under study.

In particular the relative abundance of the 1963 year class at ages 2 and 3 in U.S. landings undoubtedly was biased downward as a result of unusually high fishing mortality on this year class in 1965 (see Res. Doc. 69/__ by Hennemuth). Albatross IV surveys also showed that the 1962 year class, relative to the 1964 and 1965 year classes, was stronger at ages 1 and 2 than was indicated by the 0-group index; apparently the 0-group fish were less available than usual in the fall of 1962.

Another problem still to be resolved is the comparability of the catch data for the two series of research vessel cruises--those for the period 1953-62 with R/V Delaware, and those since 1963 with the Albatross IV. Paired-tow experiments with these two vessels were done in the summers of 1965 and 1968 each using a #36 trawl, but 0-group haddock were very scarce in both years. Therefore estimates of relative fishing power for 0-group haddock must be based on a comparison of the performance of each vessel in terms of the 0-group catch relative to subsequent catches of the same year classes (by the same vessel) at older ages. Although this analysis is incomplete, any estimate of relative fishing power particularly for 0-group fish probably will have rather low precision.

Re-calculation of 0-group indices using the current stratified sampling scheme (thereby weighting depth zones according to their area) is not likely to alter existing indices much, although such weighing is desirable from a theoretical standpoint.

0-GROUP INDEX FOR WESTERN NOVA SCOTIA (DIV. 4X)

Growth of haddock is slower in Division 4X than in 5Z and recruitment to the U.S. fishery in 4X begins about two years later at age 4, and it is more gradual with full recruitment attained only by age 6 or 7 (Hennemuth, et al, 1964). The 0-group index for western Nova Scotia was plotted against landings per day of the same year class 5 and 6 years later, in order to get a reasonably firm measure of the relative strength of each year class in the landings. 1/

In Division 4X, as on Georges Bank, there is a positive correlation between 0-group indices and commercial abundance for the same year classes (Figure 7, Table 1). The points show considerable scatter and are also best fit by a curve even more pronounced than that for Georges Bank. Again we anticipate that the commercial index for the 1963 year class (represented only by age group 5 in these data) may be biased downward because of unusually heavy fishing on this year class in Division 4X during 1966. This potential error plus the same general factors described above for the Georges Bank area will be evaluated further in the coming year.

SIMILARITY OF YEAR CLASSES IN 5Z AND 4X

Some similarity of the relative abundance of certain year classes in both the 5Z and 4X haddock fisheries was reported by Hennemuth, et al. (1964) and it has been apparent in commercial landings of subsequent years.

1/ The commercial abundance index of haddock for Division 4X is based on landings statistics for both U.S. and Canadian trawlers fishing in the first two quarters of the year, principally on Browns Bank where haddock concentrate for spawning. Catch and effort statistics since 1962 are reported in Res. Doc. 69/__ by Schultz and Halliday.

Table 1. --Abundance indices of haddock year classes in Subarea 5 and Division 4X, based on autumn 0-group catches by research vessel and on commercial landings per day in hundreds of fish. 1/

Year Class	0-Group Index			Commercial Index	
	Georges Bank	Western Nova Scotia	Gulf of Maine	Georges Bank	Western Nova Scotia
53	3.6	3.0	2.4	8.9	6.7
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55	3.5	11.8	3.2	9.9	11.9
56	2.0	3.6	1.7	9.4	10.5
--	---	---	---	---	---
58	8.5	11.5	2.4	20.7	10.9
59	9.6	10.0	5.2	16.4	20.3
60	2.4	5.0	2.1	5.5	9.2
61	1.4	1.9	1.1	3.5	3.9
62	2.6	6.0	2.7	14.2	14.1
63	12.6	37.2	9.8	23.1	22.9
64	2.0	1.1	1.0	1.5	
65	1.2	1.5	0	0.3	
66	1.7	1.3	0		
67	0	1.1	0		
68	1.0	1.5	0		

1/ See text for details on computation of indices.

A correlation has also been reported among the 0-group indices for these two areas (U.S. Res. Repts. for 1963 and 1964, Redbook series). In this document I have incorporated the entire set of available 0-group indices, including the Gulf of Maine, and it is clear that the abundance of 0-group haddock is rather well correlated among all three areas, in both autumn and summer cruises (Figure 8, Table 1).

The correlation of 0-group indices among areas for a given year raises interesting questions about the mechanisms which might account for such a pattern. Dispersion of planktonic larvae and, subsequently, demersal juveniles from one or more spawning centers, or survival factors which are common to the whole region in a given year, might both be involved. We cannot resolve these questions with the available data. However if region-wide survival factors are involved then a single 0-group index based on all areas might be the best predictor of year class strength for all areas. In fact, the 0-group index for all areas combined does give a better correlation with later abundance of year classes on Georges Bank, but the improvement is small because the correlation of 0-group indices among areas is much higher than the correlation between 0-group indices and abundance of the same year classes at older ages.

LITERATURE CITED

Colton, J.B. 1955. Spring and summer distribution of haddock on Georges Bank. U.S. Fish & Wildl. Serv. Spec. Sci. Rep. F., 156

Hennemuth, R.C., M.D. Grosslein and F.D. McCracken. 1964. Abundance, age composition of landings, and total mortality of haddock caught off southern Nova Scotia, 1956-1961. ICNAF Research Bulletin, No. 1, 1964, pp. 44-73.

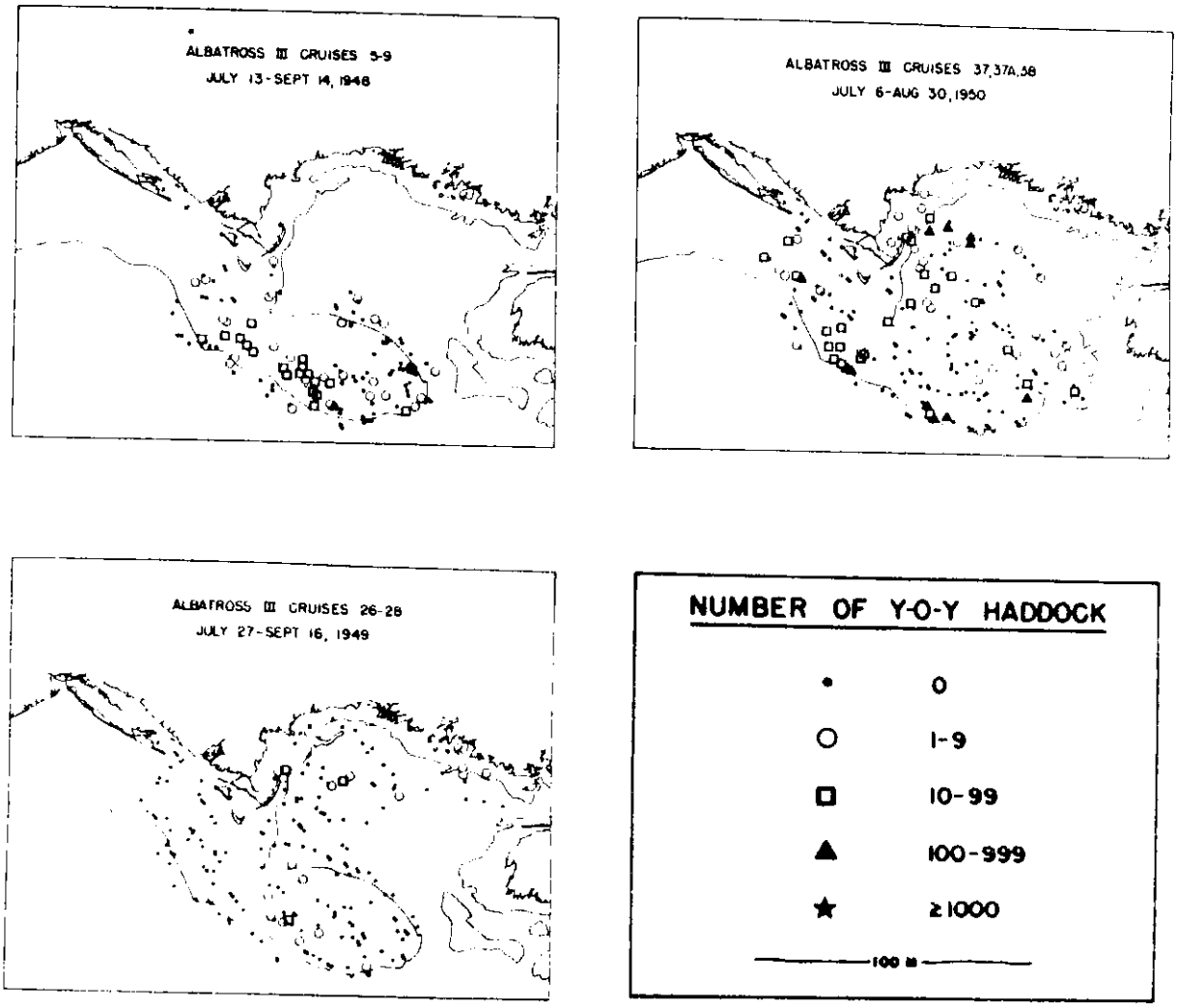

Figure 1.--Catches of 0-group haddock in 30-minute tows with #1-1/2 Iceland trawl on summer research cruises, 1948-1950.

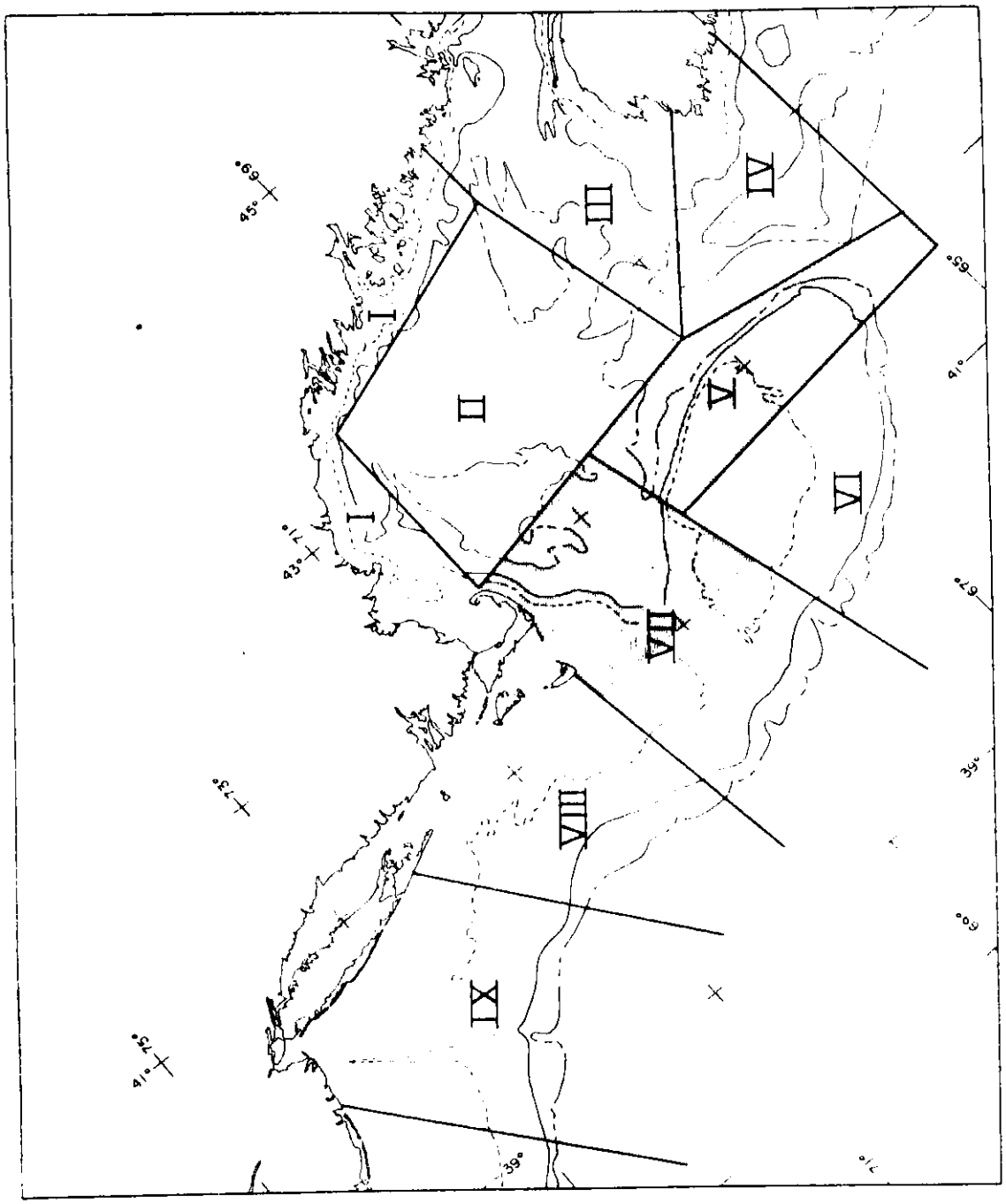

Figure 2.--Sampling areas used in autumn groundfish surveys, from 1961 through 1963. Shaded zone represents 0-group index area for predicting haddock recruitment on Georges Bank. Similar 0-group indices were obtained for western Nova Scotia (III, IV) and Gulf of Maine (I, II).

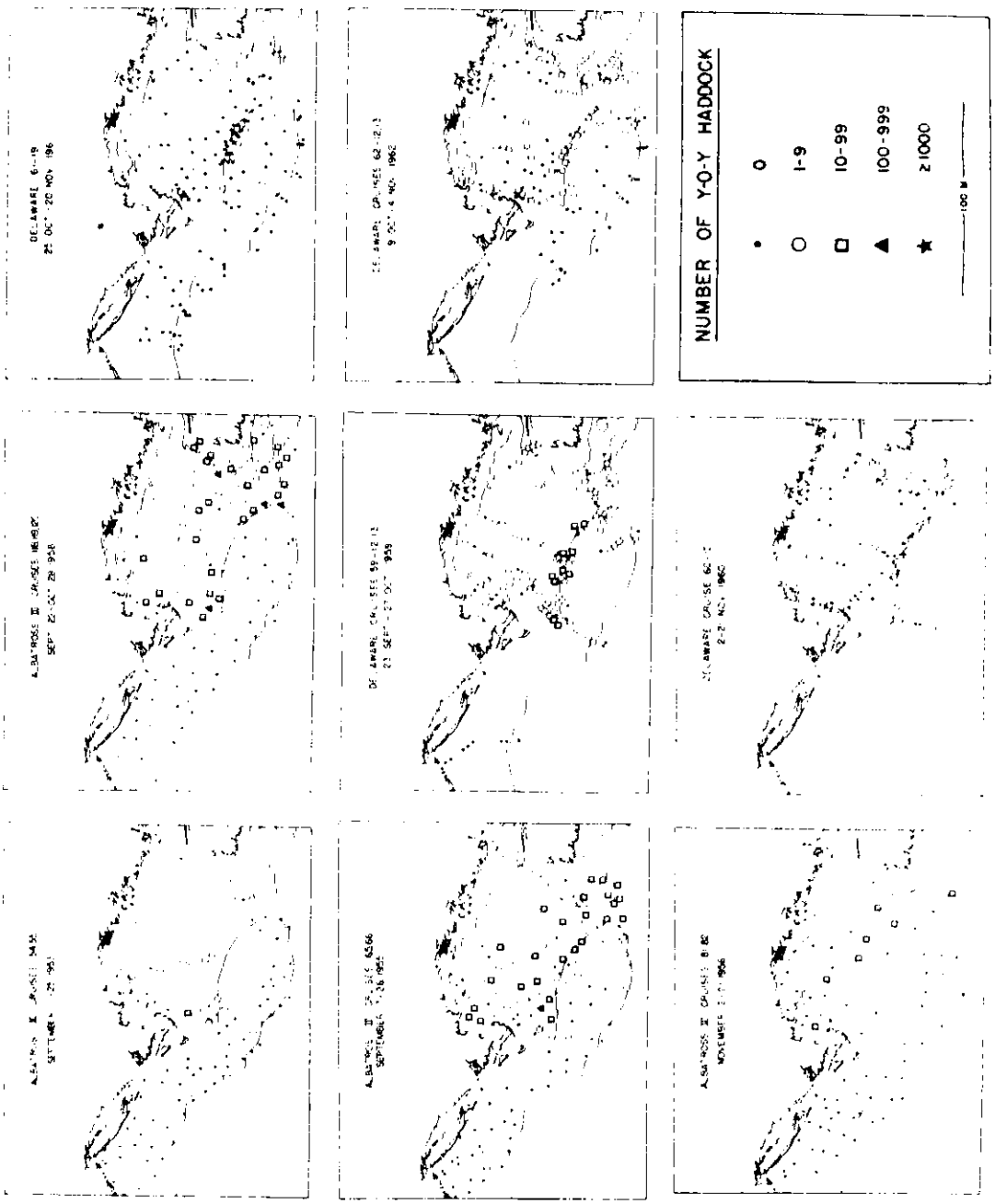

Figure 3.--Catches of 0-group haddock in 30-minute tows with #36 trawl in autumn research cruises from 1953-1962.

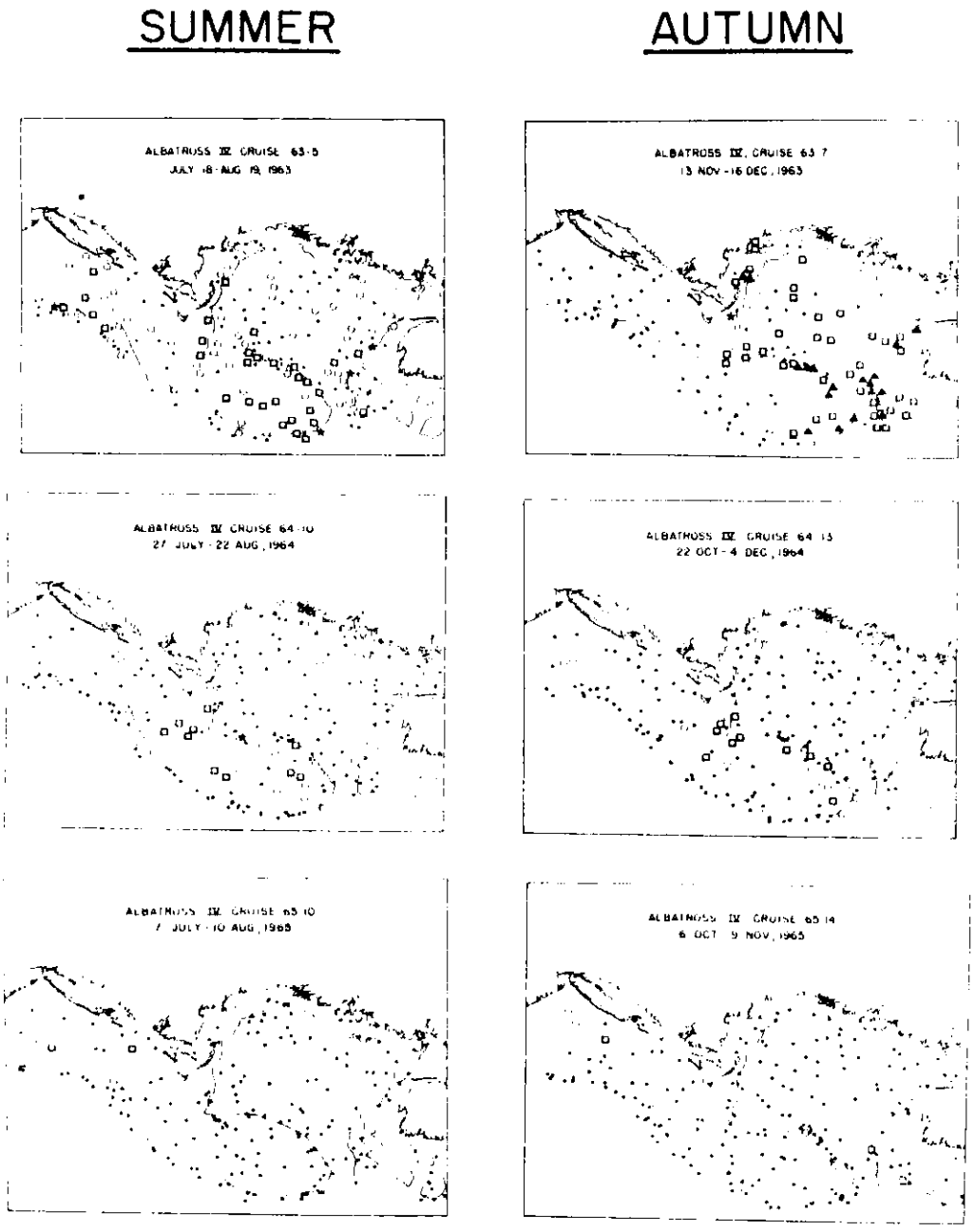

Figure 4.--Catches of 0-group haddock in 30-minute tows with #36 trawl in summer and autumn research cruises from 1963-1965 (symbols same as in Figure 3).

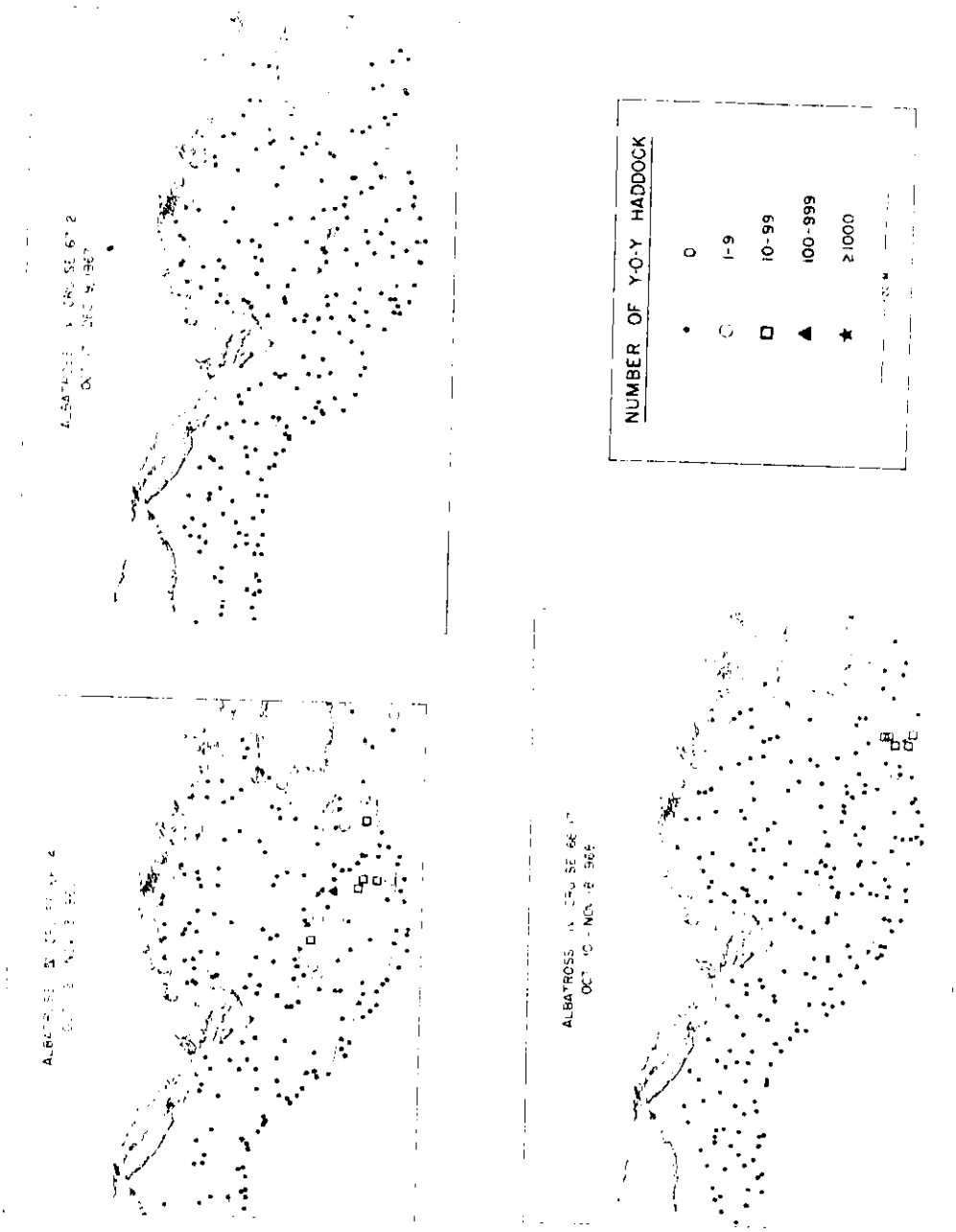

Figure 5.--Catches of 0-group haddock in 30-minute tows with #36 trawl in autumn research cruises, 1966-1968.

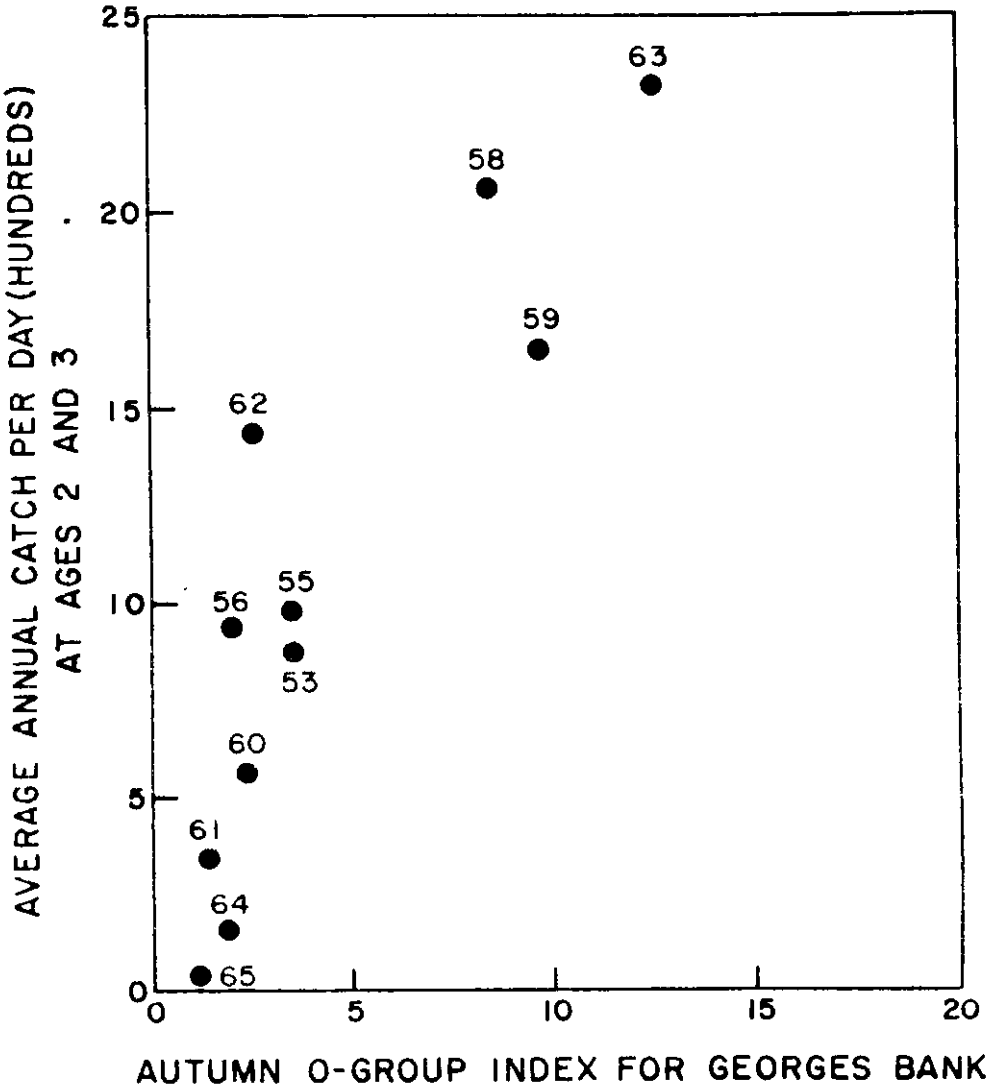

Figure 6.--Scatter plot of Georges Bank haddock 0-group indices against annual average landings per day at ages 2 and 3 for the same year classes in Division 5Z. Numbers beside points represent year classes.

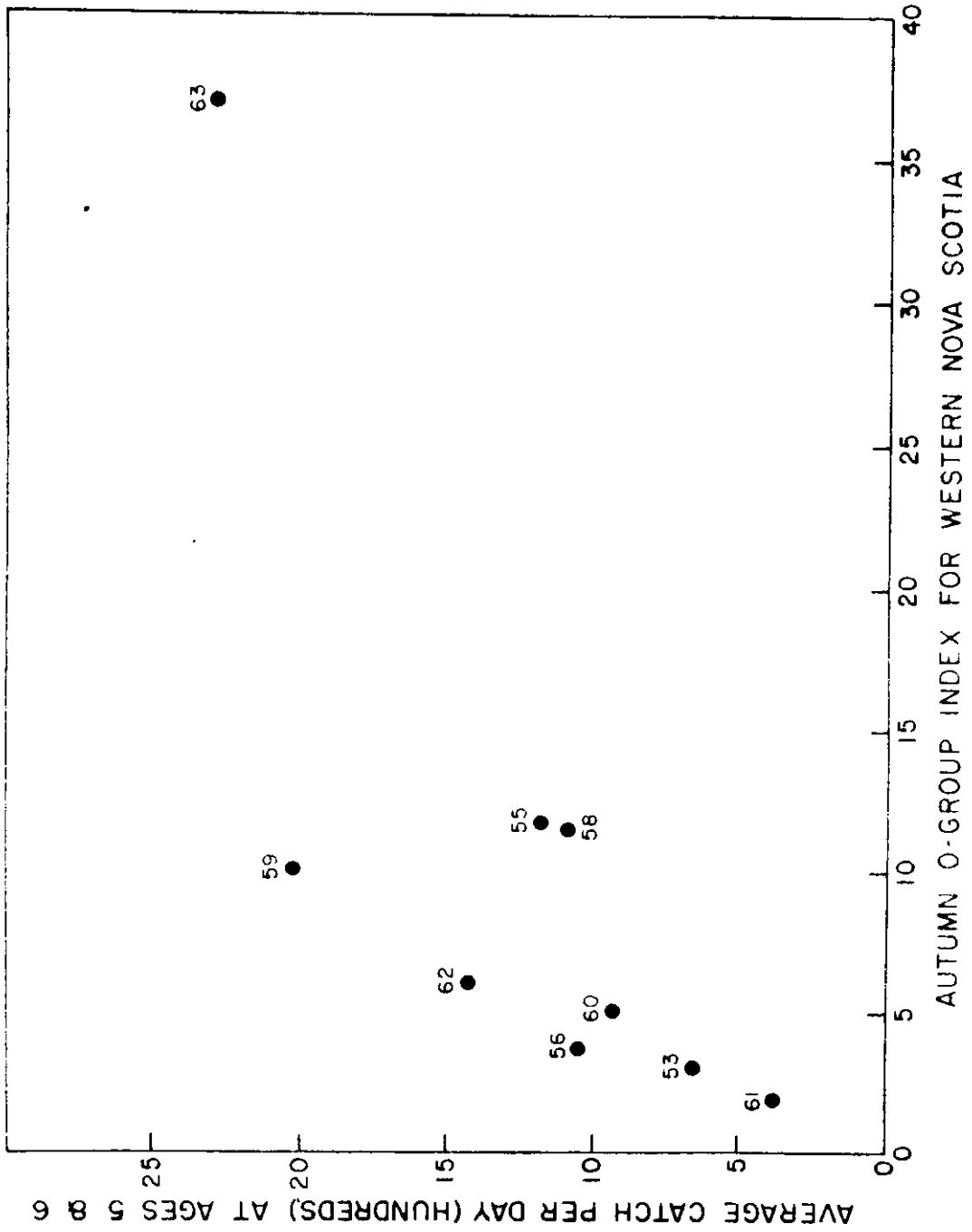

Figure 7.--Scatter plot of western Nova Scotia haddock 0-group indices against average landings per day (first 2 quarters) at ages 5 and 6 for the same year classes in Division 4X (exclusive of Bay of Fundy). Numbers beside points represent year classes.

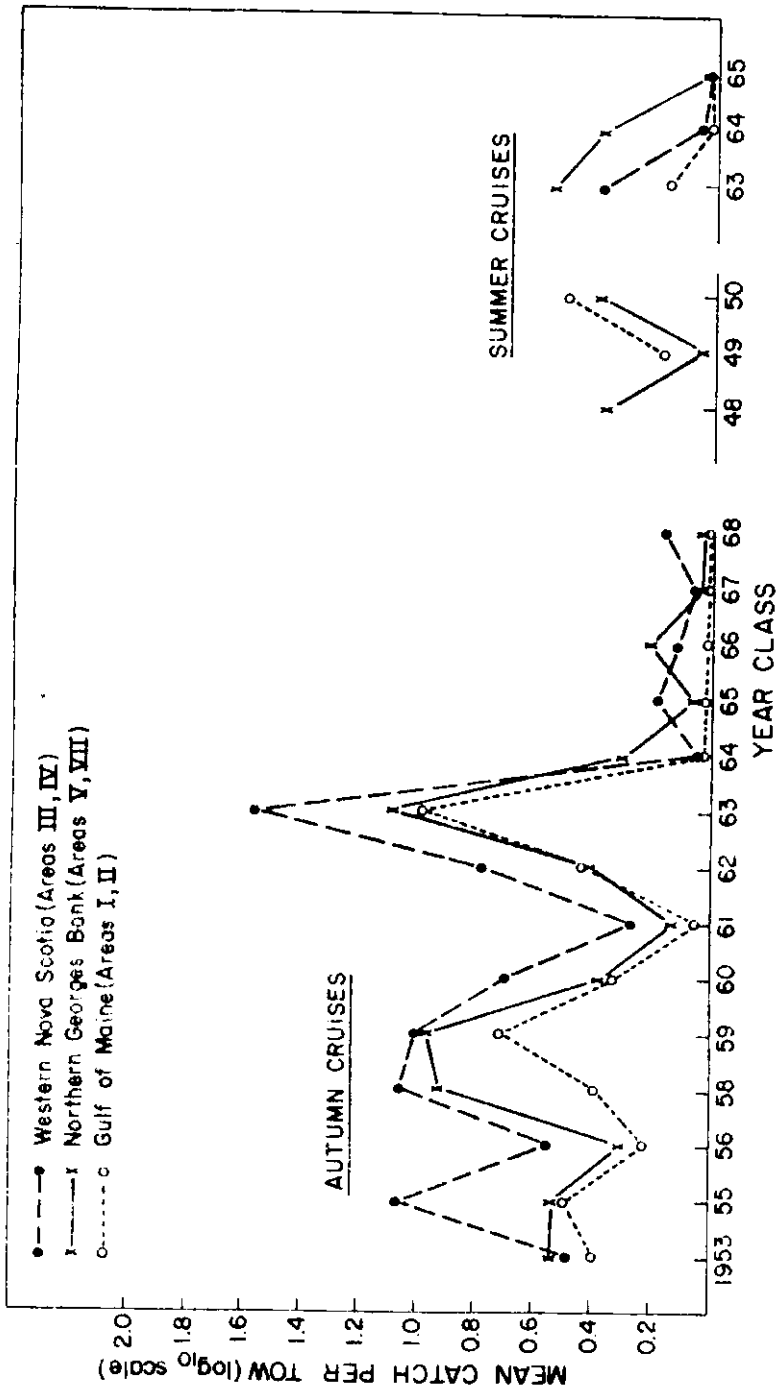

Figure 8.--Haddock 0-group indices derived from bottom-trawl surveys with research vessels in Subarea 5 and Division 4X. Areas shown in figure 2.