THE DISTRIBUTION AND ABUNDANCE OF HADDOCK EGGS, LARVAE, AND JUVENILES IN THE GULF OF MAINE--GEORGES BANK AREA IN RELATION TO YEAR CLASS STRENGTH FLUCTUATIONS OF GEORGES BANK HADDOCK.

by

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THE DISTRIBUTION AND ABUNDANCE OF HADDOCK EGGS, LARVAE, AND JUVENILES IN THE GULF OF MAINE - GEORGES BANK AREA IN RELATION TO YEAR CLASS STRENGTH FLUCTUATIONS OF GEORGES BANK HADDOCK.

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This report is based on collections of haddock eggs and of larval and postlarval haddock made during Continuous Plankton Recorder surveys in the spring of 1953, 1955, and 1956, on collections of juvenile and older haddock made during otter trawl surveys in the fall of 1953, 1955, 1956 and 1958, and on the landings of 3-year-old haddock by the commercial fleet. It is the purpose of this report to summarize data on the distribution and abundance of haddock eggs, larvae, and juveniles; to relate these data to the year class strength of Georges Bank haddock as determined from the commercial landings; and to make recommendations for future studies.

EGGS AND LARVAE

The dates of the Continuous Plankton Recorder cruises were as follows:

Albatross III Cruise No.	Date
46	March 19 - April 2, 1953
48	April 24 - May 8, 1953
50	May 25 - June 3, 1953
57	Feb. 21 - March 2, 1955
58	March 19 - April 1, 1955
60	April 19 - May 3, 1955
61	May 16 - May 28, 1955
71	Feb. 20 - March 2, 1956
72	March 21 - March 31, 1956
73	April 17 - April 28, 1956
75	May 16 - May 29, 1956

The details regarding the area of coverage and methods of collection and analysis during these cruises are given by Marak and Colton (1961), Marak, Colton, and Foster (1961), and Marak, Colton, and Miller (1961).

Spawning Location

In most cases the distribution of early stage eggs was used for delineating spawning centers, but during some cruises the peak of spawning was missed in certain areas and the approximation of spawning location was based on the distribution of late stage eggs. The period of development included in the category "early stage eggs" is from fertilization to the approach of the germinal ring to an equatorial position. At the prevailing water temperatures on Georges Bank during the spawning period (40°F. - 44°F.), this grouping includes eggs up to 8-days old.

The distribution of total and early stage eggs in the upper 10 meters as indicated by Continuous Plankton Recorder tows at the surface and 10 meters during March, April, and May 1953, and February, March April, and May 1955 and 1956 is shown in Figure 1. In all years the distribution of haddock eggs showed Georges Bank and Browns Bank to be the 2 principal spawning areas. In some years limited spawning also occurred in the South Channel and off the coast of Cape Cod, Cape Ann, and southwestern Nova Scotia.

Magnitude and Time of Spawning

Spawning on Georges Bank occurred principally in February and March and spawning on Browns Bank occurred mainly in April. To get a better measure of the relative magnitude and time of spawning in the various locations during the 3 years, the abundance of total eggs (average no. /M^3 at the surface and 10 meters) was determined for the

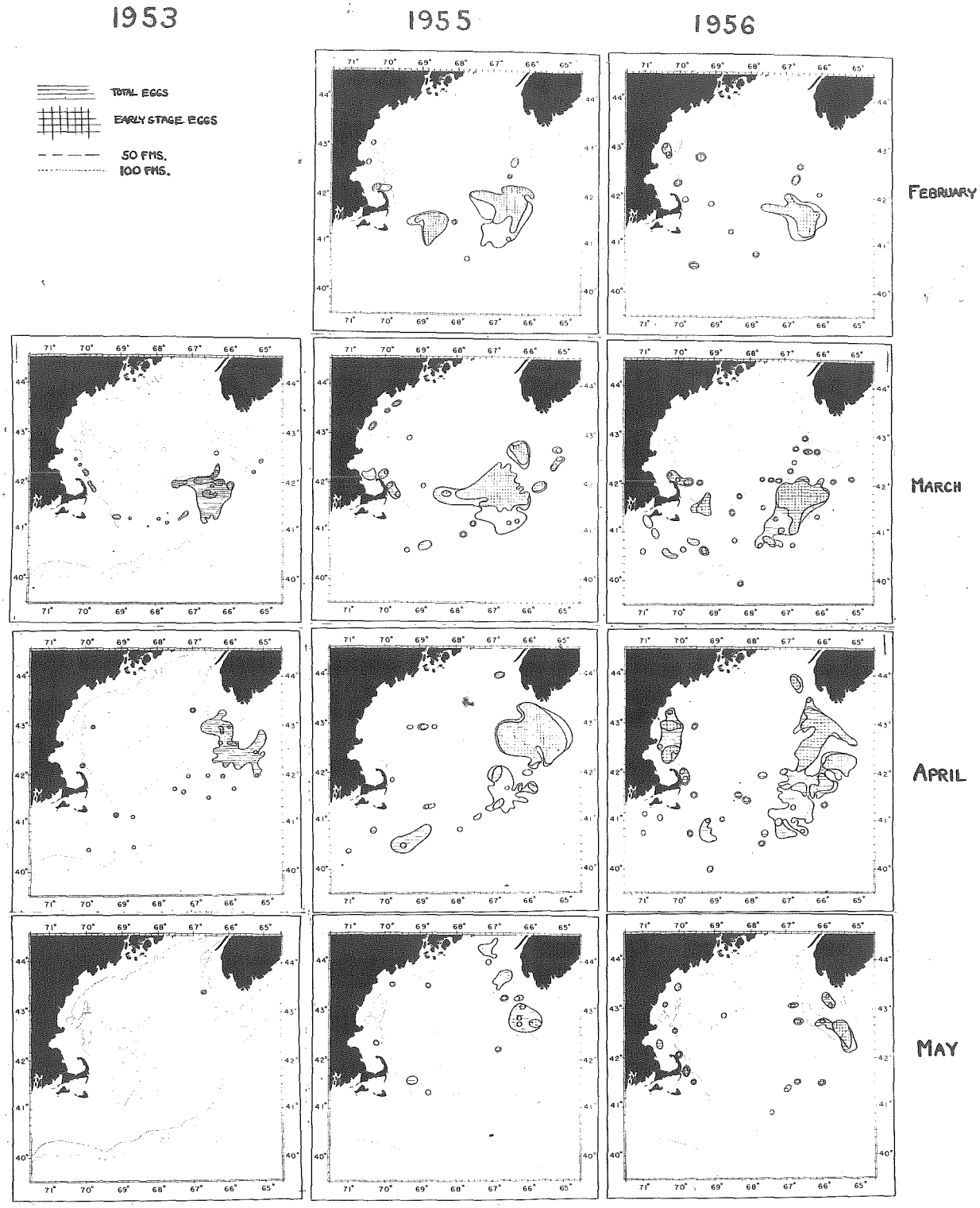

FIGURE 1. DISTRIBUTION OF TOTAL AND EARLY STAGE HADDOCK EGGS DURING 1953, 1955, & 1956.

following areas: North - area sampled north of latitude 42°N., South - area sampled south of latitude 42°N., Area 21, and Total Area sampled. These subdivisions are shown in Figure 2. The average abundance of eggs in each of these subdivisions by months and years is presented in Table 1.

The maximum number of eggs were found during March and April, and in all years the average abundance was greatest in the South (Georges Bank) during March and greatest in the North and in Area 21 (Browns Bank) during April. The March-May average abundance of eggs for the Total Area and for the 3 subdivisions was greatest in 1956 and least in 1953. The ratio of abundance in the various subdivisions in 1955 and 1956 based on the February-May average was similar to that based on the March-May average. With the exception of North and Area 21 where the average number of eggs per cubic meter was greater in March, 1953 than in March, 1956, the average abundance of eggs was greatest in 1956 in every area and month.

The abundance of eggs (March-May average) was greatest in Area 21 in all years and in every year the greatest abundance of eggs was found in Area 21 in April. The total production of eggs (March-May average) was greater in the South than in the North in 1953 and 1956 and with the exception of 1953 there was a greater abundance of eggs in the North in April than in the South in March.

Abundance of Larvae

Relatively few larval haddock were collected during the recorder surveys. These larvae occurred in small isolated patches and because of the time of coverage, the catches were made up for the most part of prolarvae and early stage postlarvae. The average abundance of early-

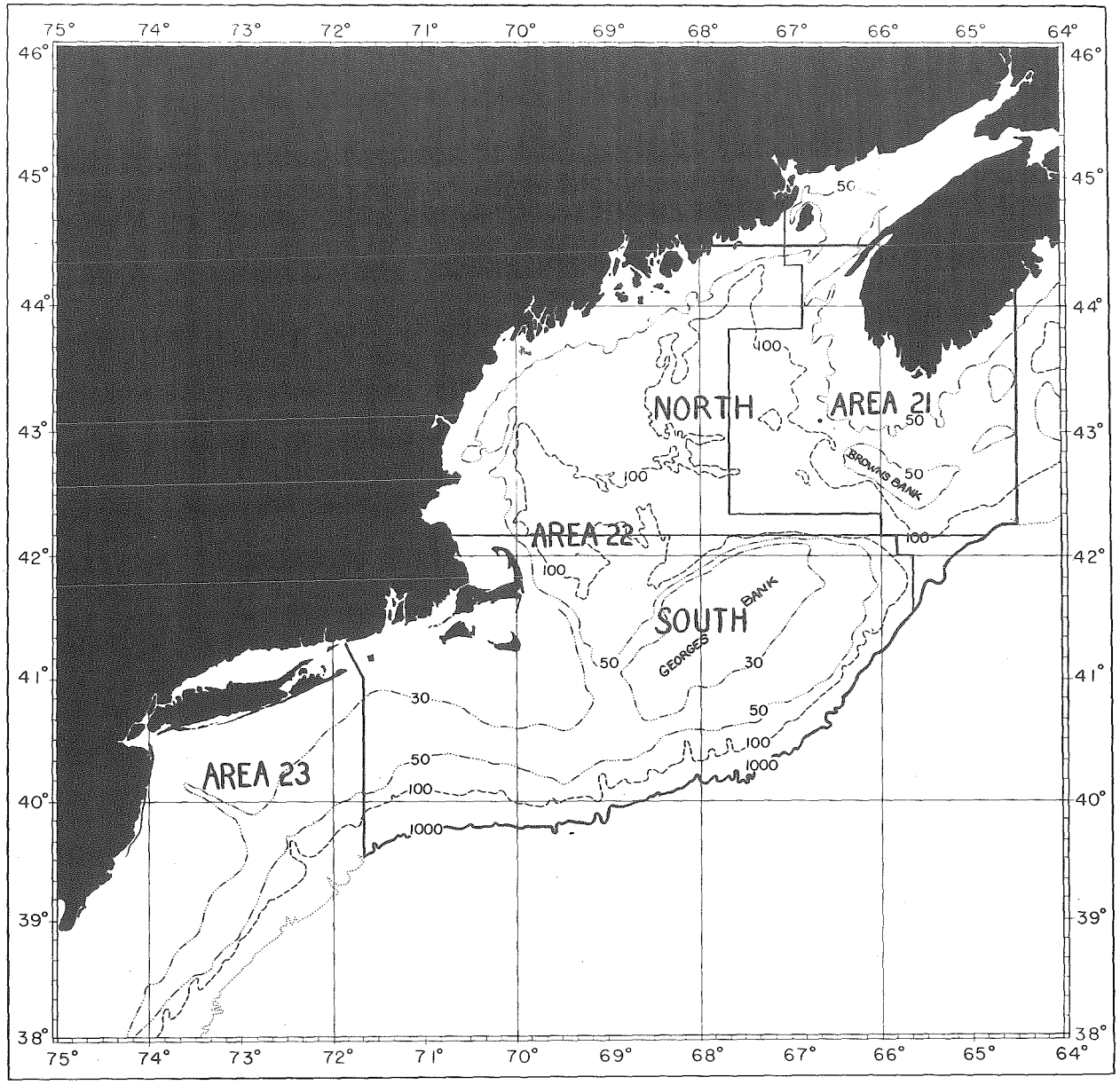

FIGURE 2. SUBDIVISIONS OF GULF OF MAINE - GEORGES BANK AREA.

Table 1.--Average abundance (No. /m^3) of haddock eggs during February, March, April, and May 1953, 1955, and 1956.

		February	March	April	May	March-May Average	February-May Average
1953	Total Area		.112	.063	.001	.058	
	North		.029	.112	.004	.048	
	South		.175	.024		.066	
	Area 21		.046	.233	.007	.095	
1955	Total Area	.093	.111	.143	.015	.090	091
	North	010	.042	.256	.037	.112	.087
	South	.140	.169	.062	.002	.077	.093
	Area 21	.010	.054	.549	.051	.218	.166
1956	Total Area	.096	.231	.232	.029	.195	.170
	North	.024	.025	.436	.055	.172	.135
	South	.145	.320	.256	.012	.196	.183
	Area 21	.020	.026	.602	.066	.231	.179

stage larvae (3.0 - 7.5 mm.) and late stage larvae (7.5 + mm.) in the North, South, and Total Area by months and years is presented in presented in Table 2.

There was a greater abundance (March-May average) of early and late stage larvae in all areas in 1956 than in 1955 and 1953. There was a greater abundance (March-May average) of early and late stage larvae in the South in all years. This is due in part to the fact that spawning occurs earlier on Georges Bank than on Browns Bank, but if one compares the abundance of early-stage larvae in the South in April (one month after maximum spawning on Georges Bank) and in the North in May (one month after maximum spawning on Browns Bank) it is seen that in every year the abundance of early-stage larvae was greater in the South. This is in direct contrast to the relative abundance of eggs in the 2 areas during March and April in 1955 and 1956 and one likely explanation for this discrepancy is that the majority of larvae which hatched from eggs spawned on Browns Bank were carried out of the area sampled by the dominant northwesterly drift.

Table 2.--Average abundance (No./m^3) of haddock larvae during March, April and May 1953, 1955 and 1956.

		March		April		May		March-May Average	
		3.0-7.5mm.	7.5+mm.	3.0-7.5mm.	7.5+mm.	3.0-7.5mm.	7.5+mm.	3.0-7.5mm.	7.5+mm.
	North			.022		.004	.004	.002	.001
1953	South	.001		.023	.007		.008	.008	.005
	Total Area	.001		.014	.004	.001	.006	.006	.003
	North					.006	.004	.002	.001
1955	South	.004	.005	.010	.009	.001	.004	.005	.006
	Total Area	.002	.003	.005	.005	.003	.004	.004	.004
	North					.007	.003	.002+	.001
1956	South	.013	.002	.010	.002	.046	.018	.023	.007
	Total Area	.010	.001	.007	.001	.029	.011	.015	.004

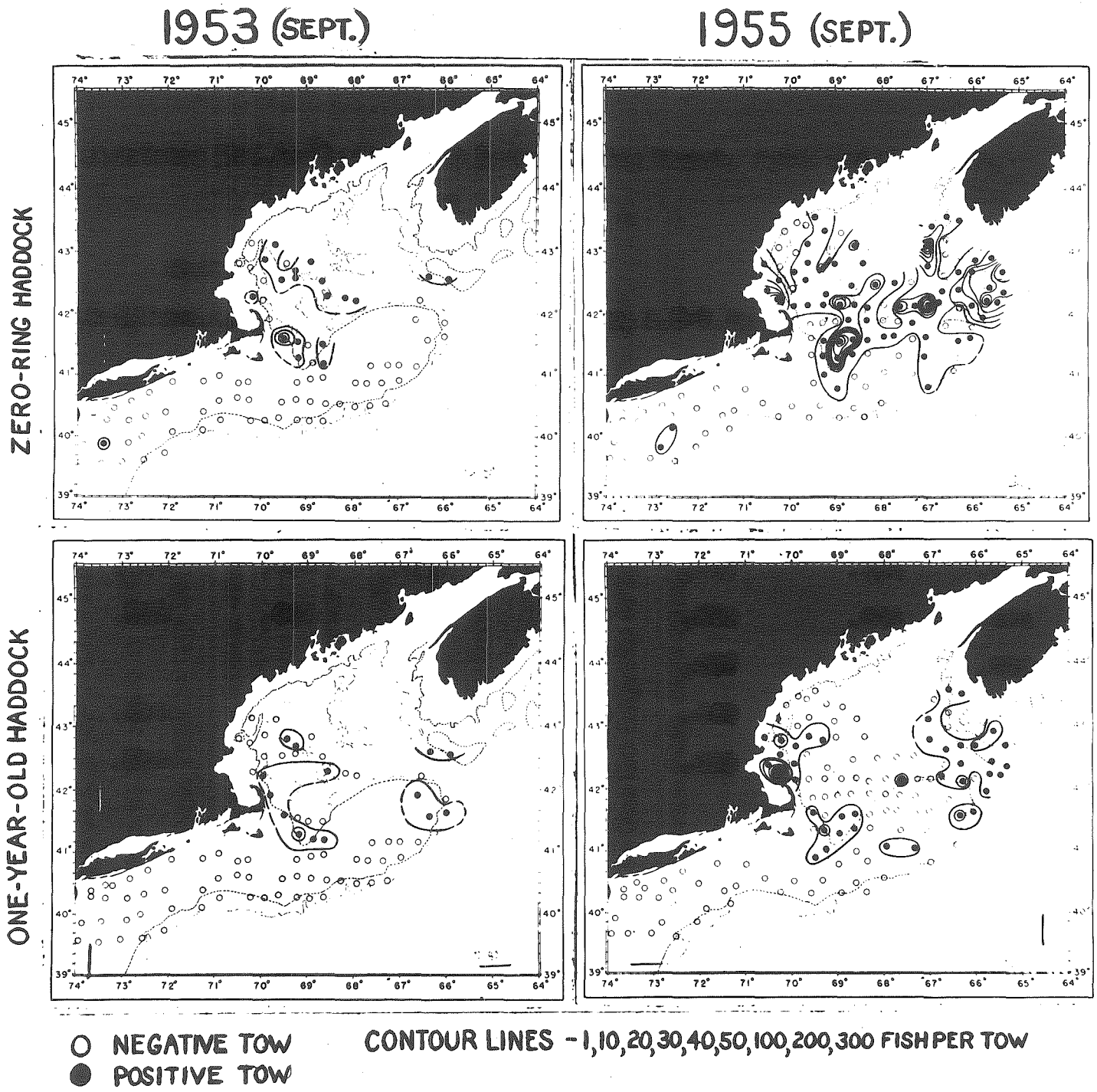

FIGURE 3. DISTRIBUTION OF ZERO-RING AND ONE-YEAR-OLD HADDOCK DURING 1953 & 1955.

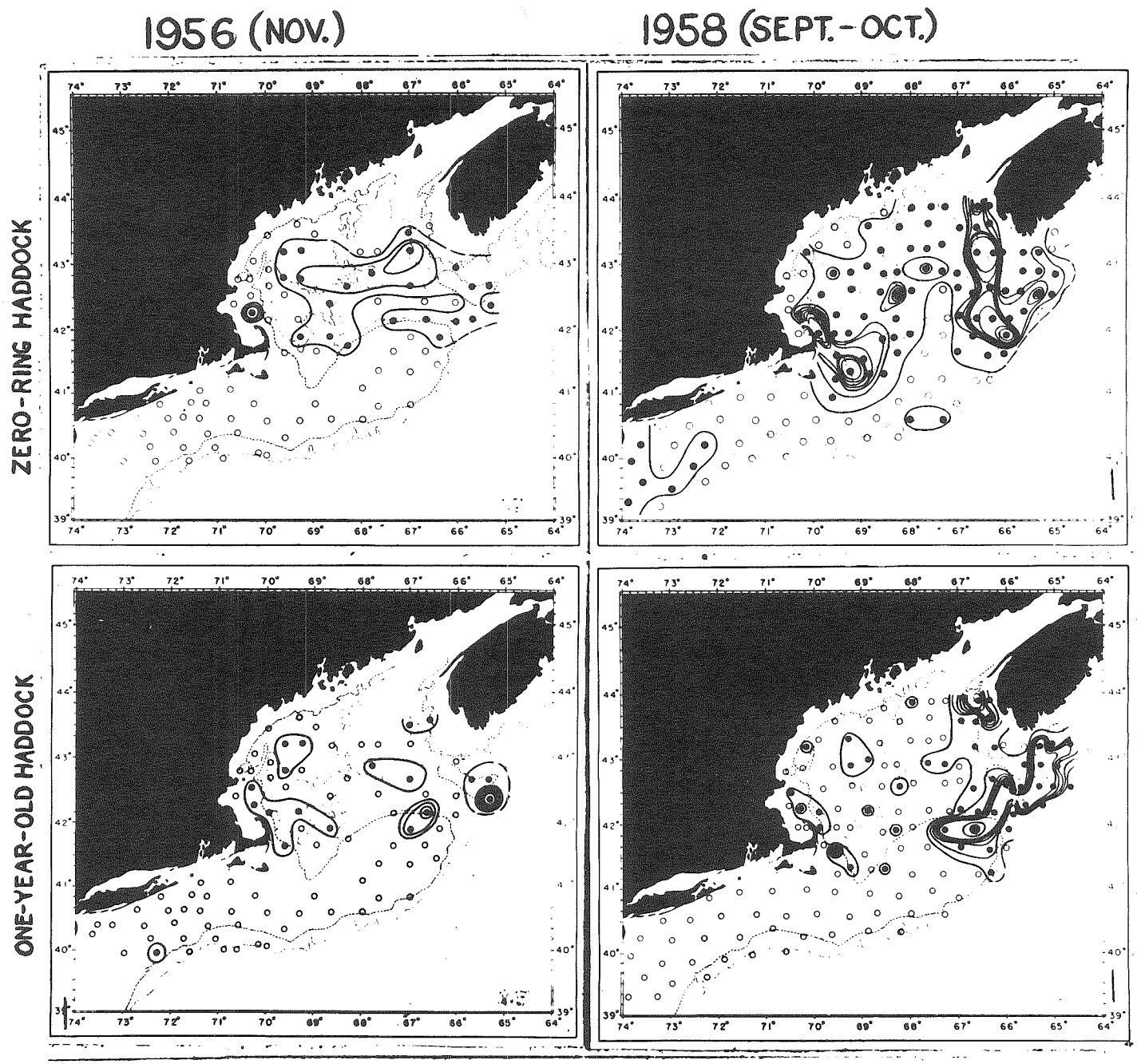

FIGURE 4. DISTRIBUTION OF ZERO-RING AND ONE-YEAR-OLD HADDOCK DURING 1956 + 1958.

JUVENILE HADDOCK

The dates of the otter trawl cruises were as follows:

Albatross III Cruise No.	Date
54	September 1 - 13, 1953
55	September 22-25, 1953
65	September 7 - 16, 1955
66	September 21 - 28, 1955
81	November 2 - 9, 1956
82	November 13 - 20, 1956
118	September 22 - October 2, 1958
119	October 6 - 17, 1958
120	October 20 - 28, 1958

The gear used during these cruises was a No. 36 Trawl with a 1/2 inch cotton liner in the cod end and upper belly. The towing speed was approximately 2.5 knots and with the exception of the 1953 cruises, all tows were 1/2 hour long from hook-up to haul-back. In 1953, 20 minute tows were made and the catch per tow has been multiplied by a factor of 1.3 to make these data comparable with those of later years.

Distribution

The location of trawl stations and the distribution of zero-ring and one-year-old haddock in the fall of 1953, 1955, 1956, and 1958 are shown in Figures 3 and 4. The contour line intervals in these figures are 1, 10, 20, 30, 40, 50, 100, 200, and 300 fish per tow. A considerable portion of the Gulf of Maine and Browns Bank was not sampled during 1953, so that the distribution and abundance of zero-ring and one-year-old haddock over most of these areas during 1953 is not known. In all years zero-ring and one-year-old haddock occurred principally in the South Channel, in the Gulf

of Maine, on Browns Bank, and on the northern edge of Georges Bank. Zero-ring and one-year-old haddock were more abundant and were found over a greater area in 1955 and 1958 than in 1953 and 1956. Relatively few zero-ring and one-year-old haddock were found on central and western Georges Bank or on the Southern New England Banks.

Abundance

To obtain a better measure of the relative abundance of zero-ring and one-year-old haddock in various areas during the 4 survey years, the average catch-per-tow was determined for specific regions within the area sampled as was done with the egg and larval data (North, South, Area 21, and Total Area). The average abundance (catch-per-tow) of zero-ring and one-year-old haddock in each of these subdivisions during 1953, 1955, 1956, and 1958 is presented in table 3.

Table 3.--Average abundance (catch-per-tow) of zero-ring and one-year-old haddock in the fall of 1953, 1955, 1956, and 1958.

ZERO-RING HADDOCK

Year	Total Area	North	South	Area 21	Year Class
1953	0.9	1.4	0.7		1953
1955	9.7	12.6	9.7	16.7	1955
1956	1.7	3.8	0.4	5.3	1956
1958	14.9	16.1	19.1	14.2	1958

ONE-YEAR-OLD HADDOCK

1953	0.9	0.9	1.3		1952
1955	4.3	6.7	1.3	4.3	1954
1956	1.5	3.1	0.5	7.0	1955
1958	9.5	13.3	7.8	23.9	1957

The average catch-per-tow of zero-ring and one-year-old haddock for the Total Area was highest in 1958, next highest in 1955 and lowest in 1953 (possibly due to poor sampling). There was a greater abundance of zero-ring and one-year-old haddock in every area in 1958 than in other years with the exception of Area 21 where the catch-per-tow of zero-ring haddock was slightly higher in 1955 than in 1958. Only in 1958 were zero-ring haddock more abundant in the South (Georges Bank and South Channel) than in the North and in Area 21. In every year in which a complete coverage was made one-year-old haddock were more abundant in the North and Area 21 than in the South. It is noteworthy that in general the abundance of zero-ring and one-year-old haddock fluctuated in the same way (both high in all areas in 1955 and 1958 and both low in 1953 and 1956). One might conclude that this was due to some sampling bias, although, with the exception of the more limited coverage in 1953, such bias is not immediately evident. For a further discussion of sampling problems see page _____.

On the basis of the relative abundance of zero-ring haddock in the various areas, the relative strength of year class is descending order is as follows:

Total Area	- 1958, 1955, 1956, 1953
North	- 1958, 1955, 1956, 1953
South	- 1958, 1955, 1953, 1956
Area 21	- 1955, 1958, 1956

It is only in Area 21 (Browns Bank) that there is a significant variation in the relative yearly abundance of zero-ring haddock.

On the basis of the relative abundance of one-year-old haddock in the various areas, the relative strength of year class in descending order is as follows:

Total Area	- 1957, 1954, 1955, 1952
North	- 1957, 1954, 1955, 1952
South	- 1957, 1954, 1952, 1955
Area 21	- 1957, 1955, 1954

For the Total Area and North the relative abundance of one-year-old haddock in various years is similar, but in the South the 1955 year class is the weakest and in Area 21 the 1955 year class ranked second, a trend indicated by the relative abundance of zero-ring haddock in that area in 1955.

RELATION OF EGGS AND JUVENILES TO BROOD STRENGTH

Because of the differential mortality of eggs, it is unlikely (and we did not expect) that any correlation would exist between the total abundance of eggs in the spring and the total abundance of zero-ring haddock in the fall or between the relative abundance of eggs and the relative brood strength based on the abundance of these fish in succeeding years. Indeed, no conclusive correlation of this nature has been demonstrated for any species of fish either on a basis of the abundance of eggs or the size of the spawning stock (Thompson, 1929; Poulsen, 1931 and 1941; Heegard, 1947; Caruthers, et al, 1951; Radovich, 1962). On the basis of the relative number of eggs our data would indicate marked differences in the relative brood strengths of the 1953, 1955, and 1956 year classes with the 1956 year class predominating, while the zero-ring haddock

abundance figures indicate that the 1955 year class was the strongest, and estimates of the relative brood strengths of Georges Bank haddock based on the commercial catch per unit effort of 3-year-old haddock indicate only a slight variation in brood strength during these years (see Fig. 5). Quantitative data on the average March-May abundance of haddock eggs on Georges Bank in 1940 and 1941 based on the collections of Clarke, Pierce, and Bumpus (1943) show that haddock eggs were twice as abundant in 1941 ($2.02/M^3$) as in 1940 ($1.05/M^3$). Yet, the commercial catch of 3-year-old haddock indicates that the relative numerical strength of the 1940 year class was over twice as great as that of 1941 (Fig. 5).

It is possible, however, that a correlation would exist between the time and/or location of spawning and the abundance of zero-ring haddock. For example, the non-tidal drift in the Gulf of Maine-Georges Bank area during the spawning season indicates that eggs and larvae in the Browns Bank area have a better chance of remaining on the continental shelf than eggs and larvae on Georges Bank (Colton and Temple, 1961) and the distribution of zero-ring haddock in the fall would tend to support this hypotheses. A variation in spawning time could conceivably effect survival in several ways. The closed circulation pattern in the Gulf of Maine-Georges Bank area evolves with the season and is not well-defined until late April (Colton and Temple, 1961). This might result in better survival of the progeny of April and May spawnings than of the progeny of February and March spawnings which would be subject to a greater offshore drift. Eggs and larvae produced from late spawnings would also develop in warmer water, metamorphose more rapidly, and thus be subject to passive drift for a shorter period of time.

In fact, however, the location of spawning did not vary markedly in the years the area was sampled and in all years maximum spawning took place on Georges Bank (South) in March and on Browns Bank (Area 21) in April. In all years there was a greater abundance of eggs in Area 21 in April than in the South in March. There was, however, a greater abundance of eggs in the South Channel in 1955 (February) than in other years (Fig. 1) and 1955 was the only year in which the March-May average abundance of eggs was greater in the North than in the South. Also in 1955 the ratio of the average abundance of eggs in Area 21 in April to the abundance of eggs in the South in March was considerably greater than this ratio in 1953 and 1956.

Considering, however, that the abundance of eggs was greater in all areas in 1956, it does not appear that the slight differences in time and location of spawning could account for the considerable differences in abundance of zero-ring haddock. It appears, as has been stated previously (Colton and Temple, 1961), that there are always enough haddock eggs produced to insure a strong year class, but that it is the variability in the mortality of larvae in the various areas that accounts for the variability in the strength of year class. Rae (1953) has come to a similar conclusion as regards the fluctuations in brood strength of lemon sole in the North Sea, i.e. good spawning does not necessarily result in good brood survival and moderate numbers of larvae may, under favorable conditions, produce good survival. It appears then that environmental factors are the key to survival. This conclusion is supported by the fact that it has only been with environmental conditions (physical or biological) that strong and persistant correlations with brood strength have been made.

JUVENILES

We did expect that there would be a correlation between the relative numbers of zero-ring haddock on the bottom in the fall and the relative numbers of these same fish in succeeding years. Although the relative abundance of zero-ring haddock in 1955 and of 1-year-old haddock in 1956 (table 3) indicate an appreciable mortality during the first year of demersal existence, it would appear that after the young haddock reach the demersal stage environmental factors which could cause mortality during the pelagic period would be mostly eliminated. Catastrophic changes in environment, like that which caused the mass mortality of the tilefish in 1882, seldom occur and would not likely effect a single year class. The only factors which could conceivably induce serious and variable mortality during the demersal phase are predation and the lack of food and it appears improbable that either of these factors could effect young haddock in such a way as to eliminate the greater proportion of fish from an entire region in any one year yet in another year leave the brood numbers almost intact. Also young haddock tend to be concentrated in areas separate from those frequented by older haddock or fished extensively by the commercial fleet and are of such small size that they readily pass through the meshes of commercial gear which facts would preclude an appreciable fishing mortality. It appears, then, that once the haddock take to the bottom mortalities would fluctuate less than during the pelagic period and that a quantitative sample of their numbers at this time would give a fair indication of the relative strength of year class i.e. - the relative numbers of zero-ring haddock would be in proportion to the relative

number of marketable age fish of a given year class.

Theoretically, zero-ring haddock are much easier to sample quantitatively than eggs and larvae, for unlike the latter whose distribution is three demensional the young haddock are all at one level (the bottom). The otter trawl has been shown to display qualitative and quantitative consistancy as an instrument for taking samples of fish (Schmidt, 1926; Thompson, 1929 and 1935; Poulson, 1931; Colton, 1955). The stable distribution of zero-ring haddock and the reliability of the otter trawl as a sampling tool point to the feasability of estimating year class strength on a basis of the abundance of haddock during the early benthic period of their life history. The work of Thompson (1929a) and Clark (1937) has demonstrated the practicality of this mode of attack.

Estimates of the relative year class strength of Georges Bank haddock are based on the average number of 3-year-old haddock caught per days fishing for haddock in subareas G, H, J, M, N, O, Q, and S by a selected group of large otter trawlers fishing out of Boston throughout the year. The 1931-1961 average catch per day has been given a rating of 10 and the brood strength for individual years is prorated on this basis. In Table 4 the average catch per day of 3-year-old haddock for 1931 through 1961 and the relative brood strength for 1928 through 1958 are presented.

Marked fluctuations in brood strength occurred during this period with a range of 0.9 in 1928 to 24.0 in 1948. To better demonstrate these fluctuations in recruitment of Georges Bank haddock, the brood strength data is presented graphically in Figure 5.

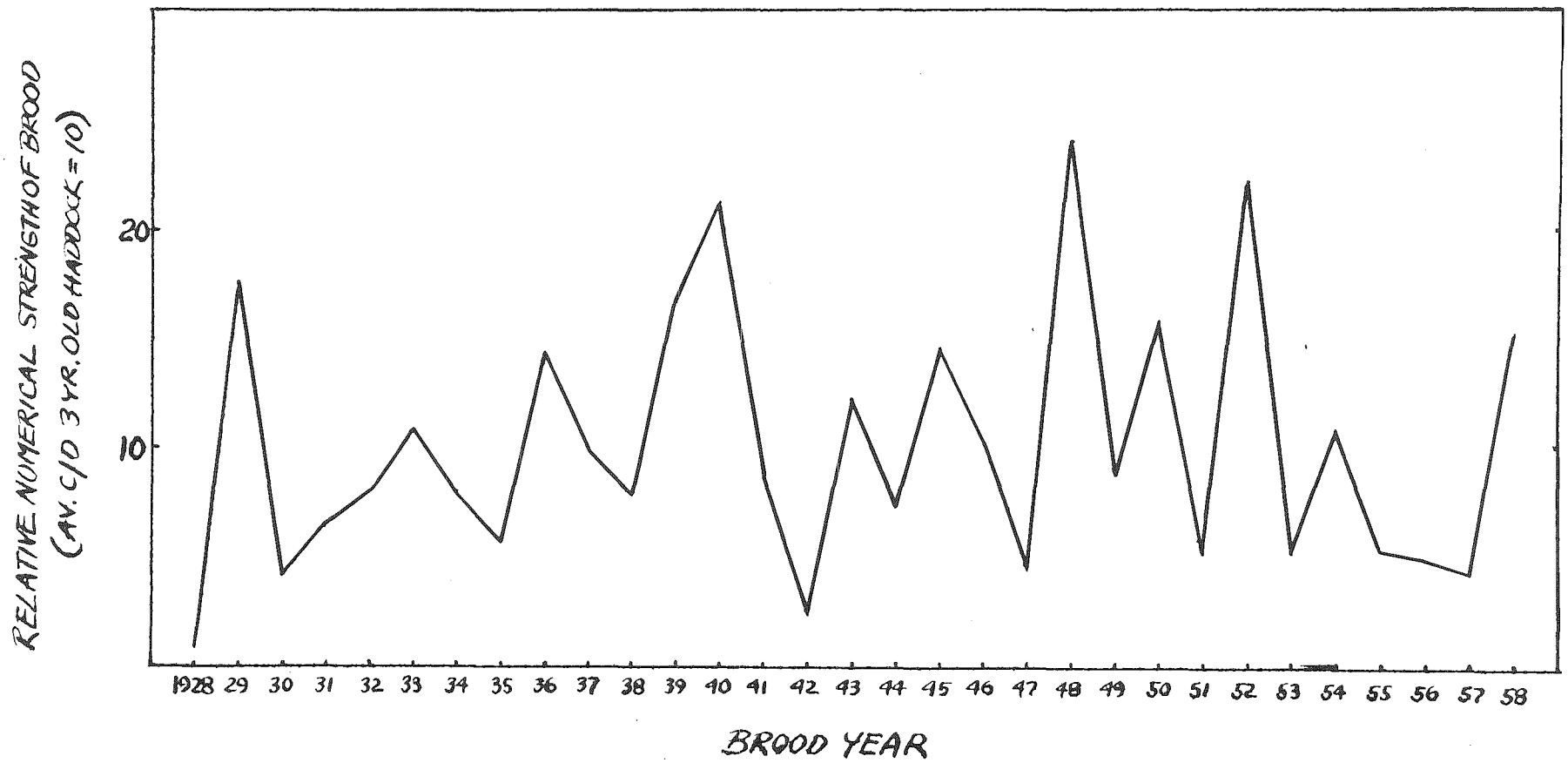

FIGURE 5. Relative Brood Strength of Georges Bank Haddock, 1928 - 1958

Table 4.--Three-year-old catch per day and relative brood strength of haddock, 1928-1961.

Year	3-year-old C/D	Index No.	Year	3-year-old C/D	Index No.
1928		0.9	1945	415	14.5
1929		16.6	1946	2090	10.2
1930		4.2	1947	1256	4.4
1931	157	6.6	1948	2495	24.0
1932	2843	8.0	1949	1748	8.7
1933	717	10.8	1950	749	15.8
1934	1128	7.8	1951	4121	5.1
1935	1378	5.7	1952	1499	22.2
1936	1845	14.3	1953	2702	5.2
1937	1331	9.9	1954	879	10.8
1938	985	7.8	1955	3806	5.3
1939	2447	16.6	1956	896	4.9
1940	1706	21.2	1957	1848	4.3
1941	1339	8.7	1958	916	15.2
1942	2851	2.4	1959	851	
1943	3633	12.2	1960	731	
1944	1492	7.3	1961	2312	

In Figure 6 the relative abundance of zero-ring and one-year-old haddock in 1953, 1955, 1956, and 1958 for Total Area, North, South, and Area 21 is compared to the relative year class strength of Georges Bank haddock during this period. The average catch per tow for 1953-1958 has been given a rating of 10 and the catch per tow for individual years prorated on this basis.

The relative numerical strength of the 1956 and 1958 brood years of zero-ring haddock in all subdivisions and of 3-year-old haddock on Georges Bank are in the same proportion (approximately 1 to 4) and the relative numerical strength of the 1954 and 1955 brood years of 1-year-old haddock in all subdivisions except Area 21 and of 3-year-old haddock on Georges Bank are in the same proportion (approximately 2 to 1). However, no consistent relation exists between the relative numerical strength of zero-ring and one-year-old haddock of the year classes represented in the total area or in any of the subdivisions and the numerical strength of 3-year-old haddock on Georges Bank. Actually the only strong correlation existing between the survey and commercial data is that 1958, the year zero-ring haddock were most abundant in all areas and in which there more zero-ring haddock in the South (Georges Bank) than in Area 21(Browns Bank), was the strongest year class as indicated by the abundance of 3-year-old haddock on Georges Bank. That a better correlation was not obtained is undoubtedly due in part to sampling bias in both the commercial and survey data.

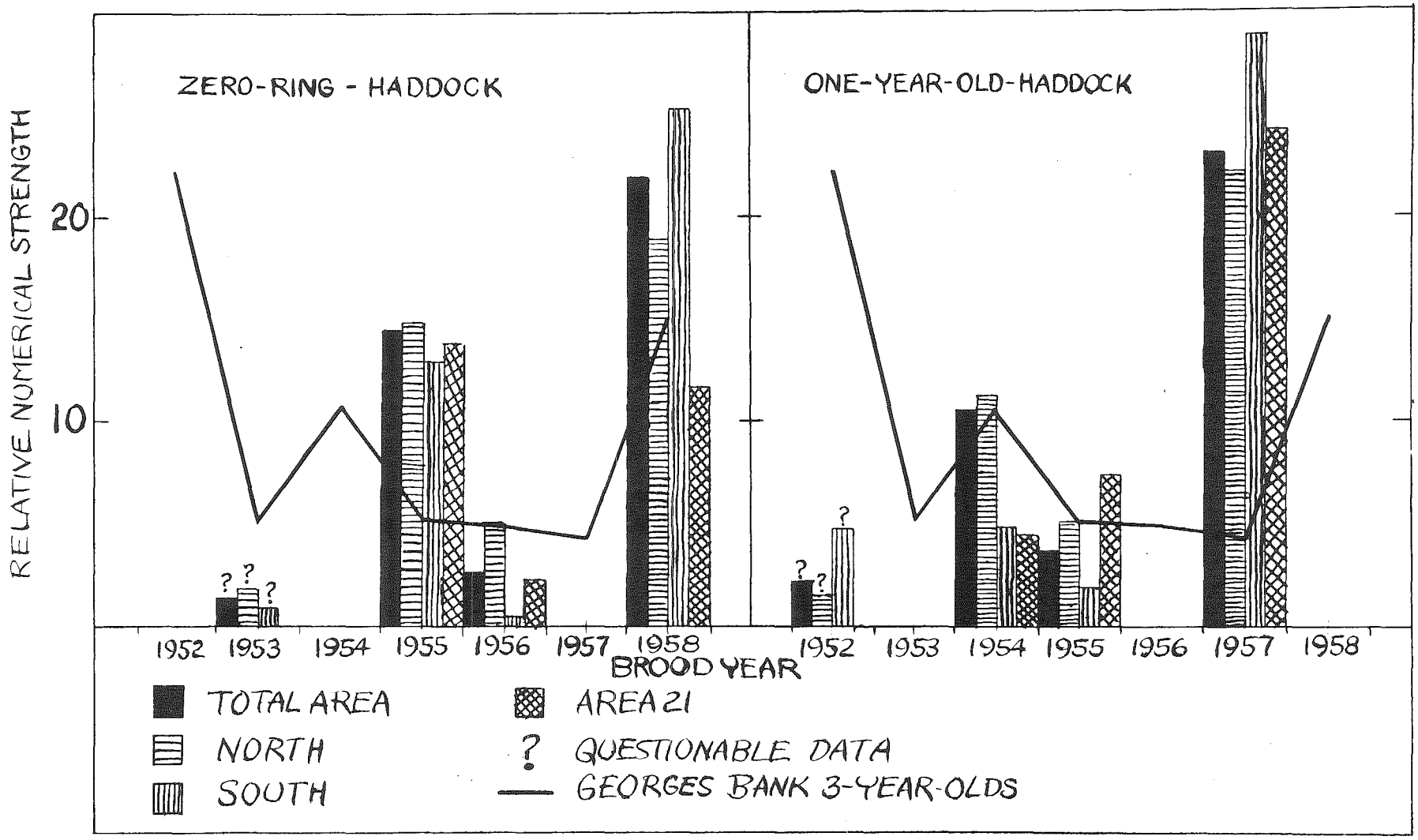

FIGURE 6. COMPARISON OF THE RELATIVE NUMERICAL BROOD STRENGTH OF HADDOCK BASED ON THE STUDY BOAT CATCH PER DAY OF 3-4 YEAR-OLD HADDOCK (AV. C/D = 10) AND THE CATCH PER TOW OF ZERO-RING AND 1-YEAR-OLD HADDOCK IN VARIOUS AREAS DURING SURVEY CRUISES (AV. C/T = 10).

SAMPLING ERRORS

Commercial

As stated previously, the estimate of the relative year class strength of Georges Bank is based on the average catch-per-day of 3-year-old haddock by a selected group of large Boston otter trawlers (over 150 gross tons) fishing on Georges Bank. Only catch data from a restricted depth zone (31-60 fms.) within Subareas G, H, J, M, N, O, Q, and S is used in estimating the abundance of 3-year-old haddock. The number of large otter trawlers ("study boats") used in this sampling varied between years and ranged from 11 in 1961 to 26 in 1950. For a full description of the development of the statistical system and the methods followed in computing indexes of abundance from 1931 to present, see Rounsefell (1948 and 1957).

Theoretically this system for estimating the abundance of haddock is sound, for: (1) the haddock fishery on Georges Bank is made up for the most part of large trawlers fishing out of Boston, (2) the difference in fishing efficiency of the 2 sizes of otter trawlers making up the study boat fleet (Group A - 167 gross ton average and Group B - 247 gross ton average) is corrected for by decreasing the figure of the fishing effort of the Group B boats by 11 percent, (3) with the exception of Subareas G and H the greater proportion of each subarea division of Georges Bank lies within the 31 to 60 fathom contour lines, and (4) productivity estimates based on the effort of the commercial fleet in terms of days fished during the period 1928 - 1936 indicated the 31 to 60 fathom depth zone to be the most productive.

Rounsefell's (1957) reasoning was:

The commercial fleet concentrate where haddock are most abundant. The commercial fleet spends the most time in the 31-60 fathom depth zone. Therefore, this is where the bulk of the haddock population is and where the most representative sample of their numbers can be obtained.

To illustrate the completeness of the study boat coverage and the proportion of the total fishing effort of the study boats expended in the 31-60 fathom depth zone, the average number of days fished per month and the number of months fished per year by the study boats within the 0-30 fathom, 31-60 fathom, and 61 + fathom depth zones within the various subareas in the Gulf of Maine-Georges Bank area during 1956, 1958, 1959, and 1961 are plotted in Figure 7. These data are plotted in terms of "fish years" (1956 equals February, 1956 - January, 1957). These specific years were chosen for it is the catch per unit effort within the 31 - 60 fathom depth zone of 3-year-old haddock on Georges Bank during these years that is the basis for the estimate of the relative numerical brood strength of Georges Bank haddock in 1953, 1955, 1956, and 1958.

The study boats did not fish in any depth zone within the central and western Gulf of Maine (Subareas B, C, D, E, and F, Area 22) during these years. The effort of the study boat fleet within the 0-30 fathom depth zone was restricted to a few subareas on Georges Bank and in the South Channel and these areas were fished for only a relatively few months of the year. The effort within this depth zone was in direct proportion to the amount of 0 - 30 fathom water within the subareas.

The major effort of the study boats within the 31-60 fathom depth

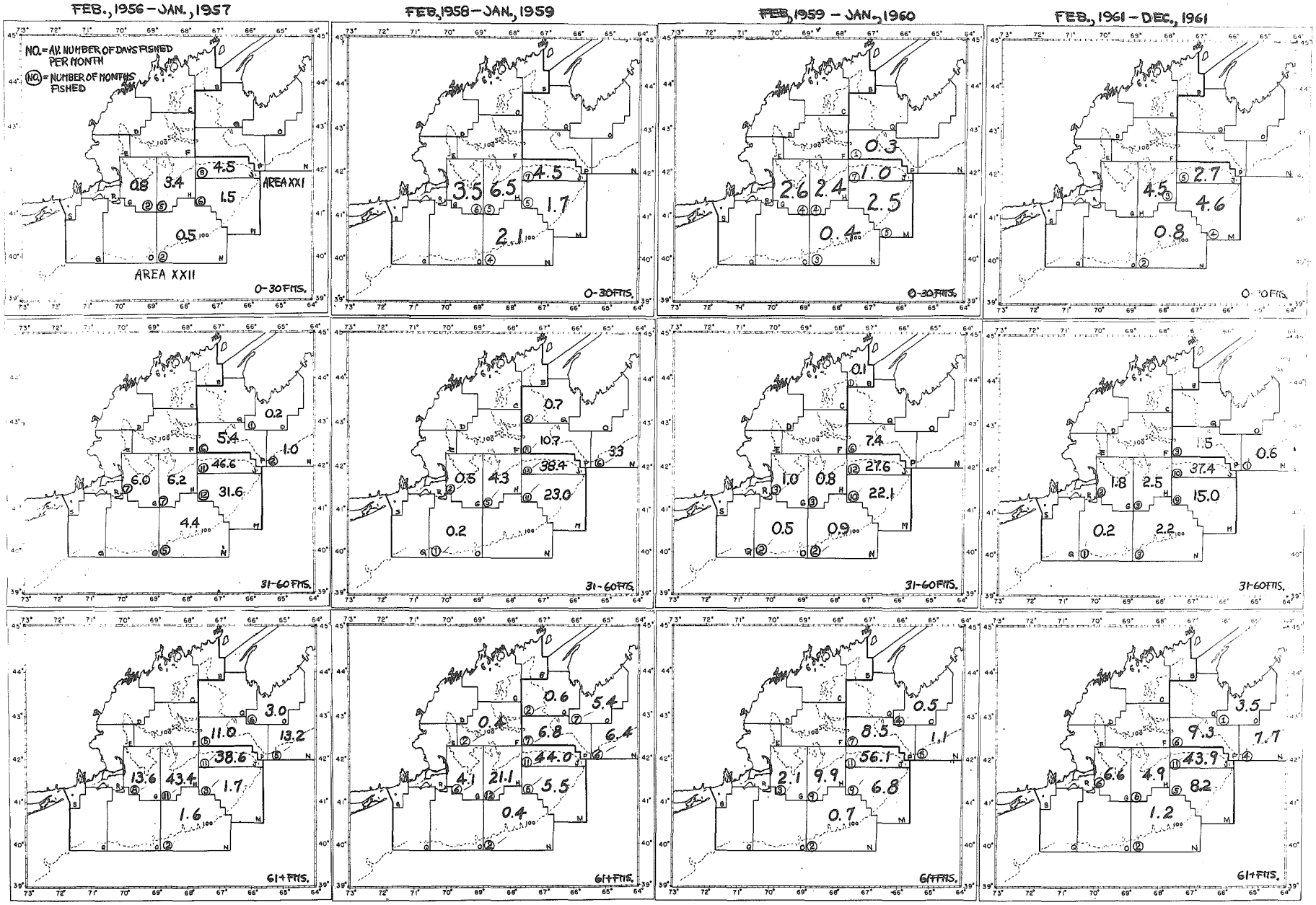

Figure 7. Study Boat Effort in the 0-30 FM., 31-60 FM. and 61+ FM. Depth Zones During 1956, 1958, 1959 and 1961.

zone was concentrated in a small sector of Georges Bank (Subareas J and M) and it was only within this area that the study boats fished throughout the year. Areas within the 31-60 fathom depth zone on the southern part of Georges Bank (Subareas N, O, and Q) and in the South Channel (Subareas G and H) were fished for but a few months out of the year and then for only a relatively few number of days. In the Gulf of Maine and in Area 21 the effort of the study boats within the 31-60 fathom depth zone was very limited and it was only in Subarea P that an appreciable amount of fishing took place.

In the 61 + fathom depth zone the major effort of the study boat fleet was expended in Subareas H and J (Area 22) and there was in general more fishing in Subarea G (Area 22) and in Subareas N and P (Area 21) than in the 31-60 fathom depth zone within these subareas. The was considerably more effort expended in the 61 + fathoms depth zone than in the 31-60 fathom depth zone in Area 21, but less fishing in the 61+ fathom depth zone than in the 31-60 fathom depth zone on the southern part of Georges Bank (Subareas M, N, and O).

To better illustrate the proportion of fishing effort in the 3 depth zones, the number of days fished by the study boats and the percentage of effort in depth zones of 0-30, 31-60, and 61+ fathoms in the Georges Bank area (Area 22, Subareas G, H, J, M, N, and O) and in the Browns Bank area (Area 21, Subareas N, O, P, and Q) for the years 1956, 1958, 1959, and 1961 are tabulated in Table 5.

Table 5.--Number of days fished by study boats per year and percentage effort in 3 depth zones within subareas on Georges and Browns Bank.

AREA 22 (Georges Bank)

Subarea

		G		H		J		M		N		O		TOTAL	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1956	0-30 fms.	10	4	40	6	54	5	18	4	6	8			128	5
	31-60 fms.	73	30	79	12	559	52	379	91	53	67			1143	46
	61+ fms.	164	66	521	82	463	43	21	5	20	25			1189	49
1958	0-30 fms.	42	43	79	20	55	5	21	6	25	83	1	25	223	12
	31-60 fms.	6	6	52	14	461	44	276	76			3	75	798	41
	61+ fms.	50	51	253	66	529	51	66	18	5	17			903	47
1959	0-30 fms.	32	45	28	19	12	1	30	8	5	20			107	6
	31-60 fms.	13	18	10	6	331	33	265	88	11	44	6	100	636	37
	61+ fms.	26	37	119	75	674	66	82	22	9	36			992	57
1961	0-30 fms.	1	1	50	38	30	3	50	16	9	19			140	9
	31-60 fms.	20	21	28	21	411	44	166	54	25	52	2	100	652	43
	61+ fms.	73	78	55	41	483	53	90	30	14	29			715	48

Table 5.-- (Continued)

AREA 21 (Browns Bank)

Subarea

		N		O		P		G		TOTAL	
		No.	%	No.	%	No.	%	No.	%	No.	%
1956	31-60 fms.	13	8	3	8	66	33			82	20
	61+ fms.	159	92	36	92	132	77			327	80
1958	31-60 fms.	40	34			128	61	1	11	133	37
	61+ fms.	77	66	65	100	81	39	8	89	231	63
1959	0-30 fms.					4	2			4	2
	31-60 fms.					89	46			89	46
	61+ fms.	14	100	6	100	102	52			122	57
1961	31-60 fms.	7	8			16	14			23	9
	61+ fms.	85	92	39	100	102	86			226	91

In all 4 years the total study boat fishing effort was greatest in waters deeper than 60 fathoms in both Areas 21 and 22. In every year the study boat fishing effort was greatest in water deeper than 60 fathoms in all subareas within Area 21, with the exception of Subarea P in 1958. In Area 22 there were marked variations in the depth zone of maximum fishing effort between subareas and this variation was in part related to the geographic location of the subarea and the relative amount of trawlable bottom in the 3 depth zones. In Subareas G and H the maximum fishing effort was in waters deeper than 60 fathoms in all years. In Subarea J, which was the most intensly fished in all years, the fishing effort was greatest in water deeper than 60 fathoms in all years except 1956. In Subareas M, N, and O the maximum fishing effort was in the 31060 fathom depth zone in all years. Not only does the greater proportion of these latter 3 subareas lie within the 31-60 fathom contour lines, but the bottom deeper than 60 fathoms in these subareas is bathed by relatively warm slope water which apparently haddock find intolerable.

In general, the fishing effort was least in the 0-30 fathom depth zone in all subareas. The notable exceptions being in Subareas G and H in 1958 and 1959 where greater effort was expended in this depth zone than in the 31-60 fathom depth zone. It is these 2 subareas that contain the greatest proportions of bottom shoaler than 30 fathoms.

If there is a direct correlation between commercial fishing effort and abundance as Rounsefell (1957) assumed, then we would have to conclude that during all 4years haddock were more abundant in water deeper than 60

fathoms and that the relative abundance of haddock in the 3 depth zones varied between years and locations. This is in contract to Rounsefell's findings based on an analysis of the catch of otter trawlers larger than 50 gross tons fishing in Subareas, G, H, J, M, N, and O, Area 22 during the period 1928-1936. His figures showed that by far the greatest effort was expended in the 31-60 fathom depth zone (0-30 fathoms-24%, 31-60 fathoms-52%, 61-125 fathoms-24%). In addition, an analysis of the 1932-1938 catch statistics showed that the catch-per-unit effort was also greatest in this depth zone.

One possible reason for the marked differences in the proportion of effort in the 3 depth zones between the 2 sampling periods is that Rounsefell excluded data from water deeper than 125 fathoms and there are considerable fishing area, especially along the northern edge of Georges Bank in water deeper than this. It should be noted here that although Rounsefell's analysis indicated that there was an equal amount of effort expended in the 0-30 fathom and the 61+ fathom depth zones during the period 1928-1936, the contours of fishing intensity shown in his Figure 4 (Rounsefell, 1957 p. 272) indicate that the fishing intensity was considerably greater in the 61+ fathom depth zone during this period. However, the most likely explanation for the marked differences in the proportion of effort in the 3 depth zones between the 2 periods is that there has been a shift in the area of maximum abundance of marketable haddock during recent years. This could be due either to an actual movement of the population of haddock or to a shift in the age of fish being sought by the commercial fleet as a result of the new mesh regulation enactment.

In any event, it is evident that: (1) the picture one gets of the relative fishing effort in various subareas on Georges Bank and thus the relative abundance of haddock in these subareas depends upon what depth zones are included in the sampling, (2) catch and effort data from waters deeper than 60 fathoms should certainly be indluded in the catch statistics of the study boat fleet if a reasonable estimate of the abundance of haddock on Georges Bank is to be made, (3) with the possible exception of Browns Bank proper (Area 21, Subareas N and P) the abundance of haddock from without side the limits of Georges Bank (Area 22, Subareas G, H, J, M, N, and O) cannot be estimated from the catch and effort data of the study boat fleet.

Even though the distribution of the fishing effort of the study boat fleet indicated that the study boat catch and effort data from a restricted depth zone would not serve as a reliable index of the total fishing effort or of the total abundance of haddock on Georges Bank, it is possible that such a restricted sampling would serve as an index of the relative abundance of certain age groups of haddock. For example, if 3-year-old haddock tended to be concentrated in the 31-60 fathom depth zone during all seasons and years or if the relative abundance of 3-year-old haddock in the 3 depth zones did not vary with seasons and years, then an estimate of their abundance in 31-60 fathom depth zone would be indicative of their abundance over the whole of Georges Bank. One way to determine the reliability of a sample from a restricted depth zone would be to compare the study boat catch per unit effort of 3-year-old haddock from the 3 depth zones over a number of seasons and years. Unfortunately, the basic

data for such an analysis is not readily available. An alternative would be to compare the distribution of 3-year-old haddock as indicated by survey cruise data with the distribution of the study boat fleet in terms of the number of days fished in the various subareas during similar periods.

Such a comparison is made in Figures 8, 9, and 10 which show the distribution of 3-year-old haddock in terms of the average catch per tow by subarea during the survey cruises of September, 1955, November, 1956, and October, 1958 and the distribution of study boat effort in terms of the number of days fished per month in the 0-30 fm, 31-60 fm, and 61+ fathom depth zones in the various subareas during similar periods.

In all 3 years the survey cruise data indicates that during the fall at least 3-year-old haddock were relatively abundant in regions not sampled by the study boat fleet. In September, 1955 the greatest abundance of 3-year-old haddock as indicated by the survey cruise samples was in Subarea E, Area 22 and relatively large concentrations of 3-year-old haddock were also found in Subareas G and J, Area 22 and in Subareas Q, O, and N, Area 21. The study boat effort during this period was restricted to a limited section of Georges Bank. The maximum study boat effort in all 3 depth zones was in Subarea J, Area 22, although considerable fishing effort was expended in water deeper than 60 fathoms in Subarea G, Area 22.

In November, 1956 3-year-old haddock were most abundant in Subarea Q, Area 21 but relatively large concentrations of 3-year-old haddock were also found in Subarea N, Area 21 and in Subareas J and E, Area 22. The study boat effort during this period was restricted to a limited sector of Georges Bank and it was only in water deeper than 60 fathoms that there was an appreciable amount of fishing in the South Channel area (Subareas G and H).

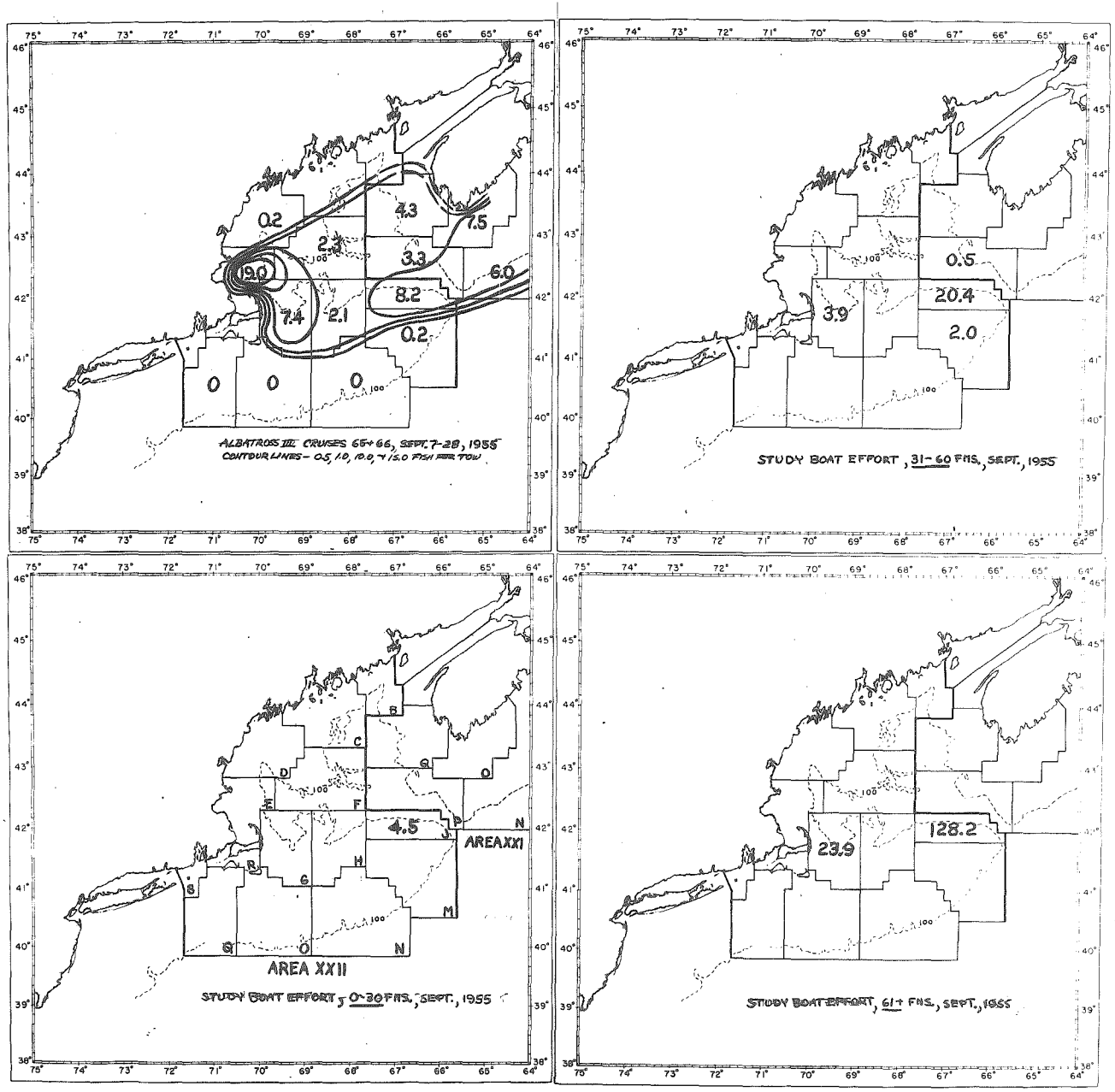

FIGURE 8. THE DISTRIBUTION OF 3-YEAR-OLD HADDOCK AND OF STUDY BOAT EFFORT DURING SEPTEMBER, 1955.

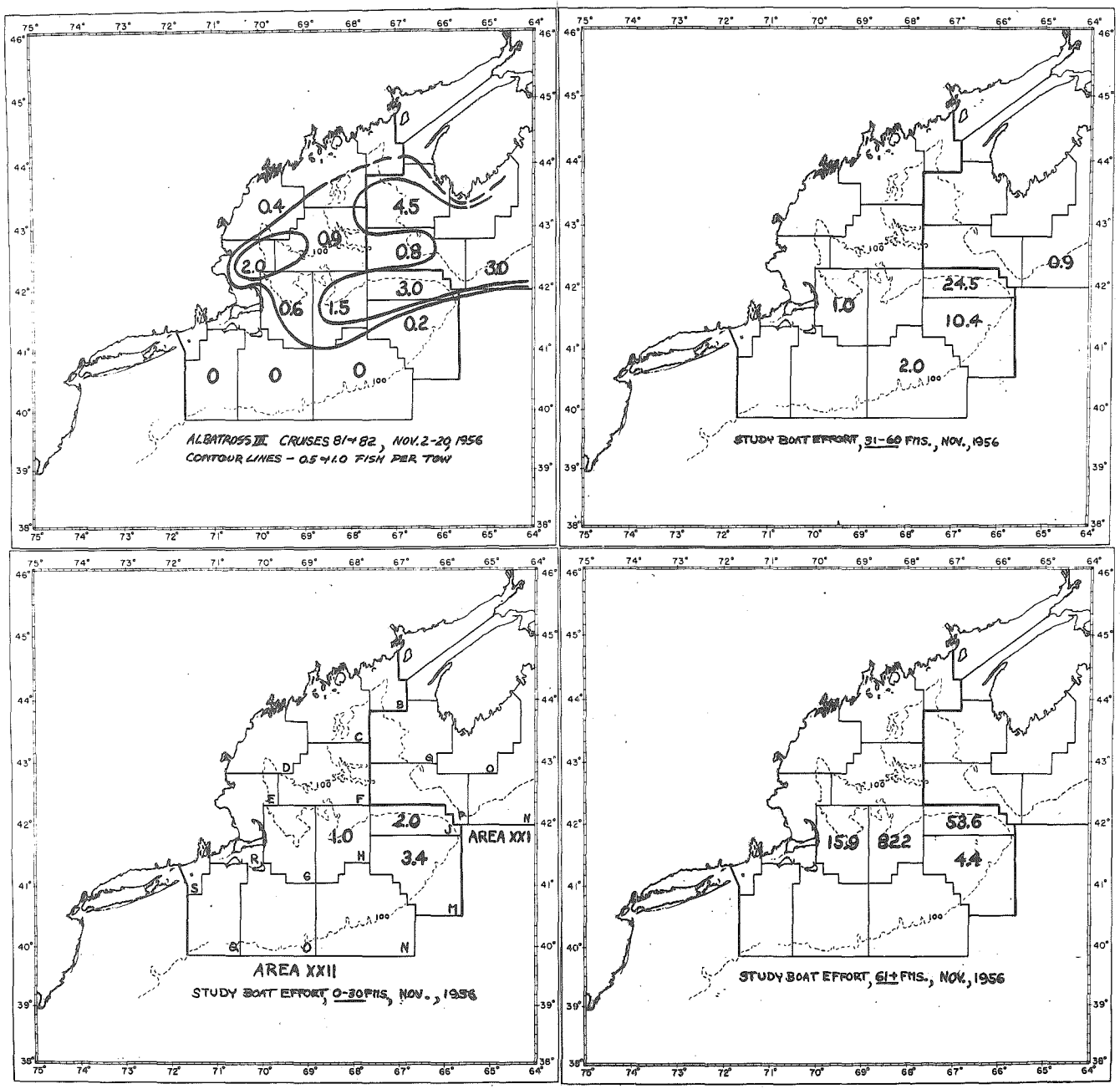

Figure 9. The Distribution of 3-year-old Haddock and of Study Boat Effort During November, 1956

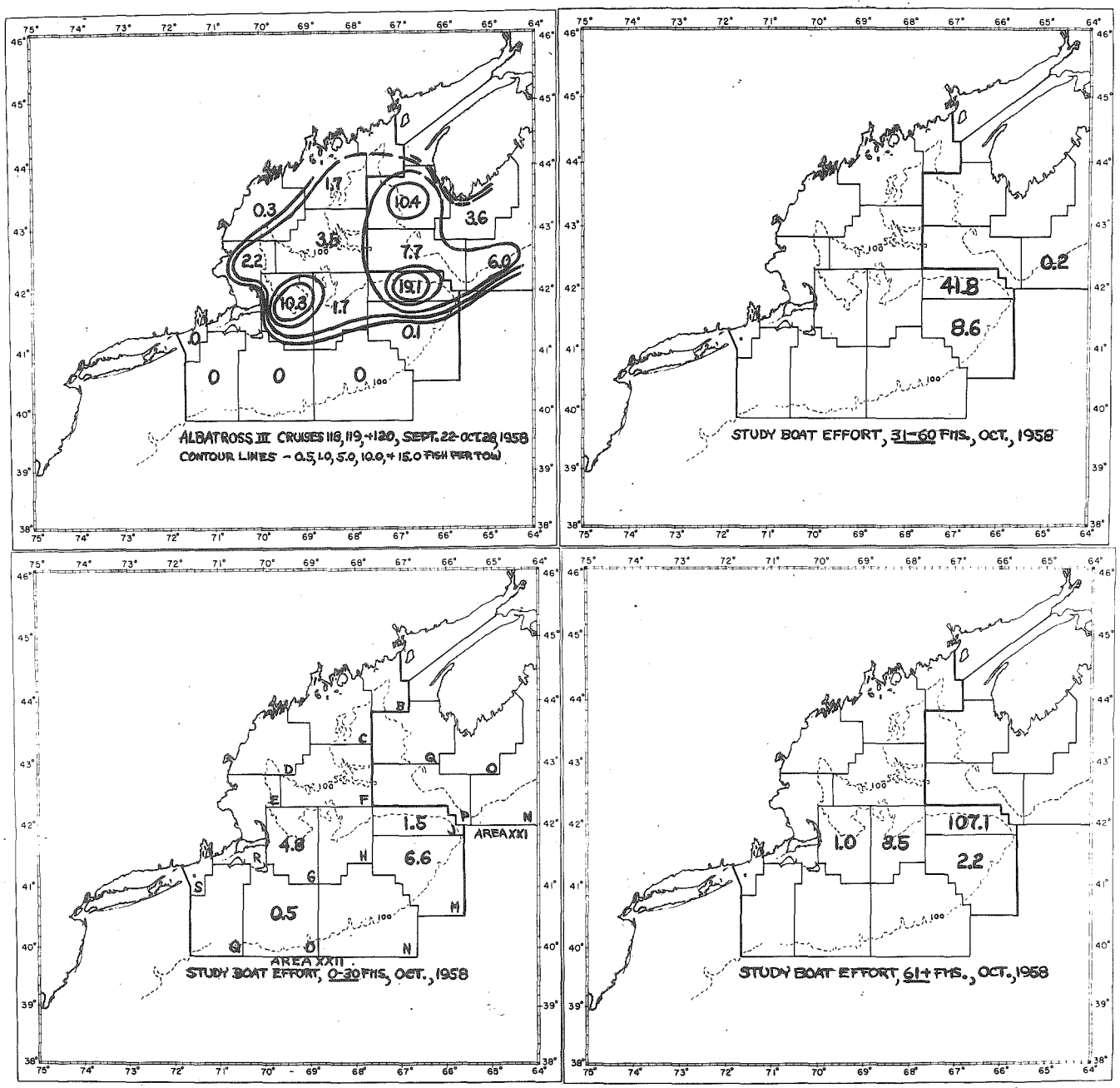

FIGURE 10. THE DISTRIBUTION OF 3-YEAR-OLD HADDOCK AND OF STUDY BOAT EFFORT DURING OCTOBER, 1958.

In October, 1958 the greatest concentration of 3-year-old haddock occurred in Subarea J, Area 22, but the abundance of 3-year-old haddock was also high in Subarea G, Area 22 and in Subarea Q, Area 21 and to a lesser extent in Subareas P and N, Area 21. The study boat effort was again restricted to Georges Bank and it was only in the 0-30 fathom depth zone that there was an appreciable study boat effort in the South Channel (Subareas G and H).

These data demonstrate that:

(1) Although the total abundance and distribution of 3-year-old haddock varied markedly between years, the total effort of the study boat fleet (average number of days fished in all depth zones) and the distribution of study boat effort was essentially similar in all years.

(2) In all years there were considerable numbers of 3-year-old haddock in subareas on Georges Bank as well as in subareas in the Gulf of Maine and on Browns Bank which were either not sampled by the study boats or included in the 31-60 fathom depth zone coverage.

(3) The amount of study boat effort in the 31-60 fathom and 61+ fathom depth zones in the various subareas on Georges Bank was usually in proportion to the relative abundance of 3-year-old haddock in these subareas, but it is apparent that a much better estimate of abundance and distribution of 3-year-old haddock on Georges Bank could be made if catch and effort data from the 61+ fathom depth zone were included in the analysis of the study boat landings.

(4) The total abundance of 3-year-old haddock in all years was greatest to the west and north of the area sampled by the study boats within the 31-60

fathom depth zone.

(5) If it was necessary to base the estimate of abundance of 3-year-old haddock on a sample of fish from a restricted depth zone, data from the 61+ fathom depth zone would provide the most reliable index, for in general the fishing effort and area of coverage was greatest in this depth zone.

(6) The study boat effort data gives no indication of the abundance of haddock on Browns Bank (Area 21) or in the Gulf of Maine in which areas 3-year-old haddock were most abundant in all years. To estimate the abundance of haddock in areas other than Georges Bank it would be necessary to include catch statistics of commercial boats fishing out of other ports besides Boston.

(7) Although 3-year-old haddock tended to be concentrated in specific regions, the survey cruises indicate that at least during the fall of the year these fish are all a part of a single population and that the 3-year-old haddock on Georges Bank cannot be considered as a distinct group.

Since the bulk of the study boat effort in the 31-60 fathom depth zone is in Subareas J and M (Area 22), it is of interest to assess the age composition of haddock in these 2 subareas as well as in other areas during the survey cruises to determine what age fish were being sampled by the study boats and how the age composition in these 2 subareas compares to that in subareas over the rest of Georges Bank and the Gulf of Maine. The age composition data in terms of the number of haddock per tow by subareas and by groups of subareas in Area 21, Area 22, and Georges Bank during the survey cruises of 1955, 1956, and 1958 is presented in Table 6.

With the exception of 2-year-old haddock in 1958 and 4-7+ year old haddock in 1955, haddock of all ages were more abundant in Area 21 and in the North than on Georges Bank in all years. With the exception of a 2-year-old haddock in Subarea J in 1956 and 1, 2, and 3-year-old haddock in Subarea J in 1958, haddock of all ages were more abundant in a subarea in the North than in any subarea on Georges Bank in all years. At the time of the survey cruises the effort of the study boat fleet in the 31-60 fathom depth zone on Georges Bank was in areas (Subareas) where there were the greatest numbers of fish (1, 2, and 3-year-olds). With the exception of 4-year-old haddock in 1955 there were greater numbers of 4-year-old and older haddock in other subareas of Georges Bank in all years. As far as the Georges Bank area is concerned, at the time of the survey cruises, a sample of 3-year-old haddock in Subareas J and M would overestimate the abundance of 3-year-old haddock on Georges Bank and underestimate their abundance over the whole area.

There was considerable regional variation in the age composition of haddock caught during the survey cruises and thus samples of the age composition from a restricted area such as that obtained by the study boat fleet in the 31-60 fathom depth zone would not necessarily be representative of the age composition over the whole of Georges Bank. For example, an estimate of the relative strength of the 1954 year class based on the abundance of 2-year-old haddock in Subareas J and M in November, 1956 would indicate that this year class was much stronger than if based on the abundance of 2-year-old haddock from all of Georges Bank during this same period.

Table 5.--Age composition (number per tow) of haddock by area and subarea, Albatross III Cruises 65 & 66, September 7-28, 1955, Albatross III Cruises 81 Σ 82, November 2-20, 1956, and Albatross III Cruises 118, 119 and 120, September 22 - October, 1958.

			1955						
		No.	AGE						
AREA	SUBAREA	TOWS	1	2	3	4	5	6	7+
	N	3	5.3	4.0	6.0	1.0	0.3	0	0
	O	2	8.0	6.0	7.5	2.0	1.5	1.0	0
XXI	P	10	4.0	2.4	3.3	0.4	0.4	0	0
	Q	6	2.7	2.5	4.3	0.5	0.7	0.3	0
	TOTAL	21	4.3	3.0	4.4	0.7	0.6	0.2	0
	C	0							
	D	9	1.4	1.8	0.2	0.1	0.1	0	0.1
	E	8	30.8	10.3	10.0	2.4	1.5	0.4	0.3
	F	10	0.1	0.2	2.3	0.3	1.0	0.5	0.3
	G	14	1.8	1.9	7.4	1.4	1.8	0.5	0.3
XXII	H	13	0.2	0.2	2.1	0.7	1.3	0.5	0.2
	J	10	1.4	2.9	8.2	3.6	1.5	0.5	0.3
	M	9	4.4	0.9	0.2	0.1	0.1	0	0.1
	N	7	0.3	0.1	0	0	0	0	0
	O	7	0.1	0	0	0	0	0	0
	Q	6	0	0	0	0	0	0	0
	S	0							
	TOTAL	93	3.7	1.8	4.2	0.9	0.9	0.3	0.2
NORTH	XXI N, O, P, Q XXII C, D, E, F.	48	7.2	3.4	5.6	0.8	0.7	0.3	0.1
GEORGES	G, H, J, M, N, O	60	1.4	1.2	3.6	1.1	1.1	0.3	0.2

Table 6.--Age composition (number per tow) of haddock by area and subarea, Albatross III Cruises 65 & 66, 1956, September 7-28, 1955, Albatross III Cruises 81 & 82, November 2-20, and Albatross III Cruises 118, 119 and 120 September 22 - October, 1958.

			1956						
		NO.	AGE						
AREA	SUBAREA	TOWS	1	2	3	4	5	6	7+
	N	2	28.5	10.5	3.0	4.5	1.5	0.5	1.0
	O	0							
XXI	P	6	1.3	4.3	0.8	1.8	0.3	0.2	0
	Q	2	0.5	7.5	4.5	8.0	2.0	1.0	0
	TOTAL	10	7.0	6.2	2.0	3.6	0.9	0.4	0.2
	C	0							
	D	7	0	0.9	0.4	1.1	0.6	0.3	0.4
	E	6	1.0	14.2	2.0	2.7	1.2	0.5	0.2
	F	8	0.1	1.1	0.9	2.0	0.8	0.8	0.6
	G	5	0.4	1.6	0.6	1.6	0.2	0.2	0.2
XXII	H	2	0	5.0	1.5	6.5	3.0	3.5	3.0
	J	5	1.0	25.4	3.0	3.6	1.2	0.2	0.2
	M	6	0	1.7	0.2	0.7	0	0	0
	N	4	0	0	0	0	0	0	0
	O	7	0	0	0	0	0	0	0
	Q	9	0	0	0	0.1	0	0	0
	S	2	0	0	0	0	0	0	0
	TOTAL	61	0.2	3.9	0.7	1.3	0.5	0.3	0.3
NORTH	XXI N, O, P, Q XXII C, D, E, F.	31	2.4	5.2	1.4	2.5	0.8	0.5	0.4
GEORGES	G, H, J, M, N, O	29	0.2	5.3	0.8	1.5	0.4	0.3	0.3

Table 6.--Age composition (number per tow) of haddock by area and subarea, Albatross III Cruises 65 & 66, September 7-28, 1955, Albatross III Cruises 81 & 82, November 2-20, 1956, and Albatross III Cruises 118, 119 and 120, September 22 - October, 1958.

			1958						
		NO.	AGE						
AREA	SUBAREA	TOWS	1	2	3	4	5	6	7+
	N	4	41.2	10.3	6.0	3.3	0.8	0	0
	O	8	28.6	6.0	3.6	2.3	0.6	0.5	0.3
XXI	P	11	14.0	15.6	7.7	3.5	1.3	0.5	0.1
	Q	11	23.9	16.4	10.4	6.0	2.2	1.3	0.5
	TOTAL	34	23.9	13.0	7.4	4.0	1.4	0.7	0.3
	C	6	0.3	0.8	1.7	1.7	0.8	0.7	0.5
	D	7	0.3	1.1	0.3	0.9	0.3	0.1	0
	E	6	2.2	6.0	2.2	1.3	0.3	0.3	0.5
	F	10	0.8	1.2	3.5	4.4	2.1	1.3	1.0
	G	10	3.6	12.7	10.3	6.2	2.9	2.0	1.6
XXII	H	7	0.3	1.7	1.7	1.3	0	0.1	0
	J	7	52.1	91.2	19.1	5.4	1.1	0.3	0.6
	M	7	3.9	0.4	0.1	0.3	0	0	0
	N	8	0	0	0	0	0	0	0
	O	7	0	0.3	0	0	0	0	0
	Q	7	0	0	0	0	0	0	0
	S	1	0	0	0	0	0	0	0
	TOTAL	83	5.5	10.2	3.7	2.1	0.8	0.5	0.4
NORTH	XXI N, O., P, Q XXII C, D, E, F	63	13.3	7.9	5.0	3.2	1.2	0.7	0.4
GEORGES	G, H, J, M, N, O	46	9.3	17.0	5.4	2.7	0.8	0.5	0.4

It is understandable why better agreement is not obtained between abundance estimates based on survey cruise and study boat data when we consider the marked differences in the number of samples and in the area and period of coverage in the 2 sampling methods. However, we should obtain similar abundance estimates if we select an age of haddock which is representatively sampled by both survey and commercial nets and compare the catch of these fish during similar periods and for similar areas. Such a comparison is made in Figure 11 which shows the relative abundance of 3-year-old haddock in 1955, 1956, and 1958 and the relative numerical strength of the 1952, 1953, and 1955 year classes of haddock based on the average catch per tow of 3-year-old haddock on Georges Bank (Subareas G, H, J. M, N, and O), Subareas J and M, and the Total Area as determined on survey cruises during September, 1955, November, 1956, and October, 1958 and the catch per day of 3-year-old haddock on Georges Bank by the study boats during these same months. The total study boat catch of 3-year-old haddock and the total number of days fished in all depth zones was used at deriving the study boat catch per day figure for Georges Bank.

The abundance of 3-year-old haddock as determined during the survey cruises was greatest in 1958 and least in 1956 on Georges Bank, Subareas J and M, and in the Total Area. The study boat figures for Georges Bank show that 3-year-old haddock were more abundant in 1955 than in 1958. Considering that 1958 was the only year in which 3-year-old haddock were more abundant on Georges Bank than in the North (Table 6) and that the survey cruises indicated that the greatest concentration of 3-year-old haddock at this time was in Subarea J (Figure 10)

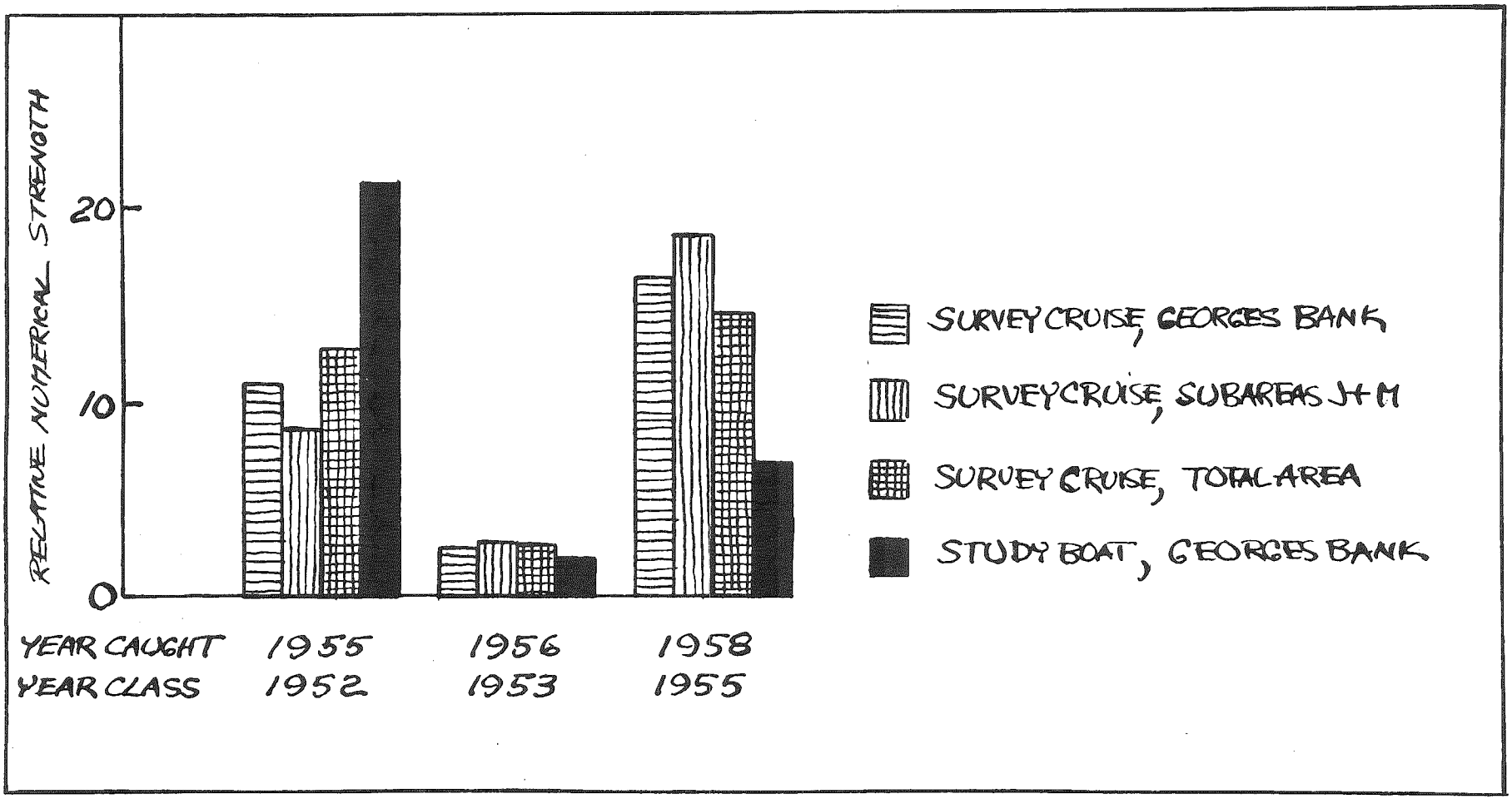

Figure 11.--Comparison of the relative abundance of 3-year-old haddock based on the catch per tow during survey cruises and the catch per day of the study boat fleet during similar periods.

which subarea is most heavily fished by the study boat fleet, it is puzzeling why there is not better agreement between the 2 sets of data. There appears to be a direct correlation between the amount of effort of the study boat fleet and the abundance of 3-year-old haddock as indicated by the commercial landings and the survey cruise data in 1955 and 1956. However, in 1958 the effort of the study boat fleet was high, but the catch per day was low. The relative strength of the 1952 and 1956 year classes based on the September, 1955 and October, 1958 study boat data is similar to that based on the 12 months data for these years (See Figure 5). It is unfortunate that no data is available on the study boat catch of 3-year-old haddock by individual depth zones during these months, for it is possible that the catch per day would vary considerably with depth.

Survey Data

As noted previously (page) the survey cruise data indicated that the abundance of zero-ring and one-year-old haddock fluctuated in the same way, both being high in all areas in 1955 and 1958 and both being low in 1953 and 1956. This tendency towards a greater abundance of fish in certain years was most marked for the younger haddock, but was also manifest in the catches of older haddock. For example, the catch of haddock of all ages was greater in 1958 than in 1956 in all the major areas and in most subareas (table 6). The result of this apparent fluctuation in fishing efficiency between years is that estimates of year class strength are dependent upon what age fish are chosen to represent the year class and in what year the sampling was done. For example, the 1956 year class would appear much stronger on a basis of the abundance of 2-year-old

haddock in 1958 than on the abundance of zero-ring haddock in 1956.

The gear and method of tow were similar during all survey cruises, so that it does not appear that the variations in fishing efficiency between years could be due to any differences in fishing technique. It is well known however, that commercial vessels tend to catch more haddock during the day than during the night and that this variation in the day and night catch is more marked in some localities (deeper water) than others (shoaler water). Suprisingly, there has never been an analysis made of the day-night variation in the catch of the commercial fleet, but it is possible that such day and night differences might be the cause of variation in fishing efficiency between years. If, for example, there were marked variations in the proportion of day and night tows between years this could conceivably effect estimates of abundance. To determine if such was in fact the case, a tabulation was made of the number of day and night tows and of the catch per tow of zero-ring, one-year-old, and 2 + year haddock during the day and night for the 4 survey cruises (Table 7). Zero-ring and one-year-old haddock were tabulated separately for it was for these ages of fish that the most marked yearly variations in abundance were observed.

With the exception of 1953 in which year significantly more tows were made during the day than during the night, the day and night effort were similar. The catch per tow of zero-ring haddock was slightly greater during the day than during the night in 1956, slightly greater during the night than during the day in 1953, and significantly greater during the night in 1955 and 1958. The catch per tow of one-year-old haddock

was greater during the day than during the night in 1953 and 1956 and greater during the night than during the day in 1955 and 1958. The average night-day ratio in abundance was greater for zero-ring haddock than for one-year-old haddock. In all years the catch per tow of 2 + year haddock was greatest during the day as is the case in the commercial catch. The day and night catch per tow ratio of 2 + year haddock was of the same order of magnitude dueing all years, but the proportion of zero-ring and one-year-old haddock was appreciably greater in the night time tows only in the years when the survey cruises indicated that these 2 age groups were most abundant (1955 and 1958). It should also be noted that the number of both day and night tows was also greatest in 1955 and 1958.

Table 7.--The number of tows and the catch per tow of haddock by day and night, September 1953 and 1955, November 1956, and September-October, 1958.

		Day(0730-1629)			Night (1930-0429)		
		#Tows	# Fish	C/T	# Tows	# Fish	C/T
Zero-Ring Haddock	1953	35	30	0.9	24	32	1.3
	1955	46	218	4.7	53	732	13.8
	1956	34	72	2.1	37	58	1.6
	1958	46	264	5.7	50	1216	24.3
	Total	161	584	3.6	164	2038	12.4
One-Year-Old Haddock	1953	38	33	0.9	24	2	0.1
	1955	42	45	1.1	54	349	6.8
	1956	35	74	2.1	37	48	1.3
	1958	46	286	6.2	50	548	11.0
	Total	161	438	2.7	162	947	5.8
2+Year Haddock	1953	38	44	1.2	24	17	0.7
	1955	42	466	11.0	51	256	5.0
	1956	35	285	8.1	37	212	5.7
	1958	46	958	20.8	50	732	14.6
	Total	161	1753	10.9	162	1217	7.5

Year class strength estimates based on the abundance of zero-ring haddock during the day and night would both indicate that the 1955 and 1958 year classes were strong, but the night time data would not only indicate that the 1955 and 1958 year classes were considerably stronger than the day time data, but that the 1958 year class was approximately twice as strong as the 1955 year class. The day time catch of one-year-old haddock would indicate that only the 1957 year class was strong, while the night time catch would indicate that both the 1957 and 1954 year classes were strong. Although not as marked, significant yearly differences in the relative abundance of 2 + year haddock also occurred between the day and night data.

Not only do estimates of abundance based on day and night observations vary, but also the distribution pattern is different if based on night observations than if based on day observations. This is demonstrated in Figure 13 showing the distribution of zero-ring haddock as determined during the day and night tows in September - October, 1958. Not only were zero-ring haddock found over a much wider area at night but also areas of high abundance (off southeastern Nova Scotia) were not indicated by the daytime data.

In Figure 12 the 4-year average catch per tow of zero-ring one-year-old, and 2 + year haddock are plotted for hourly intervals. It was necessary to group data from all 4 survey cruises in order to have a representative number of tows for each time interval. All tows made within the half hour before and after the hour were grouped (i.e. 0800 - 0730 - 0829). These data are tabulated in Table 8. In general the catch

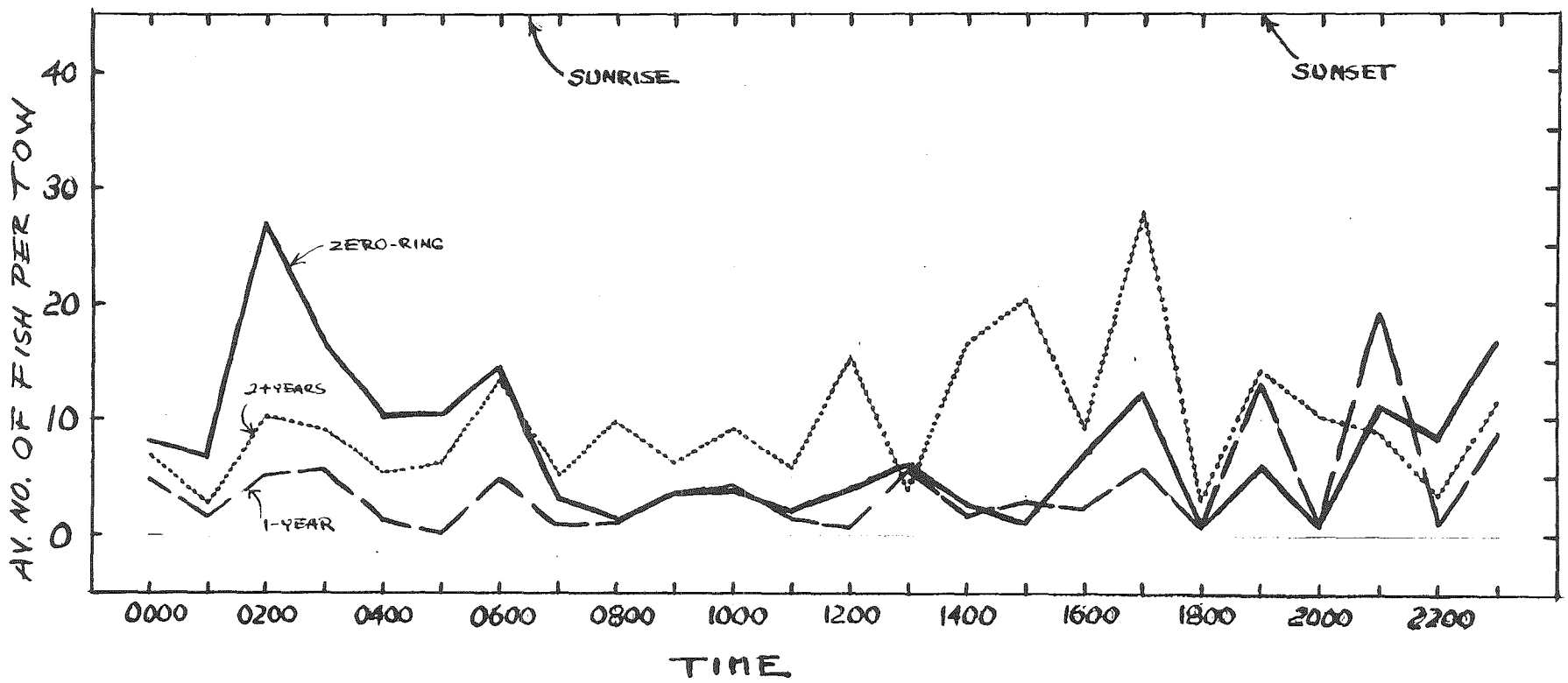

Figure 12.--The average catch per tow of zero-ring, one-year-old, and 2 + year-old haddock at hourly intervals, September, 1953 and 1955, November, 1956, and September-October 1958.

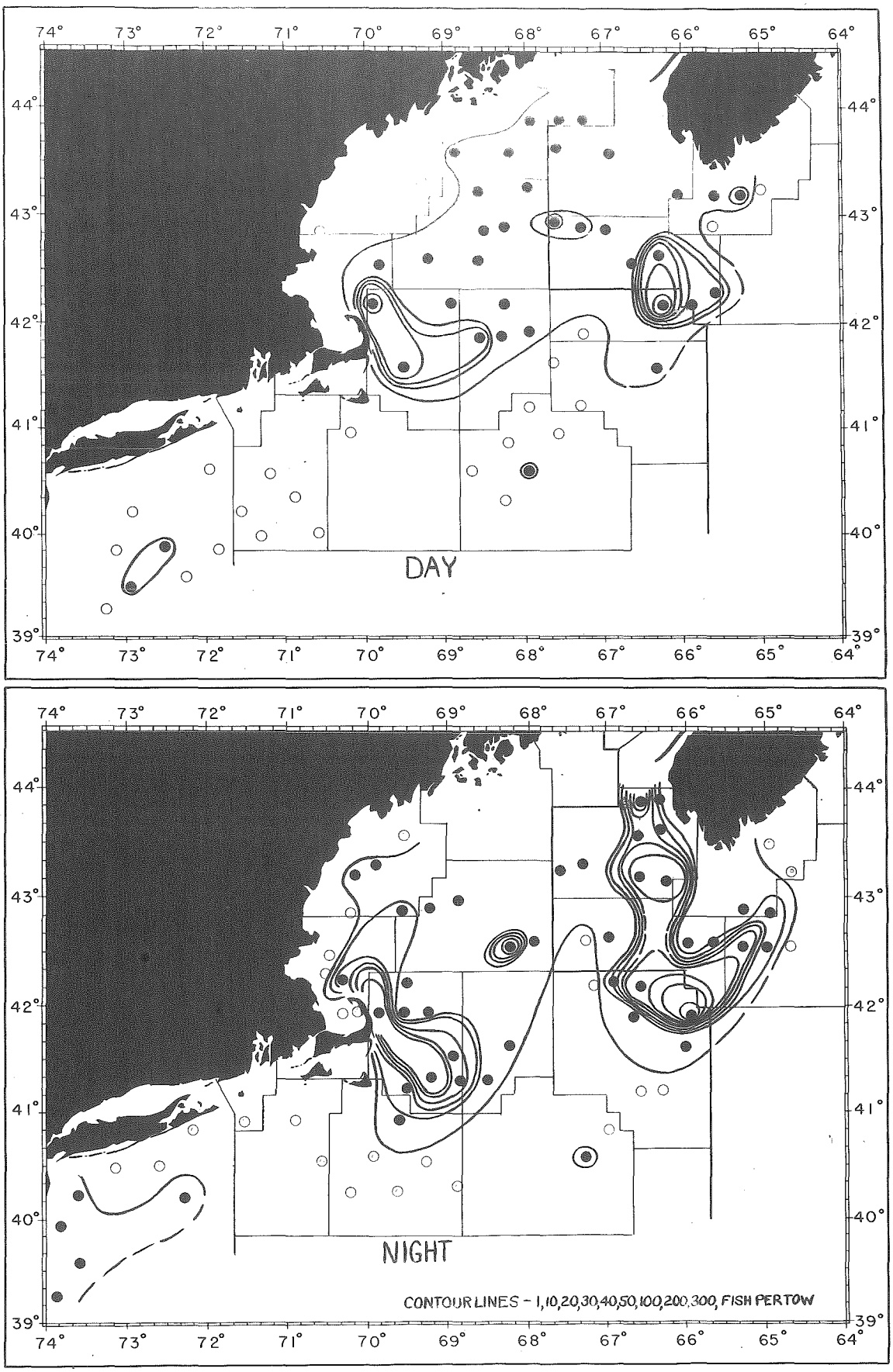

FIGURE 13. DISTRIBUTION OF ZERO-RING HADDOCK DURING THE DAY AND NIGHT, SEPTEMBER-OCTOBER, 1958.

Table 8.--Number of tows and average catch per tow of haddock by hourly time intervals, 1953 - 1958

		Zero-Ring Haddock			One-Year-Old Haddock			2 + Year Haddock		
	Time	#Tows	#Fish	C/T	#Tows	#Fish	C/T	#Tows	#Fish	C/T
NIGHT	0000	18	144	8.0	17	81	4.8	17	118	6.9
	0100	17	112	6.6	19	31	1.6	19	53	2.8
	0200	22	595	27.0	21	109	5.2	21	215	10.2
	0300	20	328	16.4	20	114	5.7	20	182	9.1
	0400	17	173	10.2	16	21	1.3	16	88	5.5
	0500	17	175	10.3	15	3	0.2	15	96	6.4
	0600	25	359	14.4	23	113	4.9	23	305	13.3
	0700	15	47	3.1	16	17	1.1	16	81	5.1
DAY	0800	18	27	1.5	17	19	1.1	17	168	9.9
	0900	17	63	3.7	18	64	3.6	18	112	6.2
	1000	21	82	3.9	21	91	4.3	21	192	9.1
	1100	16	32	2.0	16	24	1.5	16	92	5.8
	1200	13	50	3.8	14	10	0.7	14	215	15.4
	1300	15	90	6.0	14	78	5.6	14	55	3.9
	1400	15	39	2.6	15	28	1.9	15	249	16.6
	1500	20	21	1.1	22	64	2.9	22	444	20.2
	1600	26	180	6.9	24	60	2.5	24	226	9.4
	1700	12	147	12.3	12	70	5.8	12	337	28.0
	1800	19	14	0.7	20	16	0.8	20	60	3.0
	1900	23	141	6.1	23	302	13.1	23	327	14.2

Table 8.-- (Continued)

		Zero-Ring Haddock			One-Year-Old Haddock			2 + Year Haddock	
	Time	#Tows	#Fish	C/T	#Tows	#Fish	C/T	#Tows	#Fish	C/T
	2000	12	9	0.8	12	23	1.9	12	121	10.1
	2100	21	237	11.2	21	403	19.2	21	187	8.9
NIGHT	2200	21	175	8.3	20	23	1.2	20	69	3.5
	2300	16	265	16.6	16	142	8.9	16	184	11.5

per tow of zero-ring and one-year-old haddock tended to be higher during the night time hours and the catch per tow of 2 + year haddock tended to be higher during the daylight hours, but there were marked hourly fluctuations in the catch per tow of all age groups. The fluctuations in the number of fish caught between individual tows within a given hour were to great to attach any significance to the abundance figures. The main cause for the great fluctuations in the catch during day and night appear to be the marked regional fluctuations in the abundance of haddock. Obviously there were many tows made during the night in areas where there were little or no zero-ring and one-year-old haddock and many tows during the day in areas where zero-ring and one-year-old haddock were abundant. The same situation holds true for the 2 + year haddock. In any event, the day-night variability in the catch is real, but special sampling techniques (trawling at set time intervals for an appreciable number of days within a relatively small area in various deep and shoal water regions of the Gulf) are needed before this variability can be accurately ascertained.

Diurnal migration appears to be the cause of the variation in the day and night catch of 2 + year haddock. Although no sampling has been undertaken to establish if haddock move off the bottom during the night in the Gulf of Maine, trawling experiments and echo sounder observations have shown that haddock do move off the bottom at night in other areas (Woodhead, 1961). The fact that the commercial fishermen often follow schools of haddock into shoaler areas during the night indicates that such is in fact the case in the Gulf of Maine. Diurnal migration cannot explain the variation in the day and night catch of zero-ring and one-

year-old haddock unless their movement is opposite to that of all other marine animals (up in the day and down at night). It is also possible that zero-ring and one-year-old haddock do not move off the bottom at night. However, observations on the diurnal migration of herring in the North Sea (Lucas, 1936) and of haddock in the Barents Sea (Woodhead, 1961) have demonstrated that smaller fish show more tendency to leave the sea bed than do larger fish. It appears that the daytime decrease in the catch of zero-ring and one-year-old haddock is due to a variation in the catching efficiency of the otter trawl between day and night. This variation in catching efficiency could be due either to an increase in the avoidance of the trawl during the day as has been demonstrated in the case of postlarval and juvenile fish from slow moving nets towed at the surface and at mid depths or to an increase in escapement through the trawl meshes during the day. No doubt all age haddock are able to avoid the otter trawl to some extent, but it appears that the younger fish may exhibit a more rapid visual or audio response to the trawl and that the day and night variability in the catch of zero-ring and one-year-old haddock due to avoidance or escapement is greater than that due to vertical migration.

There would appear to be only 2 possible methods of reducing daytime decrease in the catching efficiency of the otter trawl. One way would be to increase the towing speed, but this does not appear practical for; (a) at high towing speed it is difficult to keep the trawl on the bottom and (b) because of imperfect filtration the amount of backwash and turbulence at the mouth of the net would be increased. It would be possible to determine the effect of the speed of tow on excapement, however,

by making a series of bottom tows at various speeds during the day and night at various depths and determining the variability of the catch of various age haddock with speed and time.

Another, and possibly more effective way would be to reduce escapement by decreasing the mesh size of the trawl wings. It appears quite possible that all age fish enter the net at the same rate, but that the smaller fish (zero-ring and one-year-olds) are able to excape through the meshes of the wings and that they are better able to do this during the day than during the night. In order to determine if this is in fact the case, it would be necessary to make a duplicate series of tows at various depths during the day and night with and without a fine mesh liner in the wings.

RECOMMENDATIONS

1. Write up a detailed description of the methods used currently and in the past for estimating the abundance and age distribution of groundfish on Georges Bank and other areas.

2. Determine the depth zone allocation of the study boat effort by months and/or seasons from 1928 to present.

3. Compare the catch per unit effort of various age haddock in the 3 depth zones by months and/or seasons from 1928 to present.

4. From (2) and (3) determine what depth zones and how many vessels must be included in the catch statistics in order to obtain a reasonable estimate of the abundance of various age haddock.

5. Determine the variation in the day and night catch of various age haddock by the study boat fleet in the 3 depth zones.

6. Compare estimates of year class strength based on the study boat catch per unit effort of 3-year-old haddock in depth zones 2 and 3 and on total yield figures.

7. In future survey cruises an effort should be made to obtain scale samples from all haddock over 30 cm., so that an accurate estimate of the age distribution at specific locations can be made and make it be possible to estimate the abundance and distribution of a given year class for a number of years.

8. Determine the variation between the day and night catch of various age haddock and other groundfish in specific areas and depths.

9. Determine the causes for the variation in the day and night catch of haddock and other groundfish.

10. Give serious consideration to the proposal (See Lab. Report No. 62-8) that commercial vessels be used for surveys of groundfish populations.

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