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Stock-Recruitment of Georges Bank Haddock

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This report was prepared in response to the recommendation by the Committee on Research and Statistics at the 1965 Annual Meeting, that data on stock-recruitment relations be reviewed.

The Pre-1931 Population

Herrington (1948) reported a dome-shaped stock recruitment relation for Georges Bank haddock during the period 1914-1940. He plotted abundance in terms of landings per day fished of spawning stock (large and scrod haddock in winter and spring) [1/] against recruitment (scrod haddock in spring and summer) two and three years later, when year classes are being recruited to the fishery as scrod. Recruitment appeared to be proportional to the number of spawners at low levels of adult stock, reach a maximum at intermediate stock levels, and then decline drastically at higher stock indices. Herrington concluded that intra-specific competition for food between adults and young was the most probable mechanism for the severe reduction in recruitment at high levels of adult stock.

To illustrate the relation we have plotted spring quarter abundance of large haddock against spring quarter abundance of scrod three years later (Fig. 1). If a smooth curve were fitted to Fig. 1, maximum recruitment would occur at an adult stock index of about 20,000 pounds per day fished, which is the same point of maximum suggested by Herrington.

There has been considerable interest in these data because they represent one of the few empirical examples in natural fish populations of an apparent stock-recruitment relation with a prominent maximum. Ricker (1954) concluded that a dome-shaped stock recruitment or reproduction curve probably was characteristic of most fish populations. Beverton and Holt (1957) considered that an asymptotic curve, i.e., without a maximum, was more likely and corresponded better with existing data. With respect to haddock in particular, there is no evidence of a maximum in the reproduction curve for North Sea haddock (Beverton and Holt, 1957).

Another unusual feature of the Georges Bank data is that abundance appeared to fluctuate widely in a cyclic manner in the early years, as could be expected in a population with a dome-shaped reproduction curve. Ricker (1954) and Beverton and Holt (1957) have shown that in hypothetical populations where the reproduction curve has a steeply descending right hand limb,

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1/--Scrod are the smallest marketable haddock ranging from about 1-1/2 to 2-1/2 pounds gutted weight with a mean fork length of 42-44 cm. Large haddock weigh over 2-1/2 pounds. With the exception of 1962-65 when calendar quarters are employed, the quarters used in this report are as follows: First quarter (spring) - Feb, Mar, Apr; Second quarter (summer) - May, Jun, Jul; Third quarter (fall) - Aug, Sept, Oct; Fourth quarter (winter) - Nov, Dec, Jan.

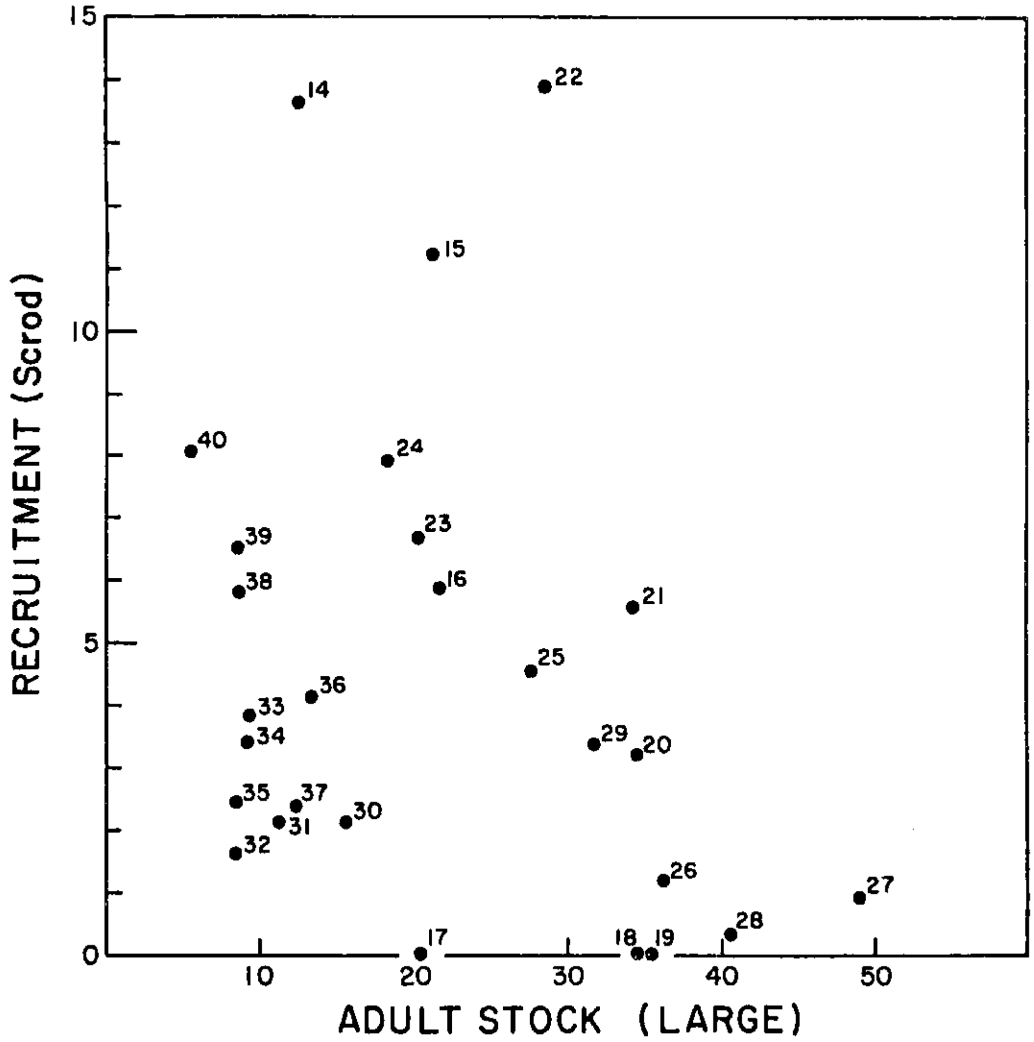

Fig. 1. --First quarter landings (lb x 10^{-3}) per day fished of large haddock vs. the same index for scrod three years later. Numbers beside points represent both calendar year and year class.

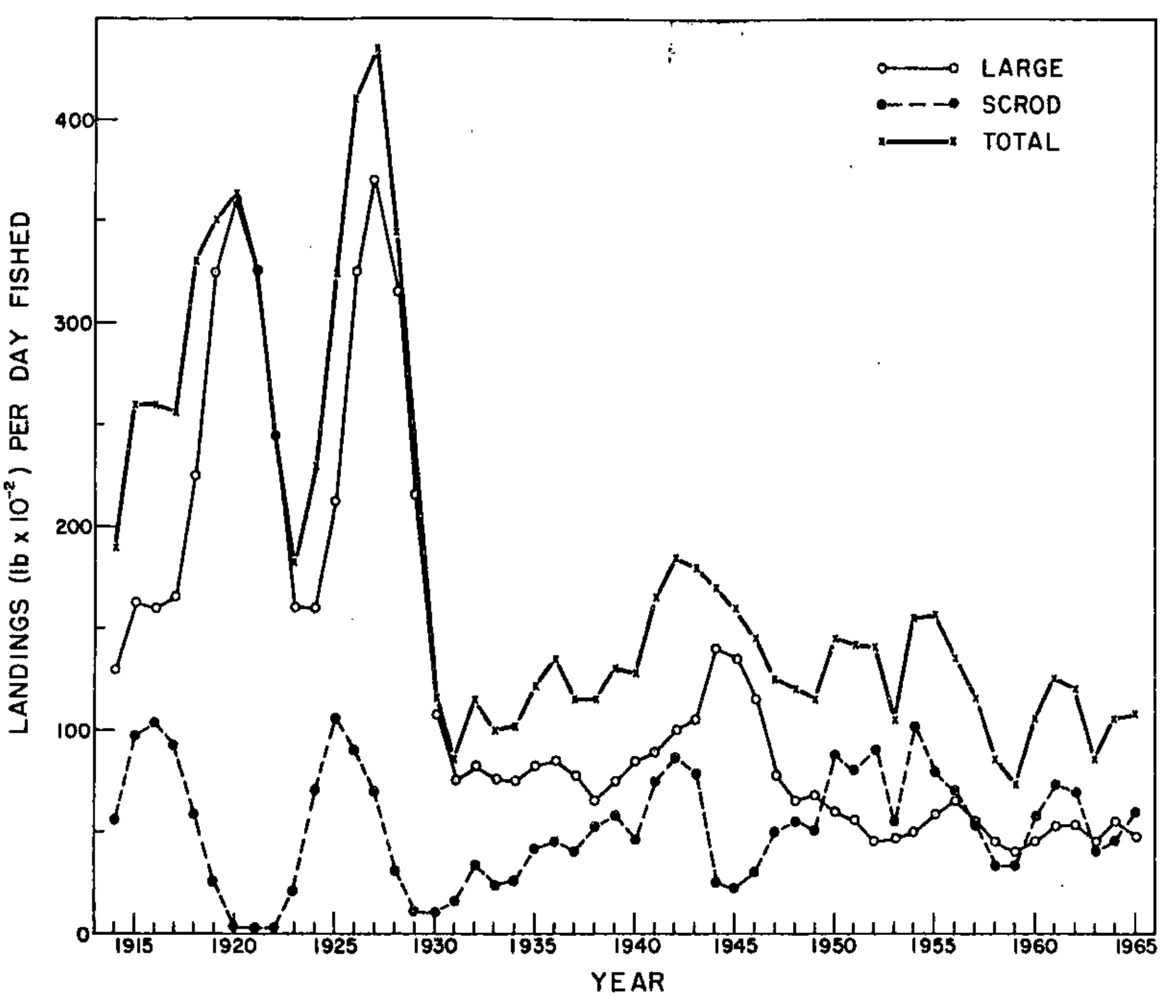

Fig. 2. --Georges Bank annual landings (lb x 10^{-2}) of haddock per day fished by otter trawlers.

population oscillations will result whenever the adult stock size reaches a point to the right of the maximum. The fluctuations in apparent abundance of adult stock and recruits on Georges Bank from 1914-31 show two complete oscillations with trough-to-trough periods of eight to nine years (Fig. 2). Ricker (1954) noted that the period of oscillation was consistent with Herrington's description of the probable size- and age-structure of the pre-1931 haddock population.

Prior to 1931 there were virtually no data on the size and age composition of landings. Therefore, in order to divide the stock into mature and immature groups Herrington assumed that the size and age composition of the scrod category in the pre-1931 period was similar to that observed after 1931. This is not an unreasonable assumption because the size limits of the market categories reported for the early years (Alexander, Moore and Kendall, 1915), were the same as those currently in use. The majority of scrod landed in spring quarters in the 1930's were three-year-olds about 42-45 cm long and most females of this size are mature. Consequently, Herrington's division of the population into spawners and subsequent recruits probably was not much different from what it would have been if age compositions were available.

However, the reliability of the abundance indices is open to question as noted by Herrington himself. In particular, he suggested that the catch-per-unit-effort indices might not be representative of the whole Georges Bank population in the early years of the otter trawl fishery when effort was low. In an unpublished report Herrington stated that, ". . . . in the early years of the fishery. . . . otter trawlers fished restricted areas of smooth bottom in South Channel and to a minor extent on Georges." Unfortunately, it was not until 1927 that landings could be assigned to the well defined statistical areas described by Rounsefell (1948). Nevertheless, a comprehensive re-analysis of these early records is in progress and may eventually provide somewhat better abundance indices. In the meantime, it is necessary to point out some obvious inconsistencies in the data as they stand.

If we assume as Herrington did that the pre-1931 scrod and large indices were reasonable approximations of the true annual abundance of their respective segments of the population, then it would appear that the pre-1931 mean level of adult stock (large haddock) was more than twice as large as the post-1931 average, although average recruitment (scrod index) was about the same in both periods (Fig. 2). A possible explanation for the difference in mean levels might be that the pre-1931 adult stock was composed of more and older age groups than the post-1931 stock. However if this were true it is difficult to explain the very rapid changes in apparent abundance of the adult stock.

Evidence from tagging (Grosslein, 1962) precludes mass movements of adults; therefore, the apparent oscillations in adult stock (more than two-fold) during the period 1917-27 can be attributed only to large fluctuations in recruitment or to biased abundance indices since fishing effort did not fluctuate widely. The rapidity of these oscillations implies that the abundance of the large category depended to a considerable extent upon annual recruitment from the scrod category; and yet there was a three-year lag between trends in scrod and large indices in the period 1914-23, and about a two-year lag in the period 1924-30 (Fig. 2). Such time lags are untenable in view of the fluctuations in adult stock indices, and consequently, the validity of the fluctuations themselves must be open to serious doubt. Consistent with this suggestion is the fact that scrod were reported to have been discarded at sea because of low prices, particularly in the early 1920's (reports of U. S. Commissioner of Fisheries for the years 1921 - 1926).

Another anomaly is that the apparent reductions in total stock in 1920-23 and 1927-30 seem too large in relation to the landings or removals from the stock. The apparent reduction in stock in 1920-23 represented nearly twice the mean stock level observed in the period 1931-34, and yet landings were less in 1920-23 than in 1931-34 (Table 1). Also, the apparent stock reduction in 1927-30 represented nearly four times the mean stock level of 1931-34, but landings were only twice as large in the earlier period (Table 1).

Table 1. --Total haddock landings from Subarea 5 and coincident changes in apparent abundance for several periods.

Period	Landings (metric tons x 10^{-3})	Landings (lb x 10^{-2}) per day fished by otter trawlers on Georges Bank
1920	46	366
1921	36	325
1922	36	245
1923	37	183
Total	155	
1927	84	438
1928	108	345
1929	126	224
1930	108	115
Total	426	
1931	68	89
1932	60	116
1933	52	97
1934	32	103
Total	212	

The drastic decline in otter trawl landings per day in the late 1920's is of particular interest because it is coincident with the tremendous increase in effort due to the rapidly expanding U. S. otter trawl fleet of the late 1920's. While haddock abundance did decline to some degree on Georges Bank in this period it seems quite possible that the decline was exaggerated by the otter trawl indices. Abundance indices based on line trawl catches suggest a much smaller decline for the same period. Landings per trip of large haddock by line trawlers fishing in the South Channel (just off Cape Cod) declined from an average of 34, 000 pounds in 1928 to 18, 000 pounds in 1932, a decline of about one-half, and similar data for Georges Bank shows no downward trend at all during the period 1928-35 (Table 2).

It is also possible that the decline was due partly to bias of the type reported by Gulland (1965) for the plaice, sole, and cod in the North Sea following the war. In the late 1920's there probably were some areas particularly on eastern Georges Bank which had been essentially untouched by trawlers in earlier years of low effort and which had localized dense aggregations of haddock. The rapidly expanding U. S. otter trawl fleet could have quickly exploited those aggregations and then would have been forced to spread out into areas of lower density, thus causing a rapid decline in apparent abundance. The same type of bias may have been present in varying degrees in otter trawl indices for the entire pre-1931 period which could exaggerate fluctuations as well as inflate the average apparent stock level.

In conclusion, it seems very likely that the pre-1931 fluctuations in adult stock and recruitment were exaggerated, thus casting doubt on the validity of the apparent stock-recruitment relation for the Georges Bank haddock. It also seems probable that the actual mean stock level over the whole of Georges Bank from 1914-30 may have been lower than indicated by the otter trawl indices. Further study of these early records is important not only for the stock-recruitment problem, but also because they play a critical role in assessing the effects of fishing on the Georges Bank stock (see Graham, 1963).

Table 2. --Number of line trawl trips and landings per trip (pounds x 10^{-3}) of haddock (market category large) reported as caught from Georges Bank and South Channel, and landed at Boston, Gloucester, and Portland [1]

Year	Georges Bank		South Channel	
	No. trips	Large haddock landings (lb x 10^{-3}) per trip	No. trips	Large haddock landings (lb x 10^{-3}) per trip
1928	265	22	369	34
1929	161	16	484	30
1930	174	20	446	26
1931	170	14	318	22
1932	192	15	231	18
1933	150	23	216	19
1934	70	18	169	20
1935	114	17	107	21

1/--Adjusted to mean number reported days absent per trip in period 1928-35: 10.4 days and 6.9 days for Georges Bank and South Channel, respectively.

The Population from 1931 - 1965

Recruitment (scrod abundance) increased rather steadily from 1931 until 1943, and the adult stock (large haddock abundance) appeared to increase in the 1940's reaching a peak in 1944 (Fig. 2). However, contrary to expectations based on Herrington's stock-recruitment relation, scrod abundance dropped drastically in 1944 and did not recover until 1947, after abundance of large haddock had declined markedly from 1945-47. Herrington (1948) suggested that overall food supply probably had decreased, thus generating severe competition between adults and pre-recruits at a lower level of stock size. In support of his conclusion he reported that in years of poor survival (1927-28; 1942-44) the "nursery grounds" were overrun by adults and growth of two-year-old haddock was below average.

Unfortunately, studies made to date on haddock growth are inadequate to test Herrington's hypothesis. Haddock were smaller for a given age in commercial landings in the early 1950's when recruitment appeared relatively high, than in the early 1940's when survival of young was lower. However, the nature of these trends in length-at-age is such that they cannot be attributed to changes in growth alone, but may reflect changes in the nature of the fishery as well as sampling bias. In any case, the trends are roughly opposite those necessary to corroborate Herrington's revised hypothesis.

In the view of Beverton and Holt (1957) once the pelagic larval stage is passed, available evidence indicates that fish have a high tolerance for lack of food, and do not exhibit drastic increases in natural mortality even when food levels are much below that required for normal growth. Consequently, in the absence of direct supporting evidence it is difficult to accept Herrington's revised hypothesis and also to attribute the steep right hand limb shown in Fig. 1 solely to competition for food between adults and demersal stages of pre-recruits. Intra-brood competition for food at an earlier (pelagic) stage would seem a more likely mechanism for density dependent control of haddock recruitment, either through starvation or through duration of exposure to predation. Cannibalism of a degree necessary to generate a severe control on recruitment is very unlikely because of the haddock's feeding habits.

Another important feature in the analysis of the Georges Bank haddock population is that in the late 1940's the fishery appears to have changed its character. Although scrod abundance rose sharply in the early 1950's from recruitment of the strong 1948, 1950, and 1952 year classes, the large haddock abundance index failed to recover and fell below the scrod index for the first time in 1950 (Fig. 2). Since 1955 the indices of the two market categories have been at approximately the same level. Minor changes in cull limits for the two market categories have contributed slightly to fluctuations between scrod and large indices but they do not account for the marked change under consideration. It should be noted that fewer haddock of age group 1 (too small for market) were landed in 1949-65 than in 1931-48, suggesting that cull size was slightly higher in the later period (see Fig. 3).

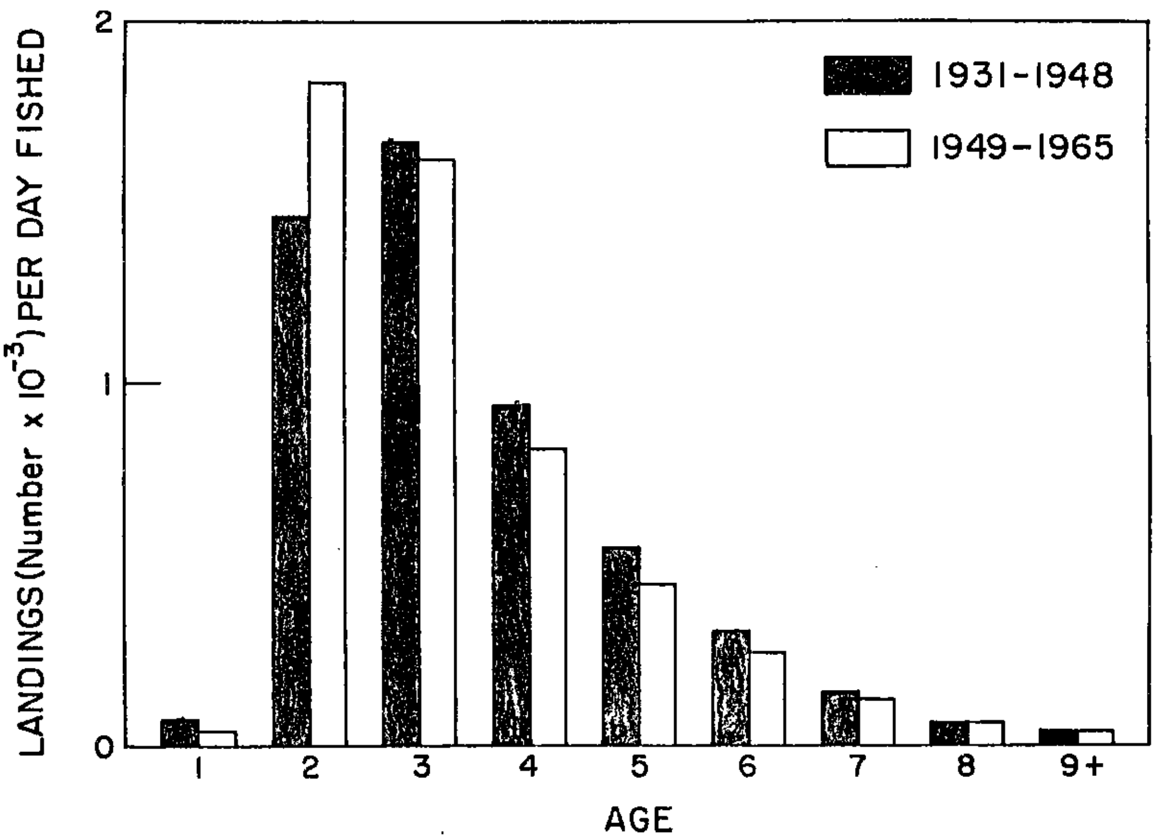

Fig. 3. --Georges Bank haddock landings (thousands of fish) per day fished by age groups in two periods, 1931-48 and 1949-65.

The most probable explanation is that younger fish came under heavier exploitation and thus we should expect an increase in apparent abundance of the youngest marketable age and a decrease among older ages. Average landings per day of age groups 2 was higher, and that of age groups 3 and older was lower in the period 1949-65 than in the period 1931-48 (Fig. 3). In order for such a change to be possible we must assume a geographic separation of the younger and older haddock on Georges Bank at least at some times of year. Such a difference was suggested by Herrington (1948). In a series of research cruises in the period 1948-50, large haddock were more abundance in deeper waters of Georges Bank in summer months (Colton, 1955). Furthermore, Colton reported that in the summers of 1948-50 the fleet was concentrated in shoaler waters of eastern Georges Bank where young haddock predominated. Given such a differential depth distribution of haddock by size, then a shift to shoaler waters by the fleet would inflate the scrod abundance index, particularly since the Georges Bank index from 1931-65 has been based solely on effort in the 30-60 fathom depth zone where fishing effort for haddock was concentrated in the 1930's (Rounsefell, 1957).

Another possible factor is increase in mesh size. With the establishment of mesh regulation in late 1953, mortality of pre-commercial sizes should have been reduced, and other things being equal (cull size, distribution of fish, and distribution and level of fishing) the average landings per day of a year class of given strength should have increased at least for the first marketable age group (age group 2). Increased efficiency of large mesh for the larger fish would tend to increase mortality among age groups above the selection range of 4-1/2 inch mesh. Consequently, part of the observed change in relative age composition may be due to the mesh regulation. However, it seems likely that most of the change is due to concentration on incoming recruits because the change occurred before mesh regulation went into effect (see Fig. 2).

Analysis of relative abundance of age or size groups by areas and all depth zones will be required for further insight into this problem. Whatever the complete explanation may be, it is clear that the scrod index and possibly the large haddock index as well, do not represent the same segments of the population throughout the entire period 1931-65.

The best measure of the relation between spawning stock and subsequent recruitment would appear to be a plot of the first quarter abundance of adult stock against the lifetime yield of the resulting year class. Landings per day of age groups 3 and older in the first quarter of 1931-56 were plotted against lifetime yield (accumulated abundance at all ages) of the year classes spawned in those years and no relationship is apparent (Fig. 4). Actual yield (total pounds) vs. adult stock shows essentially the same picture.

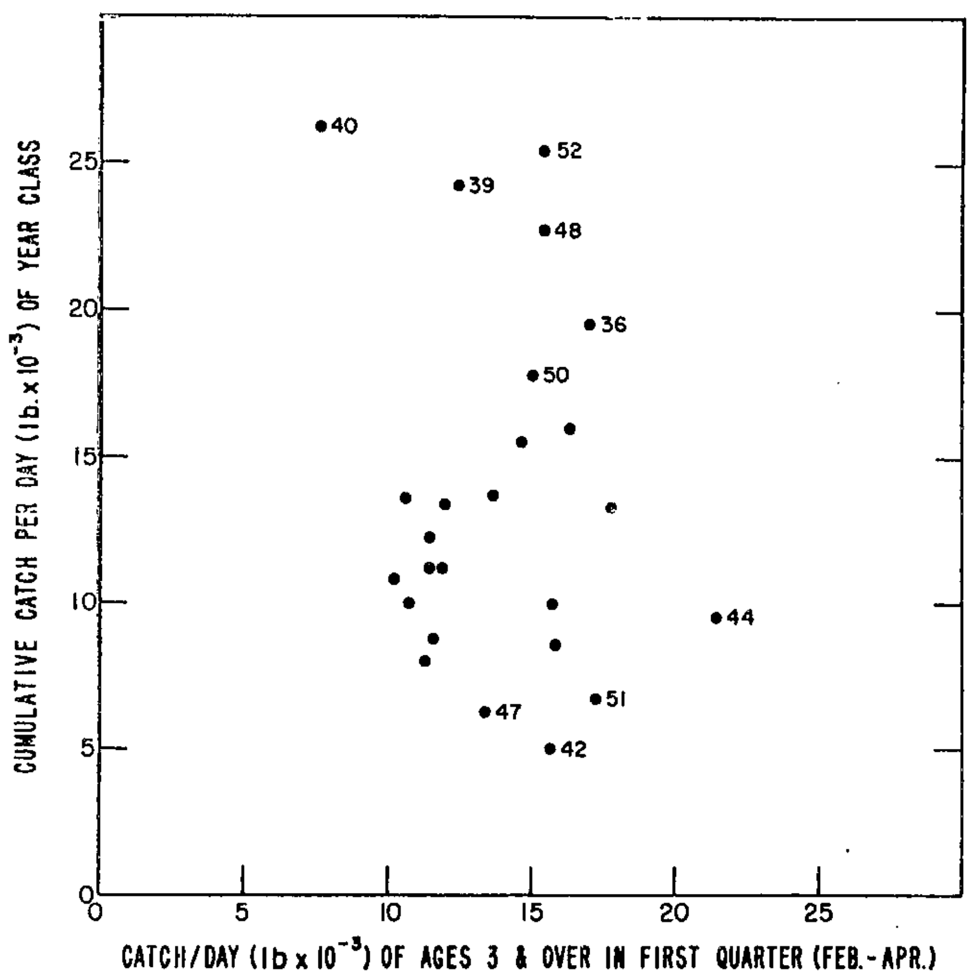

Fig. 4. --Spawning stock (first quarter landings per day of mature fish) vs. lifetime abundance index (cumulative landings per day at all ages) for resulting year class in years 1931-56. Numbers beside points represent year classes.

In conclusion, recruitment in Georges Bank haddock since 1931 shows no association with size of spawning stock. The pre-1931 data exhibit internal inconsistencies which casts doubt on their validity, and thus lead us to question the validity of the apparent stock-recruitment relation for the early years.

Since exploitation of Georges Bank haddock is expected to continue at least at its present level in the foreseeable future, there is little likelihood of an opportunity to observe large increases in the stock and the resulting effects on recruitment. Clues to the long-term dynamics of the population would be more likely forthcoming from studies of the early life history stages.

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