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Growth of immature herring in Passamaquoddy area - Bay of Fundy

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Introduction

Young, immature herring (*Clupea harengus* L.) - so-called sardines - support a major fishery in the Passamaquoddy Bay area-Bay of Fundy (ICNAF Division 4X). The fish appear first in the catch in late fall when they have just completed their first year of life, and dominate the catch in the following year. Each year, a new, easily distinguished year-class is recruited to the fishery, thus offering an excellent situation for studying the growth of young, immature herring in successive years.

Huntsman (1919), in a study of young herring in the area, reached a tentative conclusion that there were two groups of herring: spring-spawned fish which reached a length of 8.5 cm and 15 cm by the first and second winter respectively, and fall-spawned fish which reached 12.5 cm by the second winter. His study was based on the "Petersen method" of assigning ages to modes in length frequency distributions.

Parrish (MS, 1958) in a brief study of herring otoliths from Passamaquoddy Bay, noticed a difference in otolith structure between age-groups I and II, and questioned whether the age-groups present in any year were from a single population.

The aim of this work was to estimate the growth of immature herring (mainly age-group I) and attempt to identify different sub-populations on the basis of growth characteristics and size at recruitment.

Materials and Methods

This study is based on examination and analysis of 162 samples and 8200 pairs of otoliths from the period 1965-1968 (Table 1). The fish ranged from 75-220 mm in total lengths and from 0 to II years old.

Ages were estimated from the otoliths and each fish was assigned to an age-group. Age definition is based on the calendar year. Since the majority of fish are fall-spawned, a fish is considered of age-group 0 until the end of calendar year following its hatching. On January 1 of the subsequent year it is considered as age-group I.

Separation of theoretical normal distribution curves from polymodal monthly length distributions was attempted by plotting the cumulative frequency distributions on probability paper; the procedure is described by Harding (1949) and discussed by Cassie (1960).

As indices of growth, relative increments "C" and geometric (or instantaneous) growth rates "K" (Bryuzgin, 1963; Brody, 1964) were calculated as follows:

$$C = \frac{\ell_2 - \ell_1}{\ell_1}$$

and

$$K = \frac{\log_e \ell_2 - \log_e \ell_1}{t_2 - t_1}$$

where ℓ_1 and ℓ_2 are fish lengths at time t_1 and t_2 respectively.

Results

Plotting mean length at age against capture data on a time scale (Fig. 1) showed the general trend of growth. The relationship between length and time (month) for age-group I, which was well represented in all months, was obvious but it was difficult to determine the growth function due to variability in sample means.

Plotting monthly mean lengths of age-group I for successive months (Fig. 2) produced growth curves which were similarly concave upward though of different magnitude. In 1966, 1967 and 1968 sampling years (Fig. 2) growth was negligible from January to April and in 1965 from January to March.

Comparison of monthly growth increments showed that growth slowed down during the last quarter of each year (Table 2). In any year the increment of the last quarter was smaller than the increment of the previous quarter. Fluctuations in monthly increments (Table 2) and in monthly means (Fig. 2) reflected the polymodality of length frequency distributions of age-group I.

Separating the individual components which correspond to each of the modes in the polymodal length frequency distributions, and plotting the mean of each component at successive months (Fig. 3) produced growth curves which were similar to the curves produced from monthly mean lengths (Fig. 2). However three length groups appeared in all sampling years (Fig. 3). All curves were concave upward, indicating an increase in monthly growth rates until September, after which there was a tendency to a decrease in the last three months.

When monthly means were plotted on semilog paper (Fig. 4) the points were found to fit nearly rectilinear lines. This suggests that the changes in length are functions of length itself and the lengths of the fish at a given time would be represented by the growth equation:

$$\log_e \ell_t = \log_e \ell_0 + Kt$$

where ℓ_0 is the value of the variate at the beginning of the growth period, ℓ_t is the variate at the end of the period, and K is the geometric (or instantaneous) rate of growth.

The geometric rates of growth (Table 2) were found similar to the relative increments; each had the same fluctuations as the other. However, the geometric rate indicated a lower magnitude of growth as would be expected during the first years of life (Table 2).

Growth of fish of age-group I from different fishery districts was studied (Fig. 5). Data were grouped by quarters in order to minimize the fluctuations in the mean lengths. Fluctuations among districts and between quarters were distinct, and overlapping between quarterly means was obvious in some cases. None of the fishery districts tended to have fish of particular size.

Discussion

The present study confirmed Huntsman's (1919) conclusions that the growing season is from May to September. This differs from McFarland's (1931) findings that the season of growth extends into the winter.

Fluctuations in absolute monthly increments (Table 2) reflect the fluctuations in the monthly mean lengths (Fig. 2). This indicates the inadequacy of the use of monthly means in comparing monthly growth rates.

The polymodality of length frequency distributions of fish of the same age (age-group I) reflects the diversity of population elements exploited by the fishery. This is also evidenced in the wide variation in the sample means (Fig. 1).

The growth curves constructed from the theoretical normal curves of the polymodal length frequency distributions (Figs. 3 and 4) showed that at least three "size-groups" were represented in age-group I. The growth curves in all years of sampling were nearly parallel, indicating that these groups were growing at approximately the same rate. The consistency and similarity of the different growth curves in all years of sampling suggest that the differences have biological meaning. It is suggested that they are due to age differential resulting from spawning at different times.

Huntsman (1919) reported that both spring- and fall-spawned herring were found in the Bay of Fundy. However, the same author (1934) reported that spawning seems to be graded in time from early in the summer to late in the season.

Tibbo, Legare, Scattergood and Temple (1958) found "newly hatched larvae chiefly in September and October, and in some seasons hatching was extended into November and possibly into December ".

In such conditions, only the early-spawned part of the hatched larvae could metamorphose. The remainder, spawned late, may fail to metamorphose, and overwinter.

Das (1968) found that the length frequency distributions of autumn larvae were bimodal, and ascribed them to "broods" originating within the Bay. He also concluded that there was a continuous migration of post-larvae to the area during the spring.

Hence, the three size-groups which are shown in the growth curves (Figs. 3 and 4) may originate from herring which hatched in the summer-fall and the spring-spawning seasons respectively.

The fluctuations in the quarterly means (Fig. 5), and the overlapping of some of the quarters probably reflect the heterogeneity of the fishery and the free mixing of the size-groups among sampled fishery districts. This is in conformity with Graham's (1936) conclusion that "there is an apparent independence of the main stock from purely local conditions". He described the herring population in the area as an extensive body of herring in the more open sea touching the coast here and there.

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Table 1. Summary of herring samples.

Year	Number of samples	Number of fish: Passamaquoddy Bay	East Charlotte	West Iles	Grand Manan	Total	Percentage age I group
1965	30	350	450	300	450	1550	94.6
1966	34	400	800	200	300	1700	35.4
1967	51	900	1000	350	350	2600	66.7
1968	47	700	800	200	650	2350	82.3
Total	162	2350	3050	1050	1750	8200	69.8

Table 2. Herring length-growth and growth rates in four sampling years.

Increment in mm per month / Month	Sampling year			
	1965	1966	1967	1968
1	-	-	-	-
2	-0.9	-	1.8	0.4
3	2.8	-0.3	3.8	1.3
4	9.0	1.2	-11.4	-3.4
5	2.7	24.9	10.0	2.1
6	3.0	-7.3	3.0	9.7
7	2.9	24.4	7.1	-5.3
8	16.7	-0.3	23.5	16.6
9	0.5	19.4	11.0	21.1
10	3.3	2.3	3.8	9.1
11	14.0	10.3	9.3	7.4
12	-8.4	7.9	-	4.5
Increment in mm per year	45.6	82.5	62.1	63.6
Relative growth	.394	.803	.525	.528
Geometric growth rate	.333	.588	.423	.423

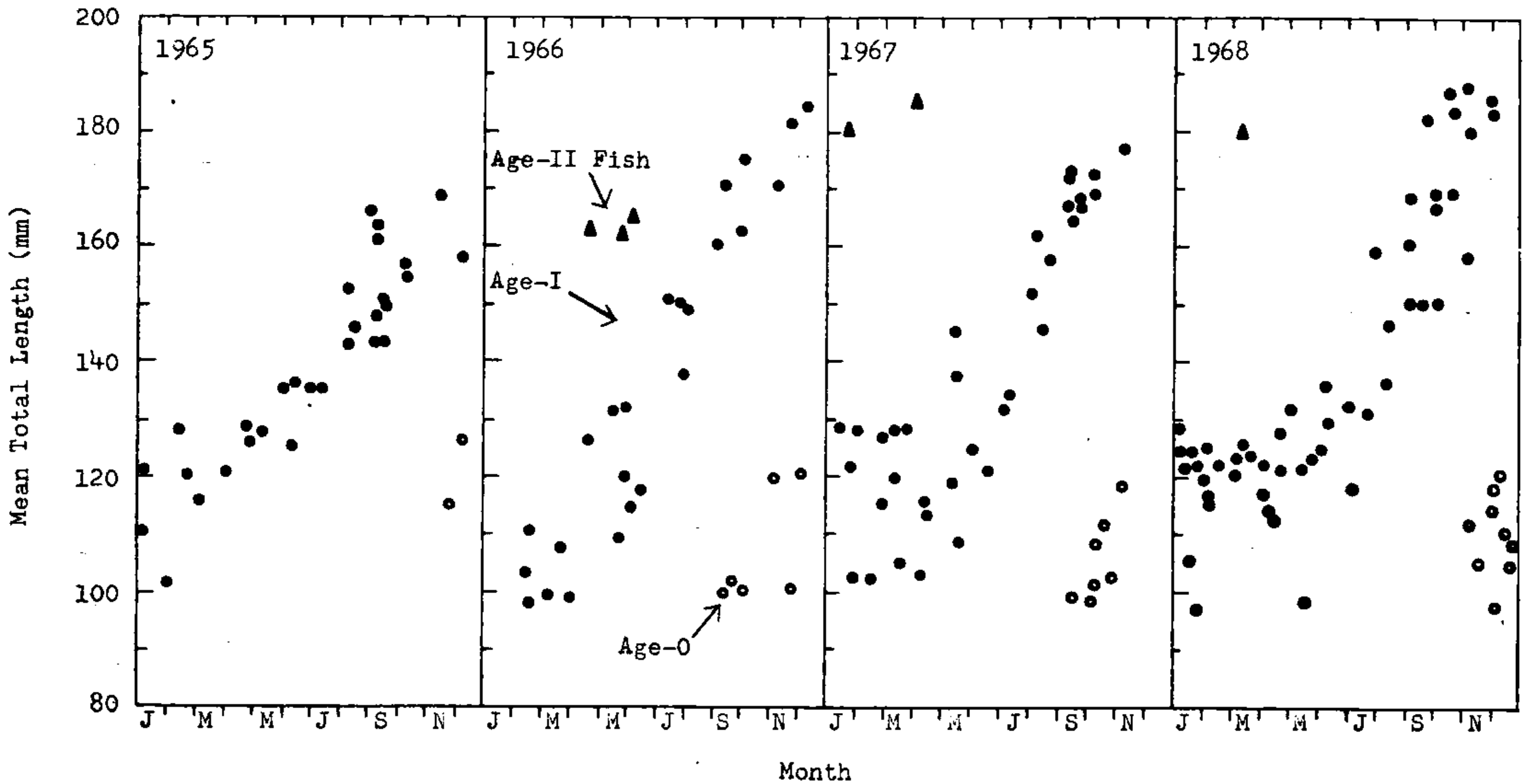

Fig. 1. Scatter diagram showing the relationship between mean length and capture date for four years of sampling.

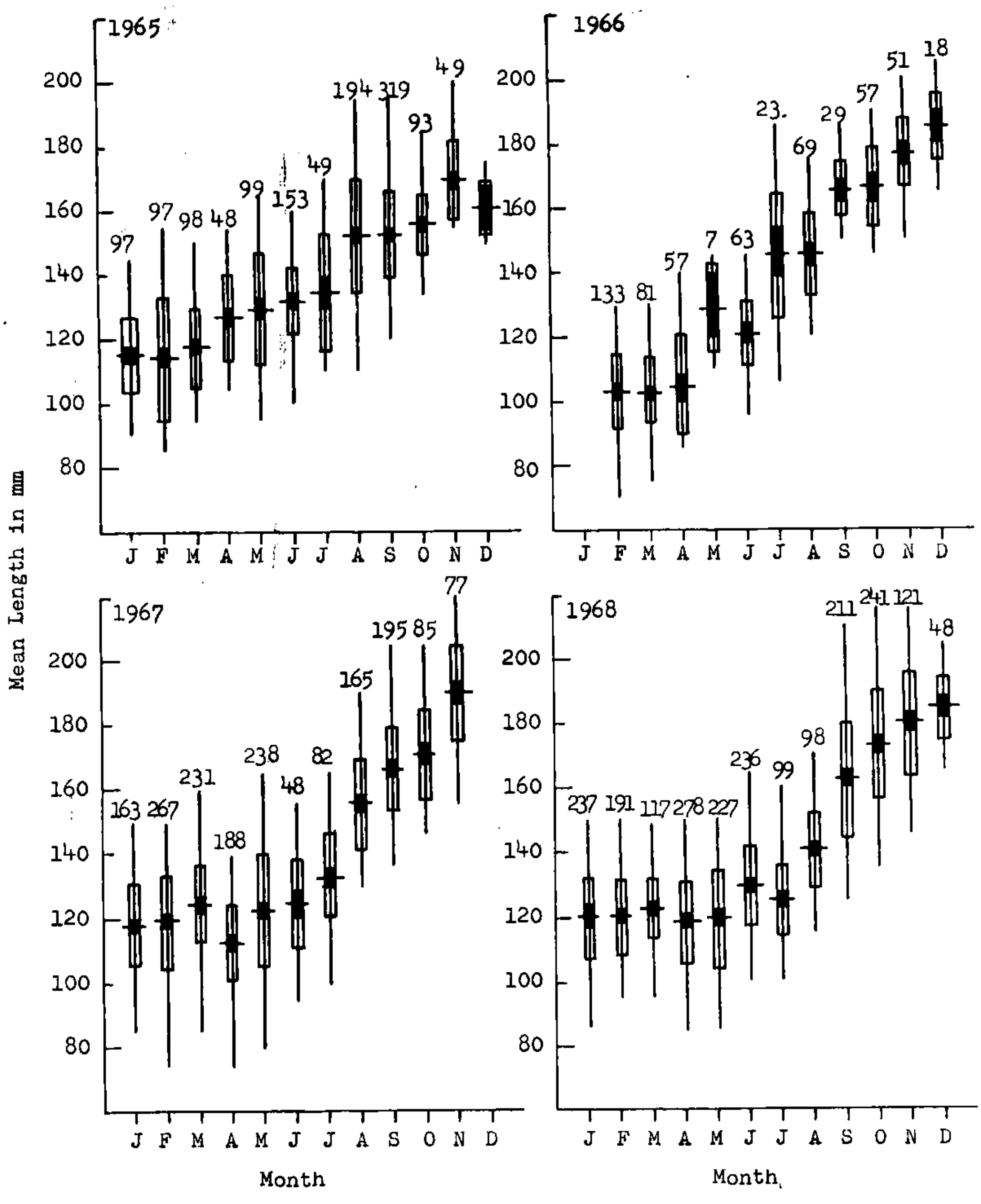

Fig. 2. Mean length by month of age-group I for four sampling years. Vertical lines show observed ranges of lengths; rectangles mark standard deviations with solid block indicating 2 standard errors from the means.

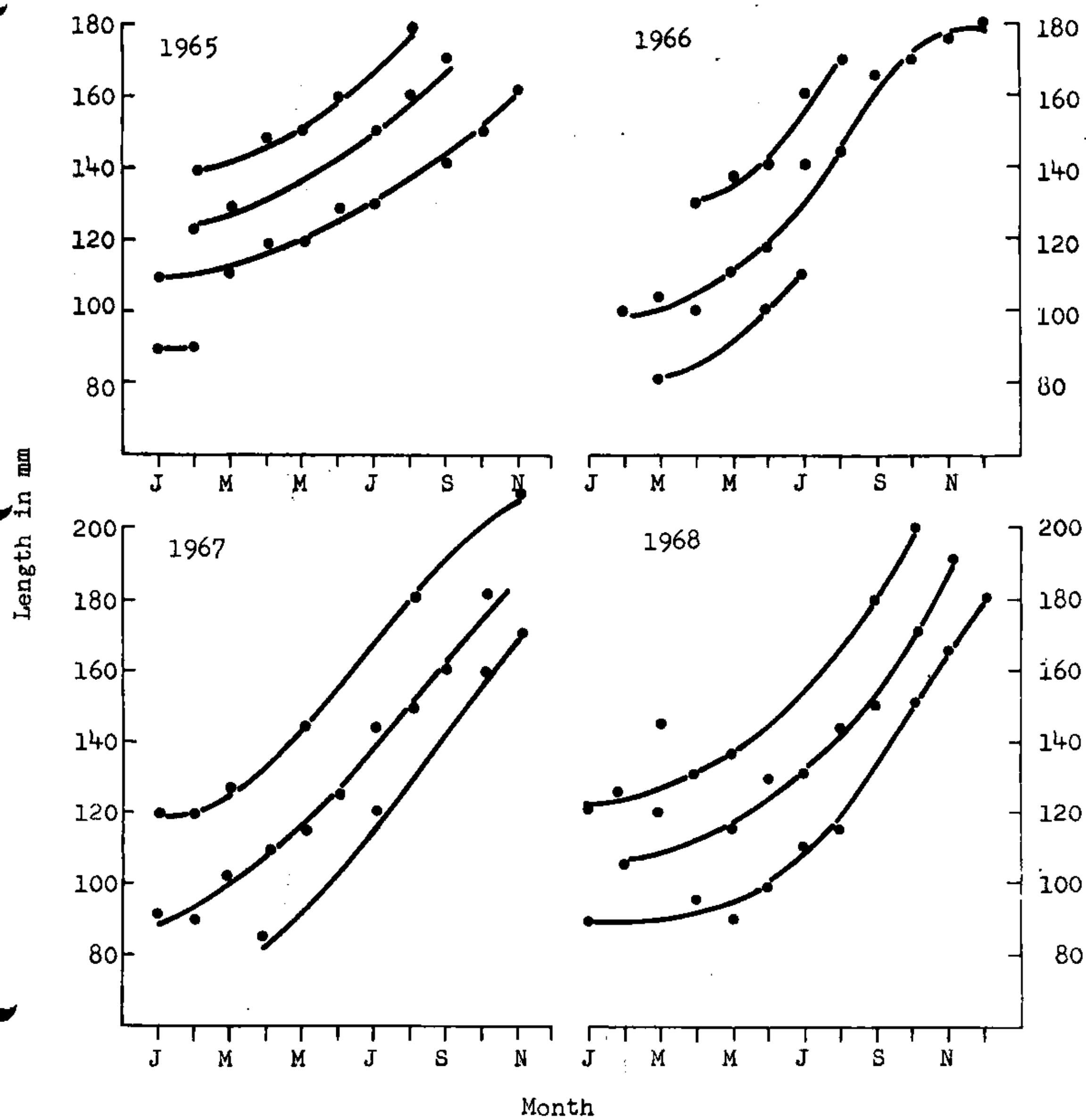

Fig. 3. Hypothetical growth curves of 3"size-groups" of herring within age-group I (Curves are eye-fitted).

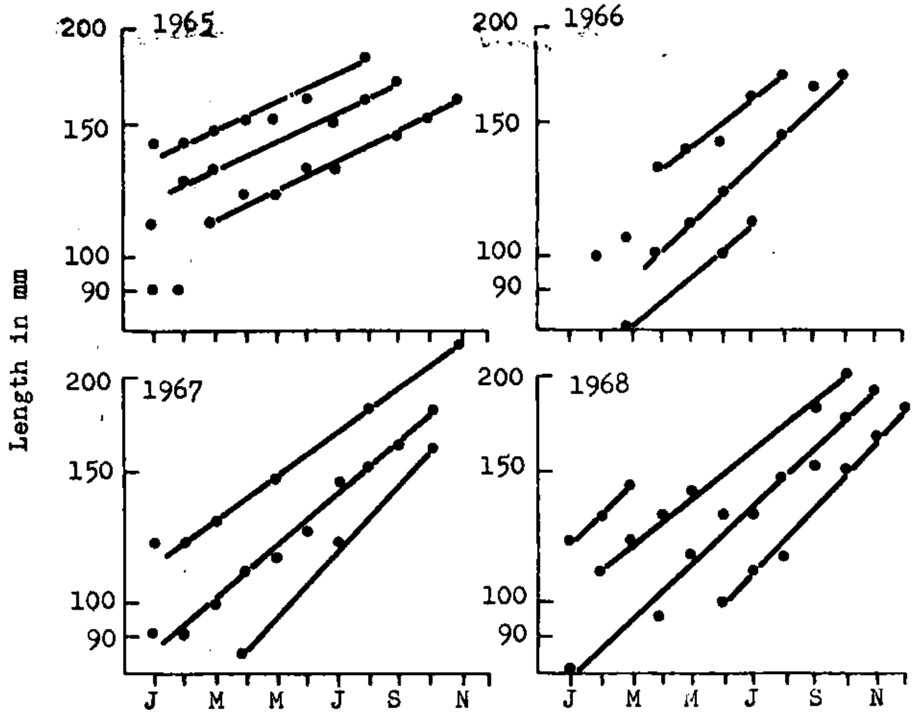

Fig. 4. The relationship of length to time (month) for different size-groups of age-group I (lines are eye-fitted).

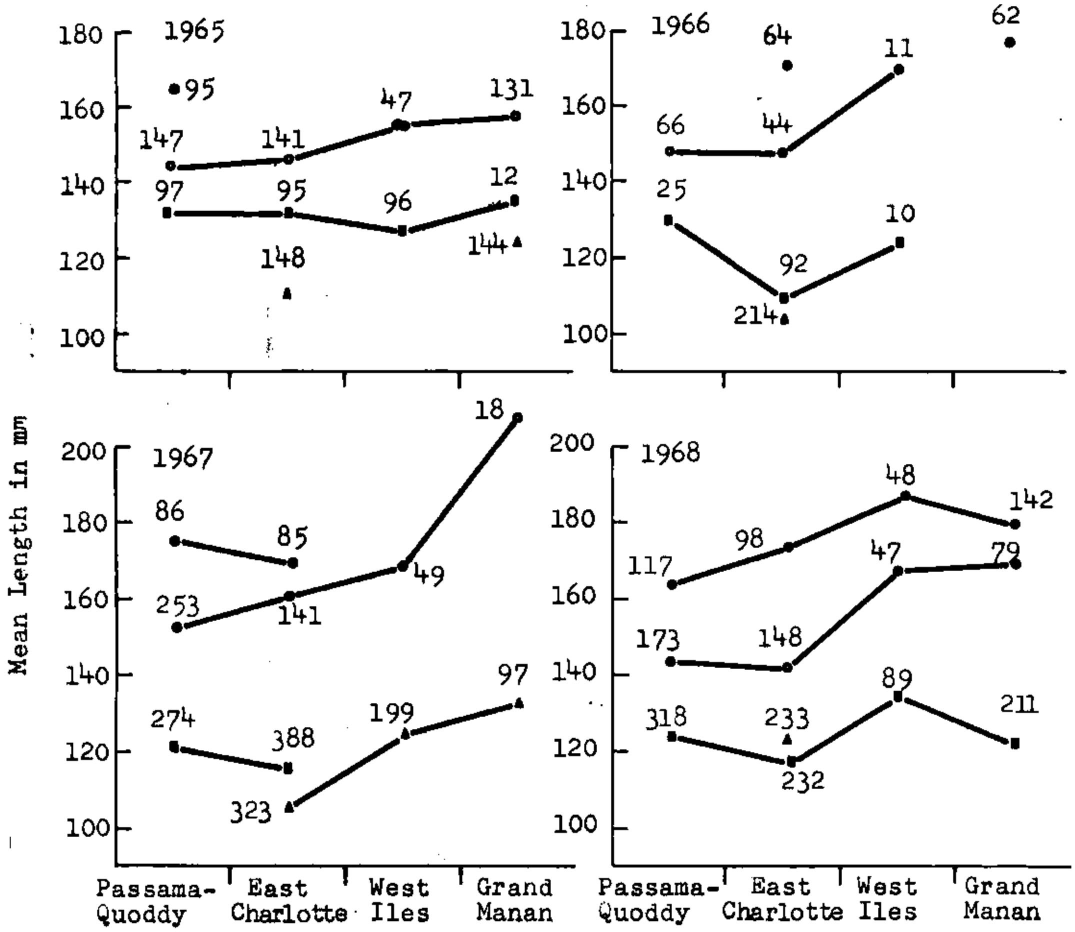

Fig. 5. Quarterly mean length of age-group I by fishery districts for four years of sampling (fish numbers are shown).

▲ 1st. quarter ■ 2nd. quarter

○ 3rd. quarter ● 4th. quarter