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BOUGHTON ISLAND, P.E.I., SCALLOP INVESTIGATIONS - 1946.

I INTRODUCTION

In the summer of 1946 the author was employed by the Fisheries Research Board with headquarters at the Atlantic Biological Station, St. Andrews, for a preliminary investigation of populations of the scallop (*Pecten grandis*) off the Maritime coast of Canada. The work was under the direction of Dr. J. C. Medcof and its primary objective was to decide whether there was any possibility of being able to forecast potential commercial catches. If this were possible the Fisheries Research Board could offer guidance to the industry toward more efficient exploitation of our scallop resources.

Although comparisons are sometimes drawn with other fisheries this report deals almost exclusively with the P.E.I. fishery on beds off Boughton Island. Besides a regular analysis of the stocks, it also treats a peculiar mass mortality which took place on the beds in 1946. The data and collections used were gathered between July 24 and August 5 from fishermen's records and on trips with three of the four boats which fished the grounds that summer. Analysis was undertaken at St. Andrews, at the Osborne Zoological Laboratory of Yale University, and at the University of Toronto.

I wish to thank Dr. Medcof to whom I am indebted for his invaluable suggestions and guidance throughout the course of the work and careful criticism of the writing of this report. I also gratefully acknowledge helpful suggestions made by Prof. G. E. Hutchinson of Yale during the first stages of the work, and by Dr. L. Butler of Toronto in analysis of the data, and wish to thank Mr. Horace Hewitt and Mr. Grant Graham, skippers of scallop boats, for their generous co-operation and assistance in making observations and collections.

II THE COMMERCIAL FISHERY

1. Beds Fished.

The commercially exploited scallop bed off the SE coast of P.E.I. is known as the Boughton Island Ground. It is about 3 miles long and 2 miles wide, centered 5 miles SE of Boughton Island. The bottom there is generally smooth and sandy but interrupted by rough sandstone ledges and some large rocks. Scallops are found in patches up to 500 yards square in 10-13 fathoms (20-26 meters) of water.

2. Vessels and Gear.

The boats used for fishing are usually from 45-60 feet long and built along the lines of Digby, N.S., draggers (fig. 1

and 2) though one, a converted Fairmile, used in 1946 measured 107 ft. Each boat carried a crew of two or three men besides the skipper and handled either one or two gangs of drags. Those boats towing only one gang use six to eight drags on a "drag bar", those towing two gangs use only five or six drags per bar (fig. 3).

The drags used at P.E.I. are essentially like the present Digby type although, as often happens in small fishing districts, modifications have been developed which the local fishermen believe are specially suited to their conditions. The frame of each drag (fig. 4A) is about 2½ feet long by 9 or 10 inches wide. To it is attached a bag 2½ or 3 feet deep composed of wire rings of 2 5/8 inches inside diameter fastened together by double washers (fig. 4B). The inter-ring spaces are about 2 5/8 inches long. The essential difference between the Digby and P.E.I. types is the addition of teeth to the latter along each of the long sides of the frame. When new, these teeth are spaced three inches apart and project about two inches from the frame. They are designed to prevent the drags from resting directly on the bottom and filling up too quickly with starfish, sea-urchins and small rocks.

A comparison was made between catches of drags whose teeth were almost worn off and those with new teeth. Both types were used in different arrangements on the same drag bar. Counts from several hauls showed that the amount of debris and number of small scallops taken by the "well-toothed" drags was considerably less than that taken by the other though catches of commercial-sized scallops were not appreciably different. Unfortunately the data supporting this conclusion were not preserved.

In 1945 an eleven-foot "deep-sea" drag like those in use on Georges Bank was tried on the Boughton Island beds by a commercial fisherman, Mr. Horace Hewitt. He reports that the bottom was so rough that the drag was often fouled in rocks and ledges and quickly ruined. Most fishermen agree that on rocky or irregular bottom the arrangement of several small drags on a long drag bar is the best known. They believe it has the double advantage that: 1) short individual drags enter and scrape smaller depressions in the bottom, and 2) since the drag bar and chain puts a heavy weight ahead of the drags themselves, they tend to "dig-in" better at relatively high towing speeds.

3. Fishing Operations.

Since the scallop grounds are only about ten miles from the home ports, Lower Montague and Georgetown, the boats return to port at night and leave for fishing again about four a.m. Dragging begins at about 6 a.m. or shortly after daylight and continues until about 7 p.m.

Standard tows are of 20 to 30 minutes duration. The method of "putting over" the drags is different from the Digby procedure. In P.E.I., the drags are hoisted clear of the deck, shoved outboard (fig. 5A) and lowered away until the top of the

Fig. 1

Fig. 2

Two views of the M.V. "Winnie Anne", a dragger used for scalloping at P.E.I. in 1946.

Fig. 3

Disposition of winch, cables, tow-bars and chains on the M.V. "Winnie Anne".

Fig. 4A

P.E.I. type scallop drag with teeth along the sides of the frame. The teeth on this particular drag are worn somewhat and shorter than on the drag to the right.

Fig. 4B

The mesh of commercial scallop drags showing arrangement of rings and washers.

Fig. 5A

P.E.I. method of "putting over" the scallop drags on the M.V. "Robert H." Drags are lowered from the boom.

Fig. 5B

Drags on M. V. "Terraplane" of Digby, N.S. ready to be "put over". Drags are merely tipped over the rail and fall with their own weight. Note the check rope around the drag bar.

tow chains is level with the gunwhales. The gear is secured there by a twist of rope until the hoist pulley hook is slackened and removed and the tow cable has been entered in the "quarter block", a guide bracket on the stern. The drags are then freed by letting go the twist of rope and run out to bottom as the boat gets up speed.

At Digby (fig. 5B) the men lean the drags, mouth downward, against the gunwhales with the edge of the frame on the rail and the bag hanging inboard. At the same time they secure the gear by a twist of rope around the center of the drag bar. The next step is to tip the drag bags overboard starting from the center one and working towards the ends. When the end drags have been tipped over the whole rig is let go by slacking off the twist of rope which until now has born the strain of keeping the drags aboard. The weight of the drags is great enough to pull the drag bar overboard and the whole gear runs to bottom as the boat gets up speed. Before the cable has been fully run out it is caught up by a hook and put through the stern quarter block. Although the Digby method is more hazardous to the men because the balance of the gear is easily upset, an experienced crew can get the drags overboard much more rapidly and with less effort than by following the P.E.I. method.

While a tow is being made the men pick up the scallops from the pile left on deck from the dumping of the previous haul, shovel the debris overboard and shuck out the meats. Figure 6 illustrates shucking.

4. Shucking methods.

The shucking procedure has three stages.

(A) The scallop is held in the left hand with the hinge in the palm and the flat left valve toward the shucker (fig. 6A). The shucking knife, held in the right hand, is inserted forward and upward along the inner face of the flat valve, being entered just above the right-hand corner of the hinge. The blade is than forced backward and downward and toward the operator in a semi-circular motion so as to sever the attachments of muscle and viscera to the flat valve.

(B) In the next step (fig. 6B) the point of the knife is hooked downward and away from the operator under the thick muscular mantle edge. The thumb is then pressed against the shell thus clamping the mantle edge between it and the knife. By lifting upward and toward the operator, the shell and the whole of the viscera ("rim") comes away leaving only the adductor muscle attached to the cupped valve in the right hand.

(C) This muscle is then scraped off into the shucking pan (fig. 6C).

Shucking

Fig. 6A

Knife inserted along left flat valve to sever muscle connections.

Fig. 6B

The mantle edge is then caught by the knife and the left valve and the rim are removed together.

Fig. 6C

The adductor muscle, which remains on the right valve, is scraped off into the shucking pan.

A F. E. I. type shucking knife shown here.

When the shucking pan is full the meats are dumped into a pail of salt water and rinsed to remove bits of shell and sand. From this they are transferred to a large cask (one-tierce size) which is kept on deck. To prevent heating of the close-packed meats in the hot summer sun, cool sea water is poured into the cask with them. More water is added as the catch increases and it may be partly changed during the day. Upon landing (about 9 p.m.) the meats are taken by truck to the freezing plant at Montague some five miles away. In warm weather this handling method permits some deterioration but apparently it is not serious enough to reduce quality to below the standards required by inspecting officers of the Departments of Fisheries and National Health and Welfare.

During the summer it was reported to the writer that a local cannery was attempting to can and market scallop "roes" (ovaries). Nothing further is known but such efforts are to be commended and encouraged. In summer the roe has about the same volume as the muscle and people at Digby and P.E.I. who have eaten roes say they are very tasty. At present, however, they are considered waste and thrown overboard.

III POPULATION STUDY

1. Sampling.

During the dragging operations on the Boughton Island ground representative samples of commercial catches were measured to study the size- and age-composition of the fished population. Entire catches of one or two drags from several different hauls, by different boats, and on different days were used as samples and the heights of all living scallops in these samples were recorded. The compilation of these measurements is considered adequate to represent the actual size distribution of the population which was sampled by commercial drags.

To sample smaller-sized scallops than those regularly taken in commercial drags, a specially built drag with "cow-chain" mesh (about one inch inside diameter) was attached to the drag bar in place of one of the regular drags. Several tows were made with this arrangement and in such cases every living scallop from the catch of the small mesh bag was used for a sample.

For recording the size (height) of scallops a measuring board (fig. 7) was used. The base measured 12" x 8" x 1" and the upright along one end, 8" x 2" x 1". A sheet of transparent celluloid 6" x 8" was pinned to this board with one edge against the upright. Scallops were placed on top of the sheet with the straight, hinged part of the shell against the upright, that is, in line with the edge of the sheet. A hole was then punched with a needle at a point on the sheet just at the edge of the shell opposite the hinge (fig. 7B). The distance from the edge of the celluloid sheet to the punch hole thus equals the shell height of the scallop measured. The heights of 200-300 scallops can be conveniently recorded on one such sheet.

Fig. 7A

The measuring board with celluloid "punch card" attached.

Fig. 7B

Recording height of a scallop.

The distribution of heights of scallops in the sample was easily determined later by placing the sheet of celluloid over a sheet of paper ruled at desired intervals and then counting the numbers of holes between each pair of lines. This system has the advantage that is is possible for one worker to rapidly obtain accurate measurements of large numbers of animals without interfering seriously with the work of the crew and the record sheet is not defaced by the unavoidable mud and water.

2. Size Composition of the Catch.

The size composition of the catch of commercial drags is represented by figure 8A and that of the small mesh drags by figure 8B. The fact that the size composition of that part of the catch larger than 85 mm. of both commercial and small mesh bags is practically the same supports the hypothesis that scallops larger than the largest inter-ring spaces (fig. 4) of the nets (larger than 85 mm.) are caught in proportions representing their actual relative frequency in the population. Sampling by the small mesh bag (fig. 8B) may supply us with accurate information on the relative abundance of yet smaller size classes in the population.

Judging from the mesh size and from dragging tests conducted in 1949 and 1950 in the Digby area of Nova Scotia it should quite accurately sample the population down to at least the 40 mm. size class. It appears that the great majority of scallops smaller than this that are taken into the drag must escape through the mesh of the net.

Although no statement can be made about the relative abundance of animals smaller than 40 mm., we may conclude, from the sampling of the P.E.I. population (fig. 8A and 8B), that there were relatively few scallops of the 40-60 mm. and 90-100 mm. size classes and that those larger than 125 mm. were rare. However there are modes in the distribution curves at 60-65 mm., 85-90 mm., and 100-105 mm.

The regularity in the spacing of these modes immediately suggests the possibility that they represent "strong" year classes in the population and that the spaces between represent either "weak" year classes or occur at sizes which are intermediate between the average sizes of consecutive year classes. To criticize this view a study was made of growth rates based on interpretation of shell annuli.

3. Measurement of Shell Annuli.

It was possible to determine the positions of annuli on 120 of the 139 shells preserved from the August 1946 Boughton Island catches. The diameter through the umbone of each of the several annuli was measured to the nearest millimeter with jaw calipers. The first clear annulus next the umbo was con-

sidered as having been formed during the animal's first winter. The measurements (see appendix) were then grouped into half centimeter size classes and summarized in Table 1. These data, giving a measure of the average height of scallops at the time of formation of each annulus, permit the inclusion of an "age scale" on the abcissa of figure 8 in which age is expressed as the number of annuli on the shell. To determine actual age about one-half year should be subtracted from the given age because spawning occurs in late summer and the first annulus is formed when the animals are a few months old.

4. Age Composition of the Stocks.

With this information on diameter of shell annuli added it will be seen from figure 8 that the modes in the size-frequency polygon occur at sizes which correspond to the mean sizes of 4-, 6- and 8-year-old scallops. The small numbers found from 40 to 60 mm. in the small mesh catches (fig. 8B) must be taken as an indication of a scarcity of 3-year-olds. Comparison of the size composition of commercial with small mesh catches shows that the 5-year-olds were well represented in the population even if not common in commercial catches and it must be concluded that commercial drags are not effective samplers of the stock less than six years old. From the depression in the size distribution of catches of both types of drags at about 95 mm. it appears that 7-year-olds were not well represented in the population.

The scarcity of scallops in this 7-year age class may be the result of:

1) Poor reproduction in 1939.

2) Heavier early mortality than in other year classes.

Heavy fishing mortality would not account for it because the 7-year-olds were less exposed to the fishery than the 8- or 9-year-olds, both of which were more abundant.

An examination of an unusual mass mortality which occurred in 1946 (see Section V of this report) showed that the 7-year-olds were not more susceptible than others of the fished population. It is concluded therefore that the relatively low abundance of the 7-year age class in 1946 was the result of a small spawning in 1939 and/or a heavy "infant" mortality after they were spawned. Similarly the scarcity of 3-year-olds must be the result of a poor brood from the 1943 spawning.

5. Growth Studies.

a. Comparison of P.E.I. with Other Populations: The average yearly growths of scallops from P.E.I., calculated in Table 1, were plotted (fig. 9) and compared with those for

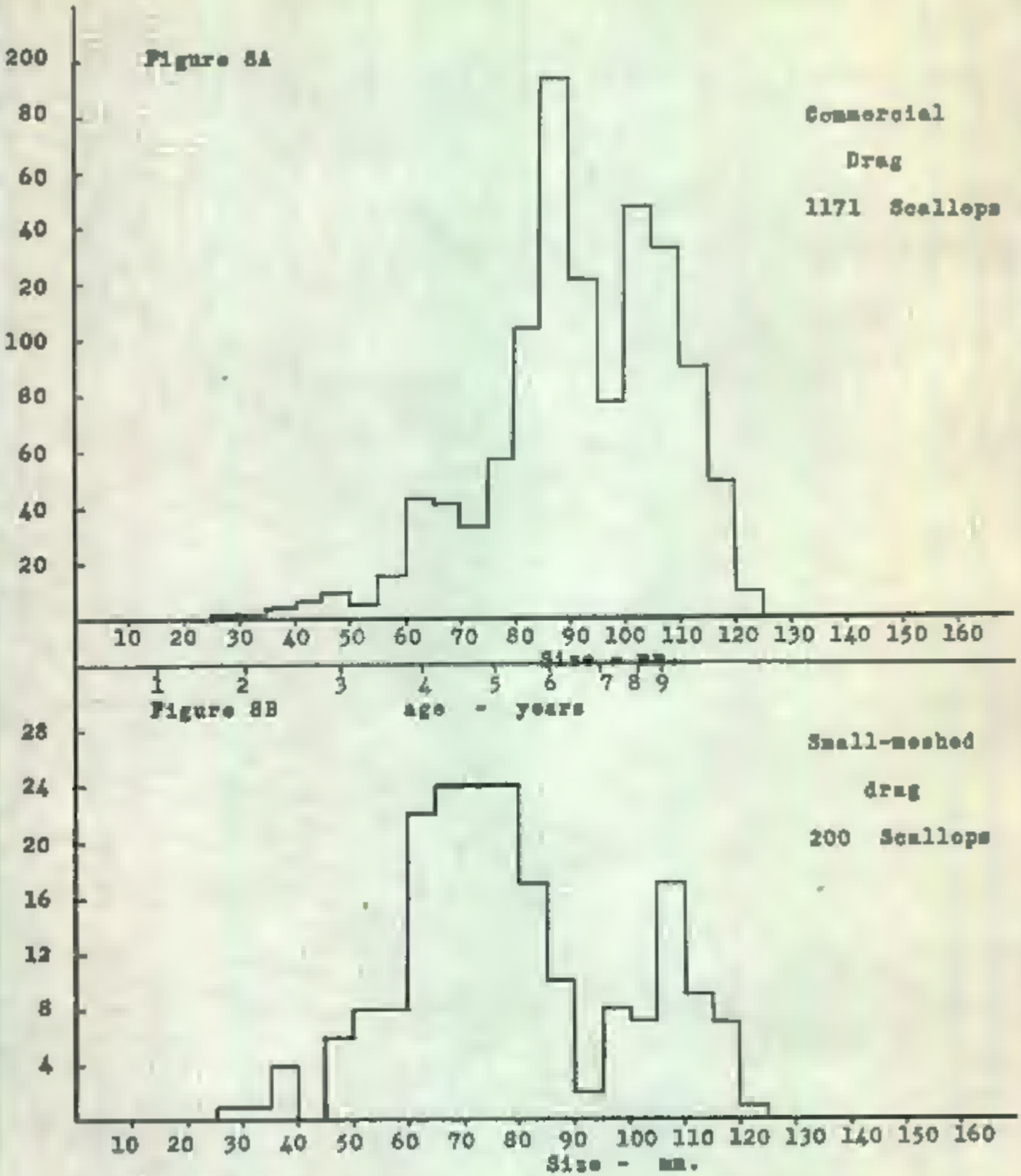
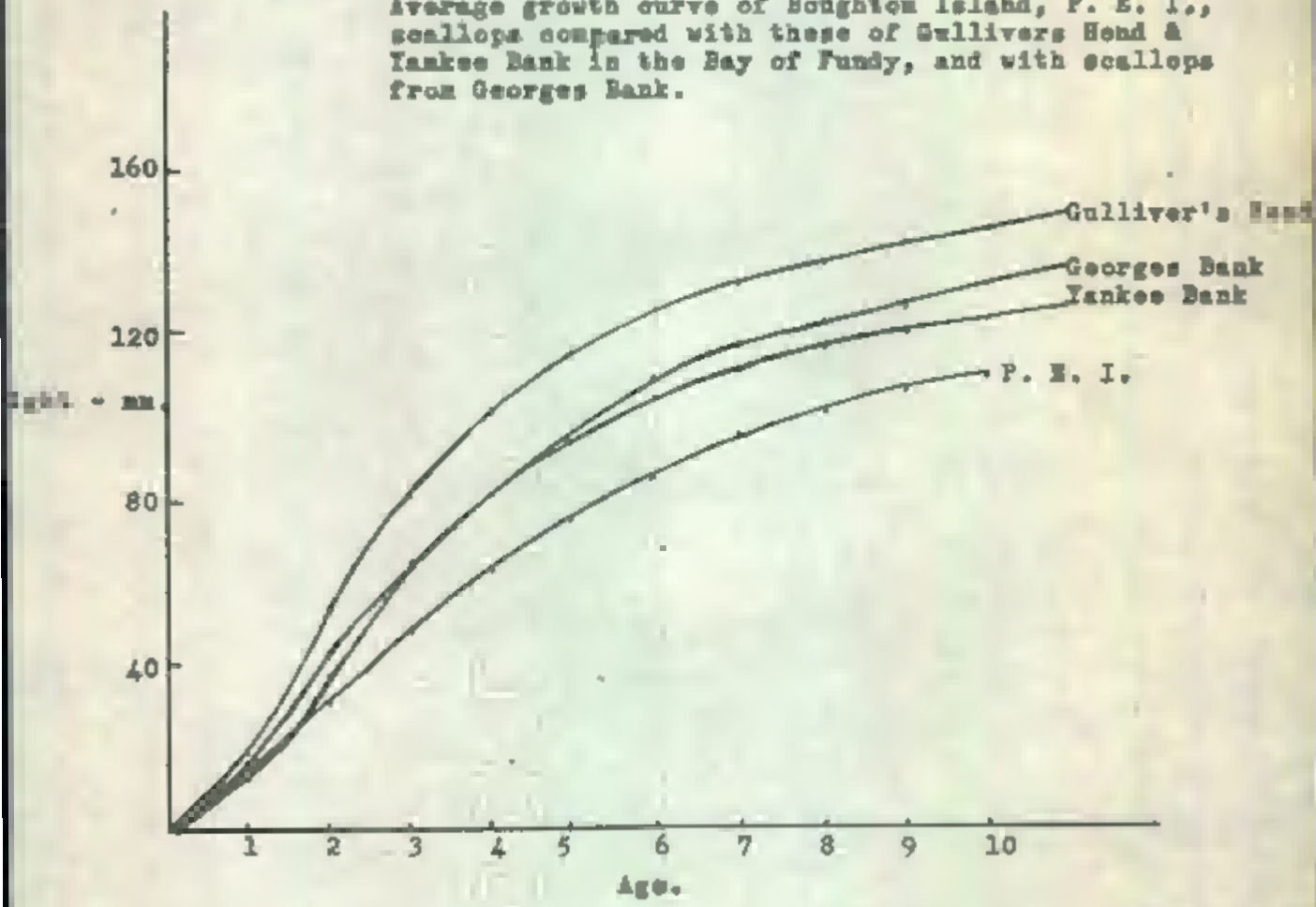


Figure 8: Size frequency distribution of 1946 samples of P. E. I. scallops from Boughton Island bed.

Figure 9.

Average growth curve of Boughton Island, P. E. I., scallops compared with these of Gullivers Head & Yankee Bank in the Bay of Fundy, and with scallops from Georges Bank.



scallops from Georges Bank, Yankee Bank and Gullivers Head. It appears that P.E.I. scallops have the slowest growth in early life and the smallest ultimate size of all.

Previous students of molluscan growth, notably Weymouth and co-workers (1930 and 1931) have found that for any species the stocks growing in southern warm-water regions generally have a faster growth in early years of life but a smaller ultimate size than those in northern, cold-water regions. Scallops appear to be an exception to this generalization. The P.E.I. scallop beds are farther north geographically than those on Georges Bank or in the Bay of Fundy but the water over them is shallower and in summer gets considerably warmer than in the other localities. They are, hydrographically speaking, further south. Their small ultimate size accords well with Weymouth's generalization but we should have expected them to show a relatively faster early growth if they are to be in complete accord with other shellfish studied.

There are several possible simple explanations for this apparent exception:

1) The growing season may be too short. It seems, however, that this should lead to a slow but persistent growth rate per year and large final size.

2) Summer water temperatures may be so high that they deter growth. Our species of scallop is primarily a cold-water animal.

3) There may be some factor other than temperature which is also important in determining how much scallops will grow. For instance, along the Maritime coast they are always found in places where there is a rapid flow of water. Possibly growth is limited by the amount of food and oxygen supplied by the flow of water and at P.E.I. this supply may be so low that it restricts growth within the range which is potentially possible under existing temperature conditions. Certainly surface currents there are the slowest of those found in the four localities under consideration as figures on current speeds entered on marine charts clearly show.

It is likely that any intensive analysis would show that the above attempts to explain peculiarities of the growth curves are oversimplified and that an interplay of factors is involved, several of which may be important.

In proffering these explanations it has been assumed that all the animals with which we are dealing are capable of responding in the same way to a similar environment. This assumption is not unreasonable since hydrographic conditions in the four localities do differ considerably. However, it should be kept in mind that the scallop population at P.E.I. has probably

been separated from those in the Bay of Fundy during most of the "Recent" period, geologically speaking. This being the case, genetic differences may be present which give rise to differences in the response patterns. The importance of this possibility can not be overlooked and should be checked by laboratory rearing of the different stocks under known conditions before any exhaustive comparison of growth in different areas is undertaken.

b. Year-to-year Growth Variation at P.E.I. The animals found in any one locality such as Boughton Island may be quite reasonably expected to have similar genotypes and therefore successive year classes should respond similarly to the same environmental conditions. But since no two year classes are likely to encounter identical environments a comparison of growth among different age groups in different years may provide information about the influence various environmental factors have on growth.

The growth data for the 1946 Boughton Island scallop collections appear in the appendix to this report and are summarized in table 2. Vertical columns give the average size (height) of animals of different ages at the beginning of each year as well as the average growth which took place during those years. Rows give average size and increase in size of animals of the same age in different years. Each diagonal row gives the growth history of a year class. From these data figure 10 has been constructed which gives the average growth curves for each year class sampled. The solid lines represent the average size of year classes at each age throughout their life history. The broken lines represent average sizes of animals of the same age in different year classes. As we might expect, each of the growth curves shows a similar pattern, though there are minor differences in size among different year classes at any one age. It is these minor differences that are of special interest in our study of the factors influencing growth.

(1) Analysis of Growth Data: An analysis of growth variation has been carried out in some detail. Two different methods (Hile, 1941, and Brody, 1947) are described in the following section and their application to the scallop data is discussed with a view to obtaining the most accurate indices possible for comparison of growth in different years in the light of known environmental conditions.

Hile's method consists of the comparison of the average percentage change in the size of animals of all age classes in one year with that in the next year and was first used to compare growths of rock bass in different years using data similar to that we have on scallops. Details of the calculations on which comparisons are based are described in the next few paragraphs.

The data in Table 2 show that in 1937 scallops-of-the-year grew an average of 13.0 mm., while one-year-olds grew an

e beginning of
e during that
ge (1936 to 19
ugust 1946.

	Average Siz	
	1938	19
	e Growth	Size
0		42.0
3	15.7	29.5
0	16.5	13.0
	13.0	0
	45.2	

average of 13.0 mm., while one-year-olds grew an average of 12.0 mm., a total growth for these 2 age classes of 25 mm., for the year. In 1938 the growth for the same two age groups totalled 29.5 mm. The difference between the 1937-1938 growths is 4.5 mm. which can be expressed as a percentage of the mean growth of 27.3 mm. in the two years, i.e., 16.5%. Following Hile's method for analysis these figures are entered as the first column of table 3 and the remaining columns are calculated in the same way, except that data were available for three age groups in the 1938-39 comparison, for four in the 1939-40 comparison and so on.

From 1942 to 1945 only the data for the first seven age groups (0-6-year-olds inclusive) were used in the calculations even though measurements from older scallops are available. The reason for this will be discussed later.

The percentage changes in growth from one year to the next (listed in the last column of table 3) were then used to compare the growth in each year with that in 1937. For instance, in 1938 the growth was 0.0 + 16.5 = 16.5 percent greater than that of 1937; 1939 growth was 0.0 + 16.5 - 3.8 = 12.7 percent greater than that in 1937, and so forth. These figures are tabulated in the first row of table 4. However, the mean of these growth changes was 15.8%, which means that the 1937 growth must have been 15.8% below the general mean for all years, rather than 0.0% as assumed by the preceding calculations. It is necessary, therefore, to subtract 15.8% from the percentage growth in each year to determine the percentage deviation in average growth for each year from the general mean of the 1937-1945 period. These figures are tabulated in the second row of table 4 and are presented graphically in fig. 11.

The curve in fig. 11, representing the first estimation of the percentage deviation of annual growth from average, indicates that growth in 1937 was relatively the poorest of the period. It improved rapidly in subsequent years to a maximum in 1941, and was progressively poorer again in the next three years with a final improvement in 1945. However, a detailed examination of the original growth curves in figure 10 shows that, although these results may be useful for making general comparisons of growth, detailed conclusions should not be drawn from them without considering the limitations of the method when applied to our scallop data.

The first limitation will appear from a consideration of the variability about successive points used to arrive at the growth curves of fig. 10. It was pointed out earlier that the growth curves for each of the several year classes had a common pattern. The more complete ones are sigmoidal starting at some point below the range of measurements and approaching a maximum which is the same for all year classes. This asymptotic nature of the growth curves inferred from the relationship between average height and age is illustrated more strikingly by table 5 data

Table 3. Calculation of percent change in accumulated annual average growth (mm.) of P.E.I. scallops from one year to the next from 1937 to 1945. All available age groups (see Table 2) are used for all comparisons up to 1941-42. Beyond this, comparisons are restricted to the 0-6 year age groups.

Years involved in comparison	Average growth to end of earlier year	Average growth to end of later year	Mean	Difference	Difference as a percentage of mean
1937 and 1938	25.0	29.5	27.3	4.5	16.5
1938 and 1939	45.2	43.5	44.4	-1.7	-3.8
1939 and 1940	61.2	66.5	63.9	5.3	8.3
1940 and 1941	82.2	86.9	84.6	4.7	5.6
1941 and 1942	97.5	89.7	93.6	-7.8	-8.3
1942 and 1943	97.3	97.9	97.6	0.6	0.6
1943 and 1944	97.9	90.6	94.3	-7.3	-7.8
1944 and 1945	90.6	96.5	93.6	5.9	6.3

Table 4. Percentage change in total annual average growth in each year compared with that of 1937 and that of the general mean for 1937-1945.

	Year								
	1937	1938	1939	1940	1941	1942	1943	1944	1945
Percent change in growth compared with growth in 1937	0	16.5	12.7	21.0	26.6	18.3	18.9	11.1	17.4
Percent deviation in growth compared with general mean of 1937-1945	-15.8	0.7	-3.1	5.2	10.8	2.5	3.1	-4.7	1.6

Table 5. Within-year-class size-ranges for scallops in the 1936 to 1941 year classes in August 1946 samples from Boughton Island, P.E.I.

	3 1935 year class scallops			4 1937 year class scallops			5 1938 year class scallops			11 1939 year class scallops			18 1940 year class scallops			22 1941 year class scallops		
Age	Min. Size	Max. Size	Range	Min. Size	Max. Size	Range	Min. Size	Max. Size	Range	Min. Size	Max. Size	Range	Min. Size	Max. Size	Range	Min. Size	Max. Size	Range
1 yr.	11	17	6	12	15	3	4	19	15	6	19	13	5	19	14	6	21	15
2 "	21	31	10	27	32	5	16	34	18	19	42	23	18	44	26	18	42	24
3 "	33	53	20	43	48	5	44	51	7	33	60	27	35	69	34	32	59	27
4 "	52	74	22	58	69	11	61	69	8	51	77	26	50	83	33	58	73	15
5 "	66	93	27	72	83	13	75	87	12	64	87	17	60	92	32	60	83	23
6 "	79	100	21	83	97	14	85	92	7	77	97	20	71	100	29			
7 "	86	105	19	93	101	8	92	98	6	79	103	24						
8 "	92	109	17	98	106	8	99	106	7									
9 "	97	113	16	104	112	8												
10 "	101	114	13															

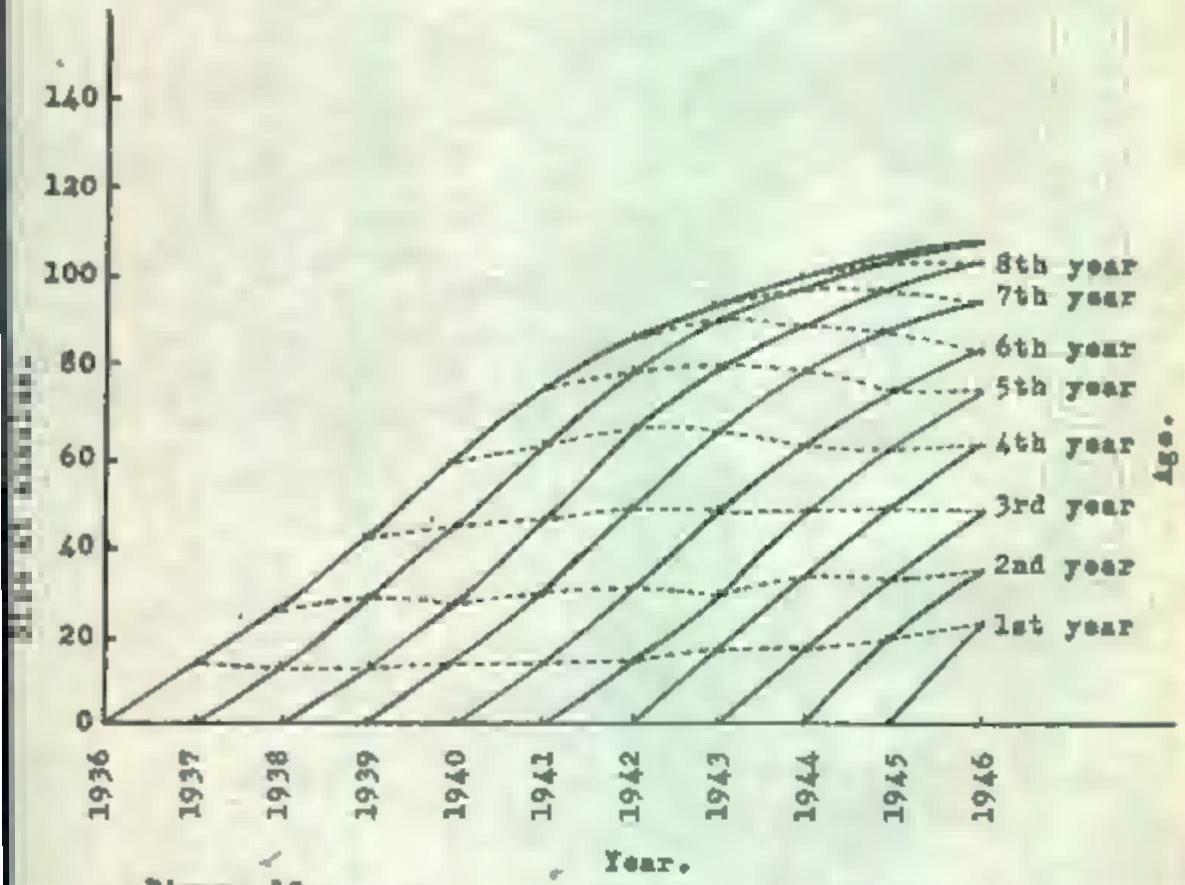


Figure 10.

Growth curves for each year class of scallops from 1936 to 1945 up to year 1946. Solid lines represent growth curves; broken lines show height attained by animals of different year classes at the same age.

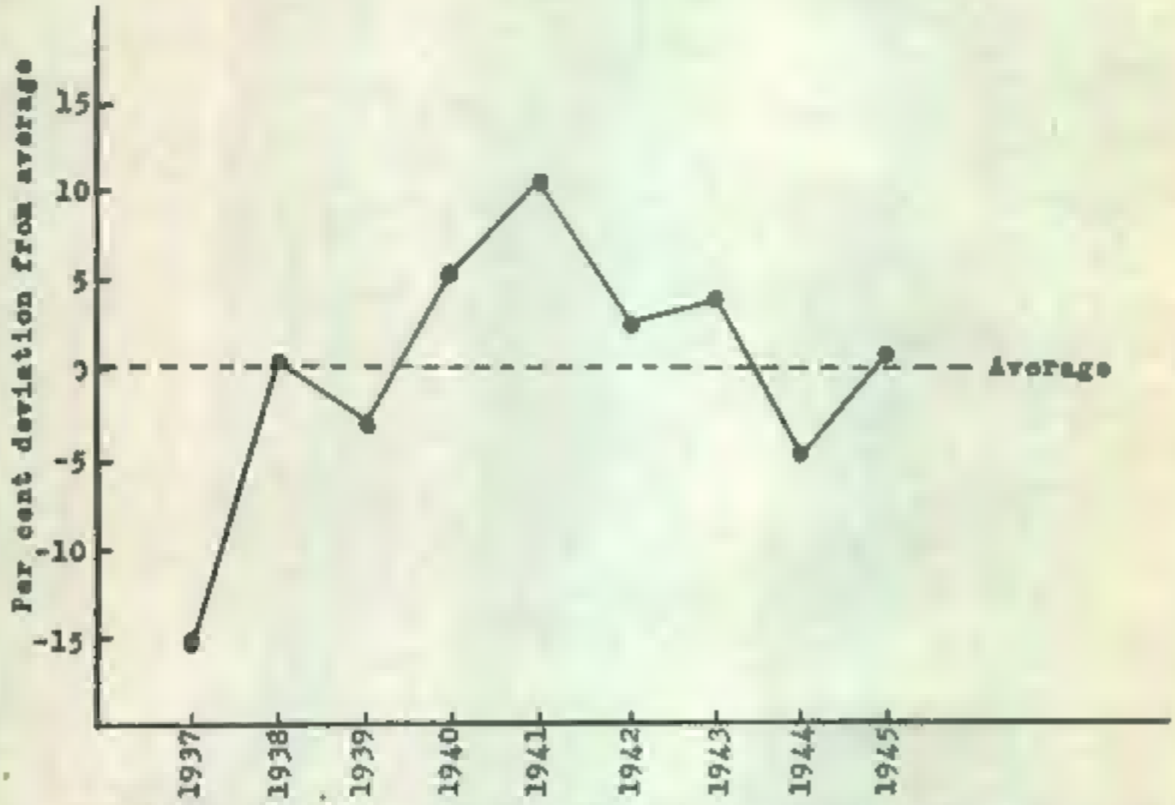


Figure 11. Per cent deviation of annual average growth of all year classes of Boughton Island scallops from average for the period 1937 - 1945.

showing the limits of the size range of the 1936-1941 year classes at different ages. The range increases each year during early life, reaches a maximum about the fifth year and thereafter decreases with age. That is, variation in size in early years diminishes in later life so that animals tend towards a common upper size limit.

If we are to divide all factors influencing growth into internal genetic and external environmental factors this pattern of variability about the mean size at successive ages must mean that the internal genetic factors which exist in all animals of a species, giving to that species its peculiarities of growth, must operate only within wide limits in early life, but must become progressively more important in controlling the amount of growth as the growth capacity of the animals is more nearly realized. If this interpretation is correct it immediately leads to the converse statement that if environment has any measurable influence on growth this influence will be most important in the early years of life. In a study of the influence of environment on growth, then, observations are more likely to be instructive if they apply to younger animals.

Accordingly calculations of the growth variation in scallops were limited to the data from the 0-6 year olds instead of including data for older age groups as Hile did though his growth data show precisely the same pattern of variation. Inclusion of points much beyond that where variability in size is at its maximum will have a tendency to lessen the contrast between growth changes in different years due to influence of environment alone which is the point of main interest, and in cases where differences, though real, may be small it will make it impossible to detect them. In the case of the scallop data use of all available records would have had little or no effect on the conclusions because of relatively great differences in growth from year to year but it could be a serious limitation to contrasts in comparisons of growth changes made by workers using more complete data than were available here.

The second limitation of Hile's method is more important to us and arises from the assumptions underlying comparisons of growth at different ages by percentage increase. The method for studying growth by relative growth rates, of which Hile's method is a variation, was first suggested by Minot (1908) who computed growth curves using increase in growth per unit of time as a percentage of size attained up to the time the increment took place. In some cases the logarithm of this function of growth when plotted against time gives a straight line (i.e. the rate of growth is constant) so that it is a simple matter to compare different curves of growth or different parts of the same curves. Indeed it is only possible to compare a growth rate function over different parts of the growth curve if this function has a straight line relationship with time, otherwise the differences

Age	Relative growth $\frac{\Delta y}{y\Delta t} \times 100$	log. $\frac{\Delta y}{y\Delta t} \times 100$
1	63.2	1.801
2	43.7	1.641
3	30.3	1.481
4	19.4	1.288
5	12.0	1.079
6	7.0	0.845
7	6.0	0.778

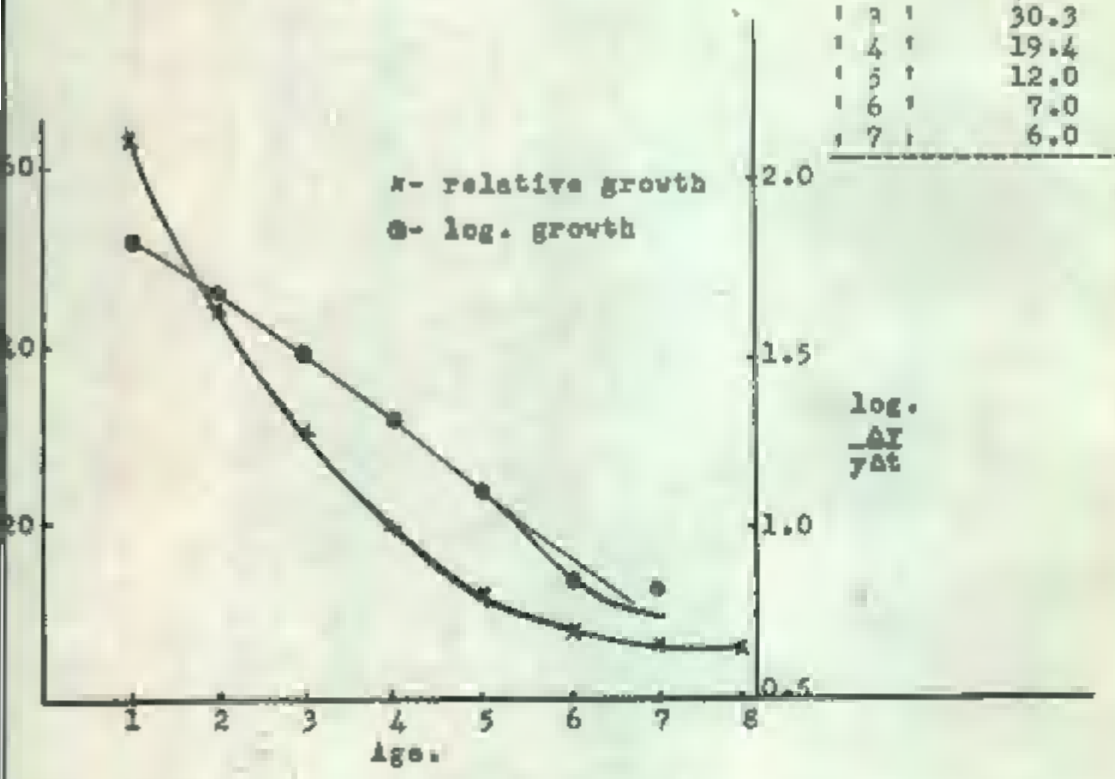


Figure 12. Relationship between age and percentage gain in length, i.e. the relative growth function, and log. of the relative growth function where y = size; Δy = gain in size; Δt = time interval, in this case, equal to one year.

in the indices to be compared are not only representative of irregularities in growth but include changes in the mathematical function itself.

In using Hile's method 1937 and 1938 were compared on the basis of one- and two-year-old growth, but 1939 was compared with 1940 using one-, two-, and three-year-old growth. As pointed out, the comparison of 1938 with 1940 growth is justified only if percentage growth gives a straight line when plotted against time, that is, for the first, second and third years. But fig. 12 showing the percentage gain in height with age shows that the straight line relationship holds only for the first three years. In fact, even the curve for logarithm of percentage growth rate on age is not a straight line. It must therefore be concluded that growth in different years can be compared by Hiles method only if the same or very nearly the same age groups are involved but that such comparisons cannot be justified if different age groups are used, as has been the case in our calculations and his.

In view of the limitations to the application of Hile's method for comparing growth in different years to the data for scallops it is advisable to find some other method which will remove these objections. It will be possible then, to compare results obtained by each method, see how great the discrepancies between them are and choose the most appropriate method as a basis for future investigations.

Brody (1927 and 1945) has divided the sigmoid growth curve into two portions which he terms the "self-accelerating" and"self-inhibiting" phases. In the former phase, which is below the upper inflection point of the curve, growth is found to change at a constant rate when expressed as a percentage of the size already attained (as assumed above, and used by Minot 1908; Weymouth and McMillan, 1930, and Weymouth, McMillan and Rich 1931). Beyond the point of inflection, growth changes at a rate which bears a constant proportion to the amount of unachieved growth. Whether or not this interpretation of the growth curves has any biological significance, the concept is useful in comparing them. Walford (1946) has made use of it in studying growth in many marine animals though his actual method is not well suited to our purposes. On the basis of Brody's observations the scallop growth data have been recalculated as a "self-inhibiting" phase of the growth curve in the manner described in the following paragraphs.

From the general growth curve in fig. 9 successive trial and error estimates were made of the upper asymptote of the curve (K). The points on the curve representing average size (Y) at each age were then calculated as K-Y then log. (K-Y) was plotted against age. That value of K which gave the best straight-line fit to the largest number of points calculated by

this transformation was found to be 145 mm. and this value was assigned to K for all the rest of the calculations. The straight line resulting from this transformation of the data is shown in fig. 13. The fit for the points involving the second to eighth age classes (30 to 100 mm.) is considered very good.

Since the growth transformation used here is a straight line over this range it can be used to compare growth increments in scallops of from 30 to 100 mm. in height. Below the 30 mm. size (two-year-old size) growth has not passed the first inflection point. Beyond the 100 mm. size (eight-year-old size) the points depart from a straight line, possibly because of some change in growth determining mechanisms.

The data on size at different ages in different years given in table 4 is recalculated in table 6 as (K-Y) and log. (K-Y) so that direct comparison can be made between them and the straight line curve of averages for the whole period described in fig. 13. For instance, a two-year-old scallop in 1938 grew from antilog of log (K-Y) = 2.074 mm. to antilog. of log. (K-Y) = 2.013 mm. These two points are located on the line for average growth and the horizontal distance between them is measured. This interval is expressed as a percentage of the horizontal distance for an average 12 months of growth. This percentage may be calculated or read directly off the graph to a high degree of accuracy by choosing the proper spacing for the points on the abcissa. In the above example, growth of two-year-olds in 1938 was 90% of that of an average years growth. Similar comparisons were made for growth at each age in each year (table 7). From them the average percentage deviations in growth in each year from the "normal" was worked out and plotted in fig. 14B and again as "months worth of growth" per year in fig. 15A. (The latter method is attractive because of its simplicity).

Fig. 14 permits a comparison of our two estimates of the percentage deviations in annual growth from average.

In fig. 14A a curve has been constructed from tables 8 and 9 following Hile's method and using the same data as used in fig. 14B based on Brody's technique, (i.e. omitting 0 and 1-year growth). The comparison shows that the points representing % deviation of 1944 and 1945 growth from the average are practically the same. As pointed out above these are the only two years where both curves satisfy the conditions under which growth is comparable on the basis of restriction of age classes and similarity in number of age groups under consideration. Points representing the 1938 to 1943 comparisons differ considerably in the two curves and these differences are especially marked in the 1938 and 1939 comparisons. Since only fig. 14B based on Brody's technique takes into account the comparability of age groups we can rely only on the points of this curve. Hile's method should be used only where there are equal numbers of age groups involved in each comparison.

Size (Y) at year and age shown. When K = 145 mm.

1942		1943		1944		1945		1946		Averages	
K-Y	log(K-Y)	K-Y	log(K-Y)	K-Y	log(K-Y)	K-Y	log(K-Y)	K-Y	log(K-Y)	K-Y	log(K-Y)
								37.7	1.576	37.7	1.576
						40.7	1.610	37.3	1.572	39.1	1.592
				45.4	1.657	42.2	1.625	42.4	1.627	43.1	1.634
		51.4	1.711	47.5	1.677	48.6	1.687	51.1	1.708	50.0	1.699
59.0	1.771	54.5	1.737	55.8	1.747	57.7	1.761	62.0	1.792	59.1	1.772
66.0	1.820	65.2	1.814	66.2	1.821	71.1	1.852	70.8	1.850	69.3	1.841
78.2	1.893	79.2	1.899	82.4	1.916	83.1	1.920	81.8	1.913	81.8	1.913
96.2	1.983	97.4	1.989	97.0	1.986	96.2	1.983	97.0	1.987	96.9	1.986
114.4	2.058	116.4	2.066	111.5	2.047	112.5	2.051	109.7	2.040	113.8	2.056
130.8		120.2		127.6		125.7		122.5		129.6	2.113

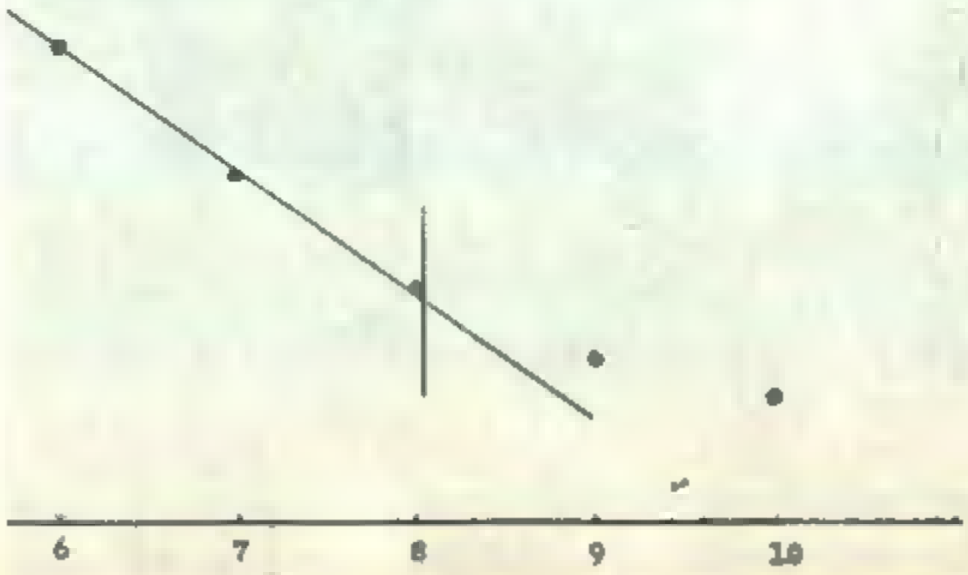
Table 6. Calculation of average growth yet to be achieved and its logarithm for scallops from 1 to 10 years old from 1937 to 1946 where maximum size K is 145 mm. and actual size is Y.

	Estimated Maximum Size (K)									
	1937		1938		1939		1940		1941	
	K-Y	log(K-Y)	K-Y	log(K-Y)	K-Y	log(K-Y)	K-Y	log(K-Y)	K-Y	log(K-Y)
10										
9										
8										
7										
6										
5									69.6	1.843
4							85.3	1.931	82.0	1.914
3					103.0	2.013	100.0	2.000	98.8	1.995
2			118.7	2.074	115.5	2.062	117.6	2.070	115.3	2.062
1	130.7	2.116	132.0		132.0		131.4		131.4	

Table 7. Percentage of the general average annual growth achieved each year by each year class and the average "goodness of growth" each year.

	1938	1939	1940	1941	1942	1943	1944	1945
10								
9								
8								
7						75	75	85
6					85	85	85	75
5				100	115	95	85	85
4			125	130	110	110	90	100
3		115	120	145	120	105	90	100
2	90	90	105	115	95	110	90	100
1								
0								
"Goodness of growth" expressed as a percentage of average 12 months growth	90	103	116	122	105	97	86	91
No. of "month's worth" of growth each year.	10.8	12.4	13.9	14.6	12.6	11.6	10.3	10.9

nship between age of Boughton Island
s and log. (K-Y) where K is the
ed maximum size of scallops and is
o 145 mm. and Y is the actual average
tained at any age. K-Y, therefore,
nts the growth increment still to be
d.



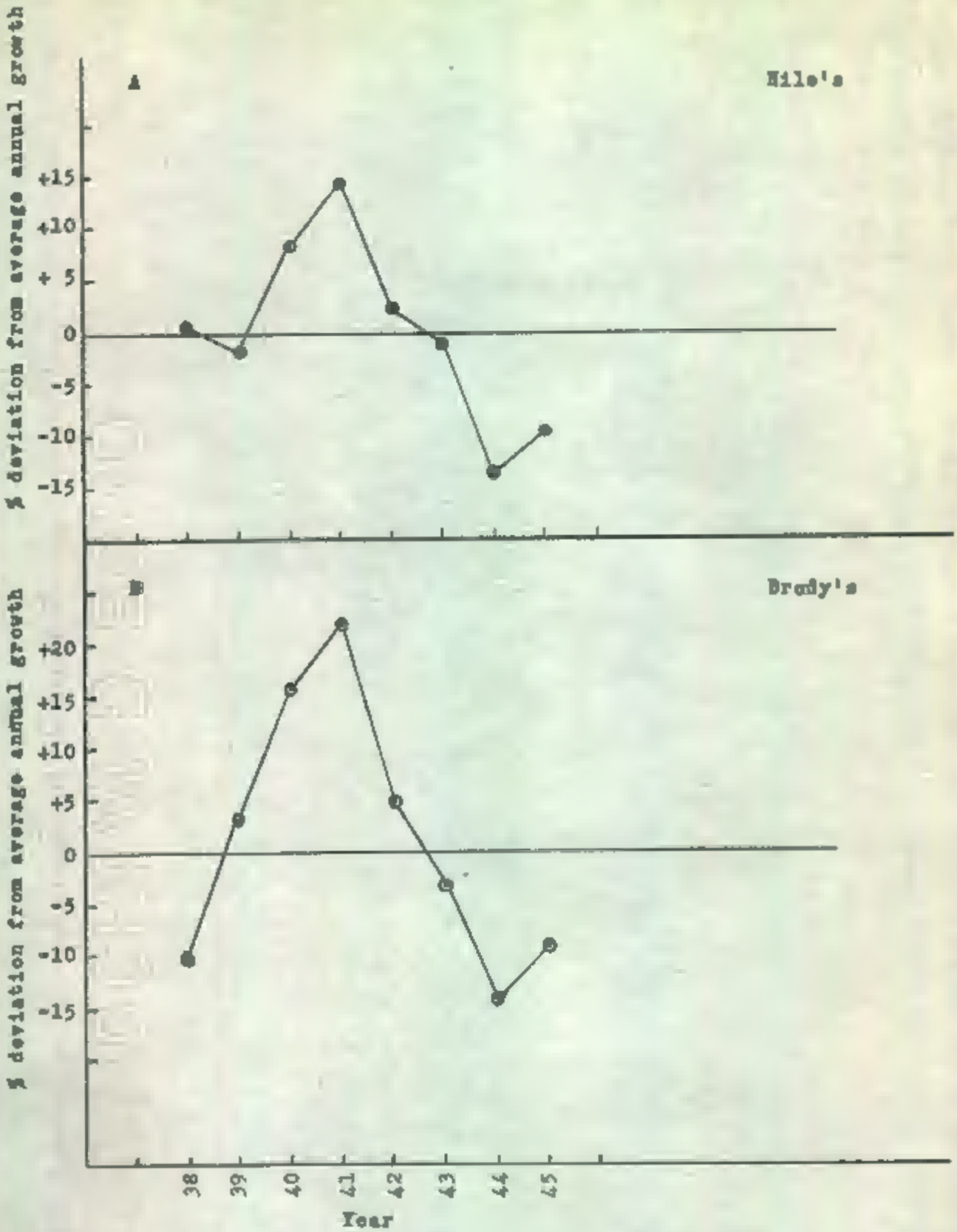


Figure 14. Percentage deviation of average annual growth from the general mean, 1938-1945, calculated after Hile (A) and Brody (B) (See text)

Having established that comparisons of year-to-year growth differences based on the second method only are reliable, it is possible to discuss these growth differences themselves.

(ii) The Influence of Temperature on Annual Growth: In fig. 15 the annual growth of scallops is compared with water temperature. Growth is expressed as the number of "months' worth of growth" that animals made per year. It appears that growth was poor in 1938, improved for three years to the maximum for the period in 1941, declined to a minimum in 1944 and improved slightly in 1945.

Fig. 15B is taken from Machey and MacLellan (1945) and shows the average summer surface water temperatures at Entry Island, P.Q., which are indicative of conditions throughout the Gulf of St. Lawrence. Temperatures were lowest in 1941 and highest in 1942 and 1945. There is an inverse correlation between water temperature and goodness of growth. This could be interpreted as supporting the hypothesis that water temperatures at Boughton Island in Northumberland Strait are so high that they deter growth of the scallop P. grandis which is primarily a cold water animal. (See earlier discussions of temperature as a growth regulator). It may be that the water temperatures are approaching the limits of heat tolerance. This possibility is referred to later in the discussion of the causes of mass mortalities.

(iii) First Year Growth: Since the study of growth employing Brody's technique does not consider the earliest stages of growth, this discussion would be incomplete without reference to growth of scallops between the time they are spawned and the time of formation of the first winter ring.

Fig. 16 shows the amount of first-year growth for the years 1936 to 1945. The average growth was 14 mm. in 1936 and 13.0 mm. in 1937 and improved slightly in subsequent years up to 1941 after which it increased rapidly reaching 17 mm. in 1942 and a maximum of 22.5 mm. in 1945. The latter of these averages may be overestimations since few specimens are involved and total heights of the animals on which measurements were made are less than the diameter of the ring spaces of the sampling gear. These conditions would tend to select only the largest and fastest-growing specimens. However, there seems to be a definite tendency toward improvement in growth in recent years. A comparison of fig. 16 with fig. 15B shows no correlation between first-year growth and summer average surface water temperatures which leads to further speculation.

It is apparent that there are two sets of factors which will influence the amount of growth achieved before the first annulus forms:

i) The time of spawning.

ii) The "goodness" of the environment for growth.

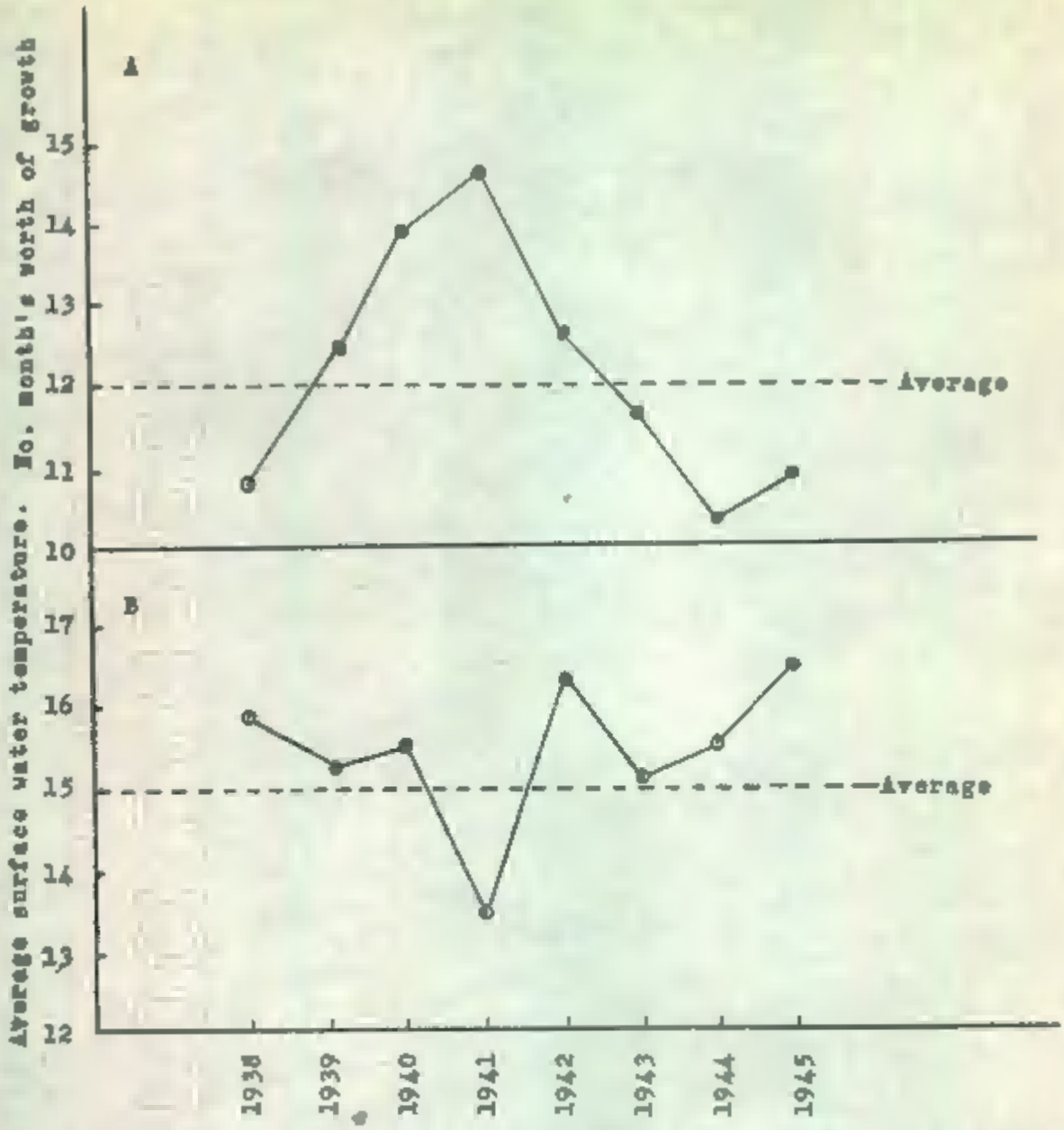


Figure 15. A. Average no. of "months'-worth" of growth achieved annually by Boughton Island scallops 2 - 7 years old from 1938 to 1945.

B. Summer average surface water temperatures taken at Entry Island, P. Q. from 1938 to 1945.

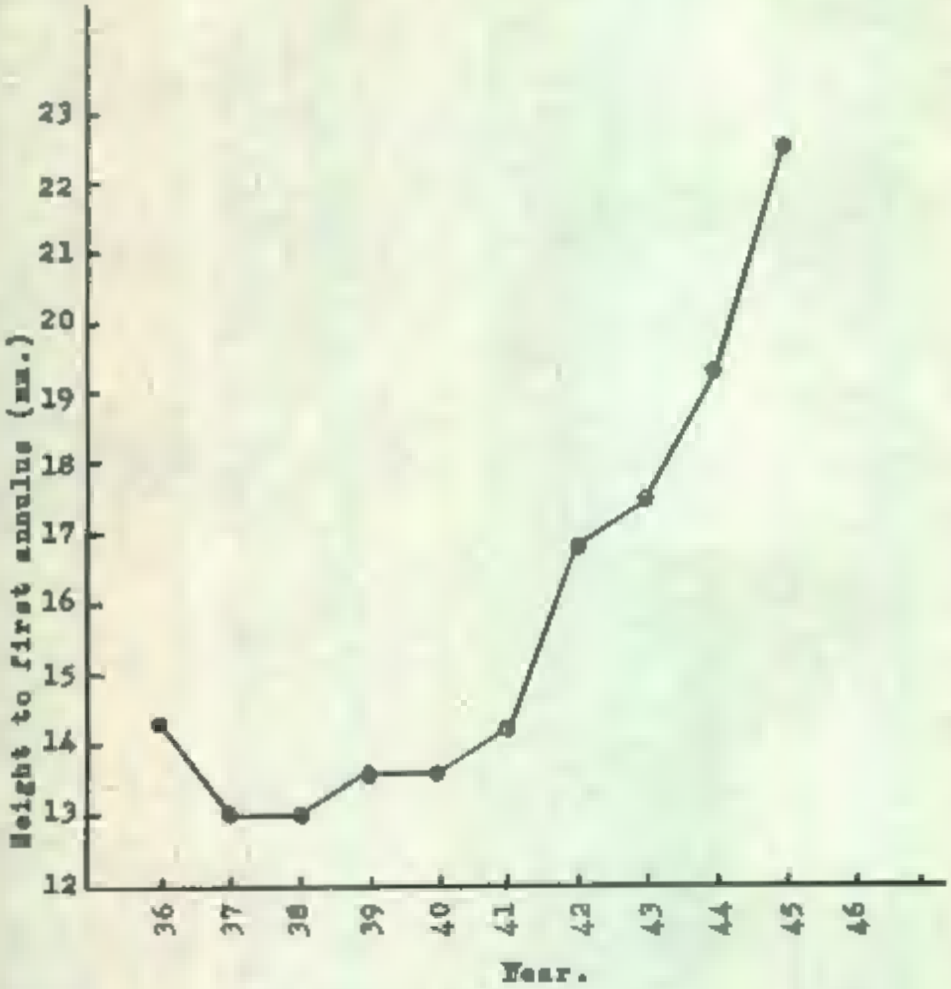


Figure 16. Average height attained by scallops of the 1936 to 1945 year classes from time of spawning to formation of first annulus.

If future investigations were to show time of spawning to be important, i.e. that late spawning allowed less growth than early spawning, then from the lack of correlation with temperature we would be forced to conclude that temperature alone does not determine the time of spawning. The importance of temperature for proper gonad development was demonstrated by Orton (1920) for oysters and is widely recognized. But more recent work by Orton (1926), Wheeler (1937), Clark and Hess (1942), Korringa (1947), has suggested that lunar cycles acting through tides or possibly light intensities, rather than temperature, must initiate the spawning act when temperatures have risen above some threshold level necessary for proper maturation of eggs and sperms. It would be necessary to postulate a similar mechanism operating on Northumberland Strait scallops.

If the amount of first-year growth is independent of the time of spawning, it must obviously be dependent on the goodness of the environment for growth, in which temperature is usually considered to play a very important part. If growth is dependent on the environment, but independent of temperature the controlling factors must also be independent of average temperature. The situation which appears most likely is that the rate of development depends on proper conditions during some relatively short but critical stage during early development. Without further data, however, it is impossible to say more.

IV CATCH RECORDS

The catch records compiled in "Fisheries Statistics of Canada" indicate that a large-scale fishery for scallops off the southern coast of P.E.I. is a comparatively recent development (Table 10). Up to 1945 catches were small and in some years no landings were reported at all. According to fishermen's reports dragging on the area has gone on for a longer time and more steadily than is indicated by the official records. For the periods when there were no official records the catch was made for local consumption only and must have been small and consequently of little interest to our immediate purposes.

1. Within-Year Variation.

The 1945 and 1946 records of daily landings reported in table 11 are from records kept by Mr. J. Hewitt of Lower Montague for the M. V. "Robert H." who generously made them available to the writer. They show a rise in catch per day with season to an early summer maximum then a dropping off toward the end of the season. The fishermen state that these seasonal variations are characteristic. The low figures for the early season (see "Mean Catch per Trip") are the result of unpredictable fishing weather in early spring, adjustments and trials of new gear, breaking in new crews, and loss of fishing time while search-

Table 8. Percent change in accumulated annual average growths of P.E.I. scallops from one year to the next from 1937 to 1945. Comparisons are restricted to the 2- to 7-year age classes. (See Table 2.)

Years involved in comparison	Average growth to end of earlier year	Average growth to end of later year	Mean	Difference	Difference in growth as a % of mean
1938 and 1939	15.7	15.5	15.6	-0.2	-1.3
1939 and 1940	33.2	36.8	34.0	3.6	10.6
1940 and 1941	52.5	55.7	54.1	3.2	5.9
1941 and 1942	66.3	58.5	62.3	-7.6	-12.0
1942 and 1943	66.1	63.8	65.0	-2.3	-3.6
1943 and 1944	69.8	61.4	65.6	-8.4	-12.8
1944 and 1945	61.4	64.2	62.8	2.8	4.4

Table 9. Percentage change in total annual average growth in each year compared with that of 1938 and that of the general mean for 1938-1945.

	Year							
	1938	1939	1940	1941	1942	1943	1944	1945
Percent change in growth compared with growth in 1937	0	-1.3	9.3	15.2	3.2	-0.4	-13.2	-8.8
Percent deviation in growth from general mean of 1938-1945	0.6	-1.9	8.3	14.6	2.6	-1.0	-13.8	-9.4

Table 10. Annual total landings of scallops for Kings Co., P.E.I. from 1933 to 1946. (Compiled from Fisheries Statistics of Canada.

Year	Total landings (pounds)
1933-39	No landings reported
1940	4,482
1941	7,470
1942	No landings reported
1943	" " "
1944	2,070
1945	29,070
1946	11,256

ing for concentrations of scallops. Fishermen believe that the dropping off in catch at the end of the season is the result of a scarcity of scallops brought about by their migration to "spawning grounds" whose positions are unknown.

The writer's observations on gonads up to August 5, 1946, when fishing stopped, showed that a few scallops from the regular beds had begun to spawn by that date. This shows that migration is not necessary for initiation of the spawning act and casts doubt on the whole theory of spawning migration as an explanation of the slump in catch per trip. The migration hypothesis becomes even less tenable when it is noted that catch per trip remained high until September in 1945, when spawning was well under way, without any striking change in catch which would necessarily follow mass emigration from the beds. Only in 1946 was the slump at all sudden. It seems reasonable to conclude that the seasonal reduction in daily landings is not the result of emigration.

Another possible explanation for the seasonal drop in catch is the reduction of the fishable stock by the fishery itself. That is, as the season progresses there are fewer and fewer animals left to catch so that unless the efficiency of the fishing effort changes, catch per unit effort should decrease. Analysis of available records suggests that this is a reasonable explanation. This is evidenced by the straight-line relationship between the catch per trip of M.V. "Robert H." and her accumulated season's catches up to the time of each particular trip (fig. 17). The 1945 records illustrate this very well. After about June 25 when the boat's catch reached a maximum (i.e. when such factors as training of crew, breaking in of gear, etc. stabilized) there was an average drop in catch per trip of 2.3 pounds for every 100 pounds additional catch by that boat. This amount of drop is reasonable considering the small size of the fishing ground involved and the intensity of the fishing effort. Three boats were dragging an area of only ten square miles. It apparently took about two weeks to discover the major concentrations of scallops on it and to begin making appreciable inroads on the stock. During the season the commercially important areas are dragged over several times, the boats vying continually for the most favourable spots. The evidence suggests that heavy fishing is the major factor normally contributing to seasonal decline in catch per trip.

2. Year-to-year Variation.

Table 10, listing the 1940 to 1946 annual total landings for Kings Co., P.E.I., shows that 1945 landings were the highest. Fisherman report that that year two boats fished the grounds regularly and that a third did "considerable fishing". In 1946, although all three boats fished regularly and a fourth made a few trips, the slightly increased fishing effort resulted in total landings which were less than half those of 1945.

Table 11, giving catch per day for the "Robert H.", which fished for scallops both years, provides further information about

Table 11. Daily landings of scallops (in pounds) by M. V. "Robert H." at Lower Montague, Kings Co., P.E.I., throughout the 1945 and 1946 fishing seasons.

	May		June		July		August		September				
Date	1945	1946	1945	1946	1945	1946	1945	1946	1945	1946			
1							270	60	270				
2							380						
3					397	147							
4			290	145	425	80			37				
5			277		539	130		18	202				
6				240	595		162		213				
7					203								
8	152			204			410						
9		85	190		422	158	387						
10					305	200	342						
11				190		175	167						
12					85	180							
13		80	460		377				234				
14		134		202	309				170				
15	127	181	92	172		97							
16		160			552		237						
17					210		182						
18			325		517	140			215				
19				120	486				245				
20		120	362	85	602								
21		45					171						
22	417		22	117		130							
23		120					233						
24		180		174	437		347						
25	288	107	355	150		80							
26			266	174		67							
27		125	237	145			90						
28		145		150	225		110		201				
29	257	172	568	27									
30	320	130	322			65	170		65				
31		205			439	90						1945	1946
Total	2561	1989	3766	2295	7125	1739	3658	78	1852		Annual Catch	17,962	6,101
No. of fishing days	6.0	14.5	12.0	14.0	17.5	13.0	15.0	1.0	9.0		No. of trips	59.5	42.5
Mean catch/trip	260.1	137.2	313.8	163.9	407.1	133.8	243.9	78.0	205.8		Catch/trip	301.9	143.6

this difference in landings. It shows that throughout 1946 the daily catches were regularly about half those for the same times in 1945 and that fishing stopped a month earlier, presumably because it was no longer worthwhile. This indicates that a relative scarcity of scallops in 1946 was responsible for the drop in landings that year. A detailed examination of the records shows what factors were responsible for this scarcity and how great it was.

a. Comparison of 1945 and 1946 seasonal declines in catch.

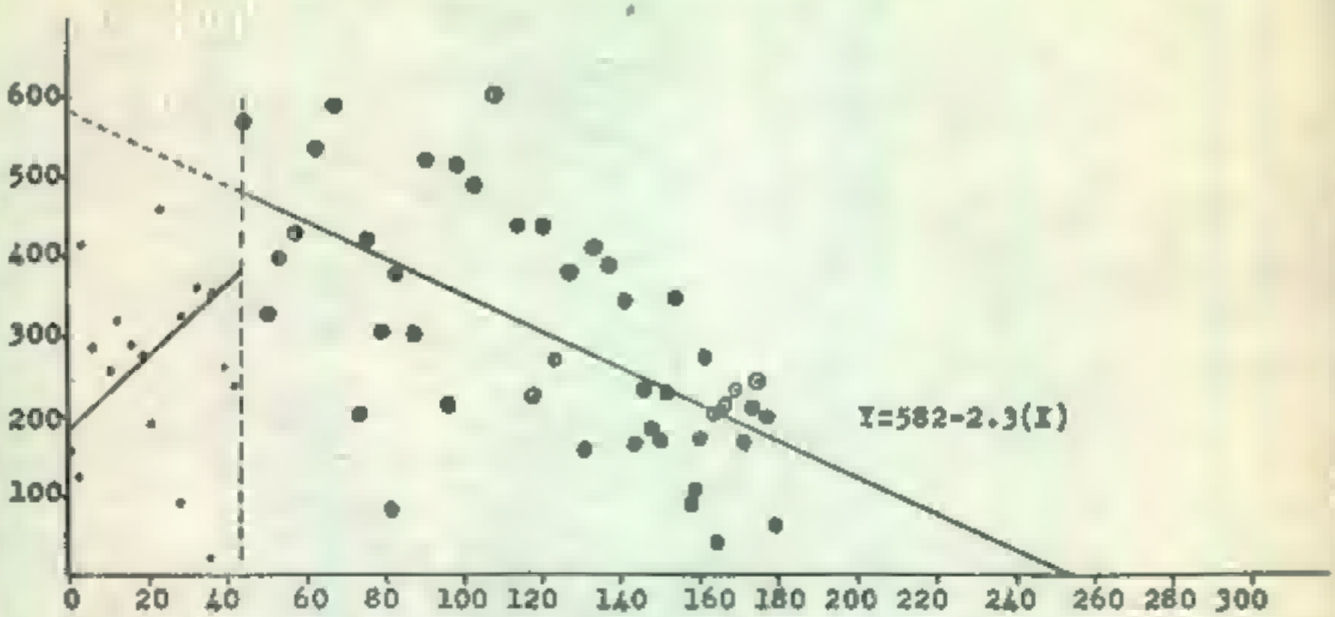
In fig. 17 each of the 1945 daily catches of the "Robert H." are plotted against total catch of the boat up to that day. From the regression line drawn through these points it is estimated that there was a drop in daily catch of 2.3 lbs. per 100 lbs. already taken. DeLury (1947) showed that when catch data are plotted in this way the intercept of the regression line on the X-axis gives an estimate of weight of initial population available to that boat (i.e. when the daily catch is 0, then the total available population has been caught). Employing this device it appears that in 1945 the population initially available to the "Robert H." was 25,300 lbs. In fig. 18 (Line A) the 1946 catch data are plotted in the same way. The average decrease in daily catch that year was 3.2 pounds/100 caught and the estimated initial population available, 8,700 lbs.

Using these data, the changes in size of population available to the "Robert H." may be traced from the beginning of 1945 to the end of 1946. The fishable population at the first of May, 1945, was 25,300 lbs. Of these 17,900 lbs. or about 71% were caught leaving about 7,400 lbs. at the end of September. From then to the beginning of May in 1946 this population apparently increased by 18% to 8,700 lbs. of which 6,100 lbs. or 70% were taken by the fishery. This means that about 2,600 lbs. remained after fishing in 1946.

These records show the magnitude of the population decrease in 1946 and support the opinion expressed in the previous section that a high fishing mortality (70%) accounts for the 1945-1946 drop in landings. However the data have two discordant features which suggest that the fishery may not have been entirely responsible.

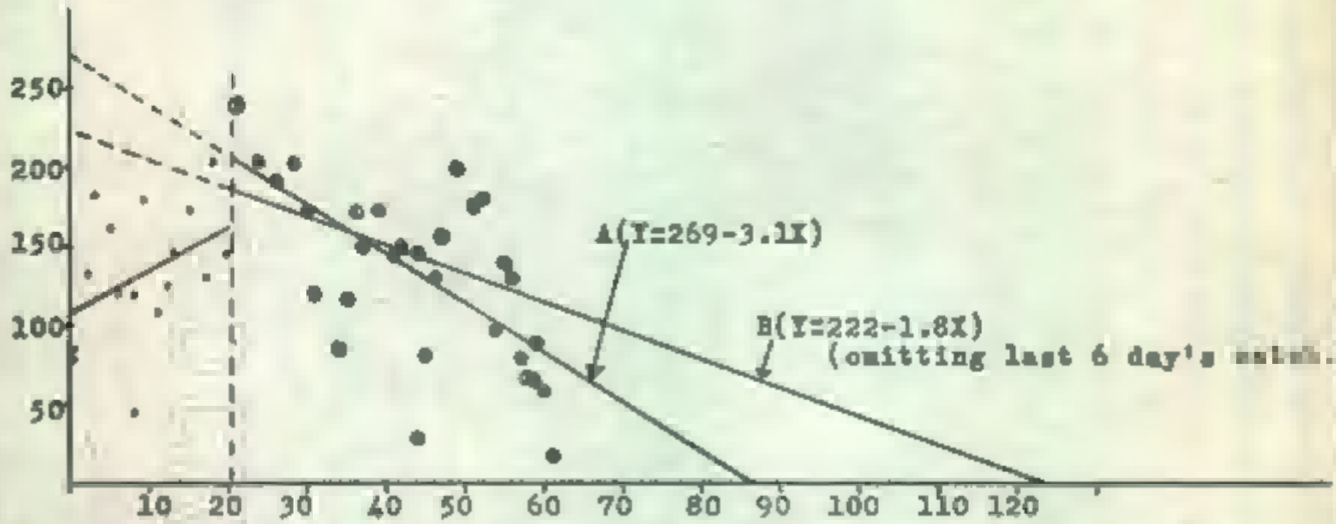
The first is that the estimated increase in weight of stocks between fishing seasons was small, 18%. This is not what would have been expected from the size frequency data in fig. 8. These indicated that there should have been a relatively heavy 1946 recruitment of fast-growing animals (5 years old in 1945) into the fishable population. These were too small to form an important part of the catch in 1945.

The second is that the rate of seasonal reduction in the 1946 catch (of 3.2 lbs. per 100 caught) is considerably higher than that in 1945 (2.3 lbs. per 100 caught) representing a slope increase of about 35%. The 1945-1946 fleet-size increase was only about



1945 $X = X_t = \frac{\text{Accumulated catch per trip throughout season}}{100}$

Figure 17. Relationship between daily catch of one boat and its accumulated daily catch per 100 in 1945 at Boughton Island.



1946 $X = X_t = \frac{\text{Accumulated catch per trip throughout season}}{100}$

Figure 18. Relationship between daily catch of one boat and its accumulated daily catch per 100 in 1946 at Boughton Island.

15%. Ricker (1940) and others have pointed out that any given increase in effort produces a less than proportionate increase in the rate of fishing, so the writer feels justified in concluding that the difference in seasonal reduction cannot be accounted for by the increased effort alone. These two observations suggest that the successive estimates of population are not strictly comparable because some additional factors intervened to produce differences in landings in the two years.

Further analysis indicates that a larger 1946 recruitment took place than is indicated above but that an unusually heavy natural mortality took place which contributed importantly to the rapid reduction of stocks in 1946.

b. Potential Increase in Fishable Stocks from end of 1945 to beginning of 1946 Season.

Table 12 summarizes a calculation of potential 1945 to 1946 increase in meat-yield of a sample of 920 Boughton Island scallops and is based on meat-yield, growth, and age-frequency distribution data. Column 1 lists the age classes represented in the catchable population and column 2 the numbers of scallops in each class. There are no actual age-frequency data available for the end of 1945 so it is assumed that each year class was present in the same proportions as at the end of 1946 (fig. 8), this is reasonable since work done since 1946 and reported elsewhere shows that 6- to 9-year-olds are about equally catchable. Column 3 lists the average meat-yield of individual animals of each age class (fig. 19). These records were obtained in 1947 and will be described in more detail in a later report. Column 4, giving the weight of meats in each age class is calculated from columns 2 and 3. The total of column 4 gives the weight of the sample at the end of the 1945 fishing season. Column 5 gives the % increase in weight of each age group in one year and is derived from the data of fig. 19. Column 6 is the product of columns 4 and 5 and gives the weight of the sample at the end of 1946. Changes in weight of the total population may be inferred from corresponding changes in the sample which is considered representative of it.

The 7,400 pounds of meats which remained after fishing in 1945 correspond to the sample weight of 8,960 gms. (total of column 4) less the weight of the 5 year olds - 1,200 gms., that is, 7,760 gms. The five-year olds must be eliminated because they were not large enough to form an important part of the catch in 1945. The potential increase in fishable population then is represented in the sample by the increase from 7,760 gms. to 11,550 gms. (the total of column 7) a growth of 3,790 gms. or about 49% per annum, [redacted], and was itself 49% of 7,400 lbs, that is, 3,630 pounds in one year. In one inter-season (September to the following June) scallops should realize about 80% of their total annual growth, therefore if none died 7,400 - (3,630 x .80) =

Table 12. Calculated potential annual increase in meat yield of a 1946 sample of 920 Boughton Island scallops 5 to 9 years old.

1	2	3	4	5	6
Age class	Number in sample	Av. wt. of individual meat (gms.)	Initial wt. of sample (gms.)	% annual increase in weight	Final wt. of sample (gms.)
5	300	4.00	1,200	200	2,400
6	180	8.00	1,440	144	2,070
7	140	11.50	1,610	124	2,000
8	130	14.25	1,850	113	2,090
9	100	16.00	1,600	109	1,660
9+	70	18.00	1,260	104	1,330
Total	920		8,960		11,550

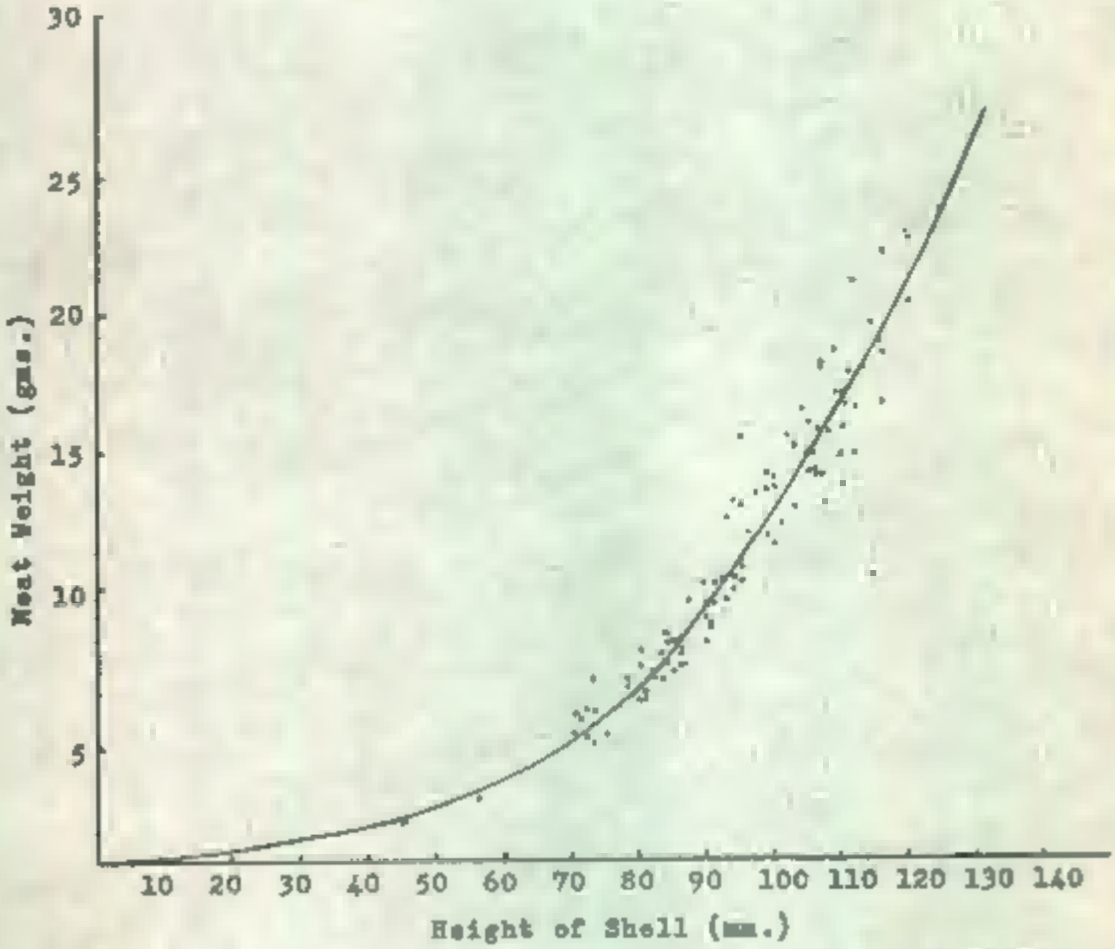


Figure 19. Relationship between height of shell and weight of meats of a sample of 102 scallops taken at Boughton Island -- August 4, 1947.

10,300 lbs. would be present at the beginning of the 1946 season's fishing operations.

c. Comparison of Potential Increase and that Calculated from Catch Statistics.

These calculations demonstrate that the population was potentially capable of increasing 39% in meat yield from the end of 1945 to the beginning of 1946. This does not accord well with the 18% of the increase calculated from the catch data. This disparity is actually less than just indicated because so far natural mortality has been disregarded.

With the exception of a case of unusual mortality discussed later, there are no good estimates of natural mortality rates. At the same time there is no evidence from collections made at P.E.I., or any other bed, which would indicate that it is sufficiently important to reduce a potential increase from 39 to 18%. Further information about natural mortality could be obtained by comparing size frequency distribution records for 1947 with those of 1946 if catch records for 1947 were available. For the present, however, the writer assumes that the ordinary natural mortality is not of sufficient importance to explain the difference between these two calculated recruitments and that unknown factors must be at work. Evidence presented later in this report supports this view but it is obvious that no final conclusions can be drawn without further information although there is reason to speculate on the effects of dragging.

d. Effect of Dragging on Catch.

Besides natural and fishing mortality already considered, there is another factor which may influence catches importantly. Recent work at Digby, N.S., has indicated that on relatively rough bottom one tow with standard scallop drags takes only about 5% of the commercial-sized scallops on the ground over which it passes. Many of the rest must be shifted from their position on the bottom where they are catchable to positions between rocks and into crevices where they would be inaccessible to drags. Although the effect would not change true abundance it would reduce catches until such a time as the animals had an opportunity to readjust themselves on the bottom. If this readjustment is a slow process, and it may well be, this disturbance effect might account for part of the drop in catch as the season progresses. Conversely adjustment of scallops to more catchable positions in the period between fishing seasons may give a falsely high impression of the extent of recruitment at the start of each new season. The possible importance of disturbance and readjustment in affecting the catch is another point favouring the conclusion that the 39% estimate of recruitment is nearer the truth than the 18% and that notwithstanding natural mortality the initial available population in 1946 was closer to 10,300 lbs. then

to 8,700 lbs.

e. Discrepancy between Recruitment Estimates.

Assuming that the population increase from 1945 to 1946 was greater than that calculated from catch records, it is imperative that the data in fig. 17 and fig. 18 be re-examined to see how this discrepancy arose. The first thing to be considered is the increase in fishing effort that took place in 1946. Any such change in effort would have the effect of increasing the slope of the regression line and would give a reduced estimate of initial abundance in the year of greater effort as compared with a similar estimate for the year of small effort. Actually the rate of decrease in catch for 1946 was -3.2/100 (fig.18) compared with -2.3/100 in 1945 (fig. 17) an increase in slope of 35%. As pointed out earlier, however, only 1 boat was added to the fishing fleet in 1946 and it fished only part of the year. It appears that this increase in fishing effort is not large enough to have produced the indicated increase in rate of reduction of stocks, being more of the order of 10 or 15%. It is concluded, therefore, that although increased fishing effort could produce the discrepancy between the two calculations of initial population, the change in effort which actually took place was far too small to account for it. It appears that some other factor must also be involved.

Examination of the catch data for 1946 (fig. 18) shows that a series of six very poor catches occurred together at the end of the season. It is to be expected that daily catches will vary considerably because unsettled weather gives rise to fishing days of unequal length. But personal observations by the writer have established that with the exception of the last of these six days the poor catches were not the result of bad weather. During the first five days, fishing weather was good and the number of hours fished each day was close to average. Furthermore, several spots on the beds which earlier in the season were highly productive yielded such poor catches as to finally discourage all fishing effort. At the same time unusually large numbers of empty shells and dying scallops suddenly appeared in the catches. It is concluded that the poor catches resulted from a sudden reduction in stocks which resulted from a mortality of epidemic proportions.

To check the catch statistics for evidence of effects of this mortality the regression line for the 1946 data was recalculated omitting the last six catches. The result (fig. 18, line B) produces a regression line which has a slope of -1.8 lbs. per 100 lbs. caught and gives a new estimate of initial population in 1946 of 12,300 lbs. Obviously the inclusion of these six catches considerably increased the estimate of rate of decrease in stocks and produced thereby an underestimate of initial population. In comparing these initial 1946 population estimates, 12,300 lbs. and 8,700 lbs, it must be remembered that daily catches are so variable

as to preclude accurate calculation. However, all the evidence presented points to the larger being more nearly correct; the initial 1946 population was probably between 10,000 and 12,000 lbs.

f. Summary and Conclusions from Catch Data.

The comparison of the catch data for 1945 and 1946 may be summarised as follows:

In 1945 a large number of fishable scallops was present on the Boughton Island bed. That year fishing was intense and and apparently removed about 70% of available stocks.

The inter-season recruitment was of the order of only 40% so the available stocks at the beginning were considerably smaller in 1946 than in 1945. This resulted in a poorer average daily catch in 1946 which was exaggerated by a slight increase in total fishing effort.

The sudden remarkable decline toward the end of the 1946 season and the termination of fishing in early August is believed to have resulted from a drastic reduction in stocks produced by an unusual and heavy mortality and not by "depletion" by the fishery. Catch statistics indicate that in six days the effect of the mortality was sufficient to increase the average rate of drop in catch from about 2 lbs./100 caught to 3 lbs./100.

Considering only the data which suggest that the reduction in catch per day is attributable to heavy fishing, one would normally be inclined to advocate the institution of some sort of control which would restrict the total effort as a device for maintaining production at the highest sustainable level. However, the occurrence of heavy mortality would nullify such efforts. Before any conservation programme can be worked out the causes for the mortality must be discovered and understood. Because of its importance in this connection, what we know of the mortality is discussed in a separate section below.

MASS MORTALITY - 1946

1. Evidence

During the sampling of the Boughton Island population in 1946 unusually large numbers of empty scallop shells were observed in late July and early August. The two valves of these "dead" shells, called "bivalves" by the fishermen, were still attached by the hinge ligaments and could not have resulted from shucking because shuckers always separate the two valves. The suddenness of their appearance and the lack of encrusting growths on the shell interiors showed that this mortality was quite recent.

Mr. Horace Hewitt, owner and skipper of the M. V. "Robert H." which worked the Boughton Island beds, has fished scallops locally for several years. He states that this mortality has occurred before and to the best of his memory and experience has recurred every four or five years. His impression is that it happens in years when abundance is high. He reports having seen a few dead scallops during the last two weeks in July 1945. The catch records show no serious reduction at that period, however, and it is concluded that any mortality that year must have been of minor importance.

2. How the Population is Affected.

The writer's examination of commercial catches showed that the mortality in 1946 was extensive and selective. Up to one-third of the scallops taken in the drags in August were dead. Fig. 20 shows the size-frequency distribution of 368 empty shells taken in four separate hauls -- two on July 26 and two on July 31st -- of the seven commercial drags used on the "Robert H.". The close correspondence of their size frequency distribution pattern with that of the older animals in the living population (fig. 8A) indicates that all size classes above 75 mm. (age classes beyond the 4-year-olds) were equally affected. The drags brought up many scallops 25-75 mm. in height but practically no "dead shells" of this size and none at all that were less than 60 mm. In fact only a very few small dead scallops were observed in all catches made during the period of observation (July 24 to Aug. 5). This vigorous condition of the young is a striking feature of the mortality and will be discussed later in this report.

As might be expected there is a variety of opinions as to the cause of mortality and these deserve mention.

3. Tentative Explanations.

a. Starvation: Many of the fishermen attribute this mortality to lack of sufficient food to maintain the population. Superficial examination of dying scallops obtained in 1946 showed normal development and plump bodies which would not be expected in poorly-nourished animals. Besides this, young animals up to 75 mm. were sound and well nourished throughout the period. It is concluded therefore that the mortality has resulted from some factor other than starvation.

b. Destruction by Enemies. Among the "trash" brought up in the drags many animals were found apparently associated with scallops on the beds. Three species of starfish were commonly found, of which specimens were occasionally found inside the mantle cavity or clasped over the shell in the same fashion as when attacking other bivalves. One species of sea-urchin (*Strangylocentratus droebachinsis*) was found to be quite common. Occasionally these were inside the mantle cavity of half-dead, gaping scallops with their tube feet

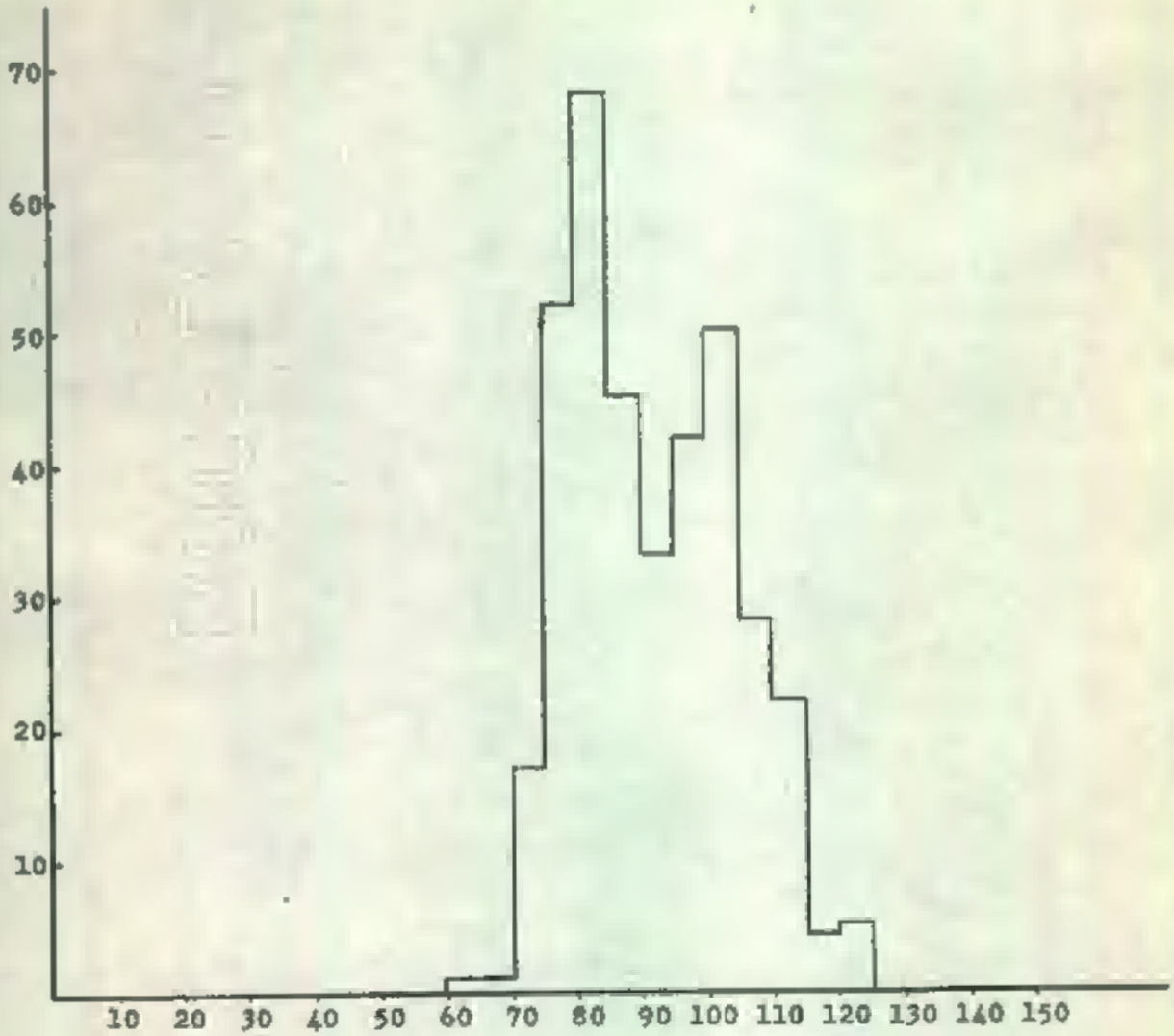


Figure 20. Size frequency distribution of 366 empty shells collected from four drags of the commercial catches off Boughton Island, P. E. I. -- August, 1946 (compare Fig. 8)

attached to the viscera. Small fish, thought to be the young of the monkfish (Lophius(piscatorius) americanus) were also found inside the mantle cavity but these were not frequent and it is doubtful if they act as predators.

Numbers of all such animals associated with the scallops and which may be predators on them seemed to be too small to account for the mass mortality. In any case their effect should be a progressive one, rather than suddenly appearing as it was in the middle of summer. In the writer's opinion predation does not provide a satisfactory explanation for the mortality.

c. Epidemic Disease. A third conjecture attempts to explain the P.E.I. scallop mortality as analogous with that of the oyster (Needler and Logie, 1947) which reduced the whole stock to a very low level for several years. Following this a resistant strain developed which has repopulated much of the devestated area.

Points of resemblance and difference between the two mortalities are set forth below:

Oyster Mortality	Scallop Mortality
1. Occurred about the beginning of August and rose to a maximum in autumn.	1. Occurred about the last of July, maximum not known.
2. Yellow-green pustules were common pathological symptoms.	2. No evident symptoms preliminary to death.
3. Excessive mortality up to 50% per season.	3. Extent of damage great, estimated up to 30% of fishable stocks during 1946 period of observation.
4. Mortality appeared each year for several years.	4. Does not seem to occur every year.
5. Stocks of young and adults both seriously affected.	5. Young apparently not affected.
6. Survivors had very poor average growth and physical condition.	6. No evidence of poor growth or physical conditions of surviving scallops.
7. Recovery from disease is slow, dependent on development of resistant stock.	7. Little known about the mortality, but if, as fishermen suggest, it is periodic there is probably no resistance acquired. Recovery must be rapid which would argue against a persistence of a virulent disease.

The differences between the mortalities are sufficient to indicate that, if a disease is responsible at all, the scallop mortality is not caused by the same organism that affected the oysters. In the writer's mind a contageous disease which is peculiar to scallops is not regarded as a too remotely possible explanation but features #2, 6 and 7 in the above list suggest that a physical explanation is more likely.

d. Lethal Water Temperatures. Another explanation which has been suggested is based on the scallop's inability to withstand sudden changes in hydrographic conditions. Huntsman (1918) described variations in the size-frequency composition of stocks of starfish at different levels on the steep sub-marine slope of the Cheticamp side of Northumberland Strait and explained them by postulating (1) greater resistance of small than of large animals to sudden changes in temperature and (2) oscillations of the thermocline. Smith (1940) showed that small starfish are more tolerant of high temperatures than large starfish and concluded that temperature is a primary factor in regulating the starfish populations in Bideford river. Similarly Kerswill (1941) showed in laboratory experiments that small quahaugs survived higher temperatures in sea water for longer periods and had higher lethal temperatures than large quahaugs.

Considering these findings, observations on the scallop mortality suggest that sudden temperature changes may have caused the mortality because few small dead scallops were found in the catches at any time.

Lauzier (1946) has shown that in late August 1946 the thermocline off the S.E. coast of P.E.I. was at about 25 metres. The water temperature just above it was 15°C. and just below 5°C. and that strong S.E. winds caused upwelling in this area temporarily raising the thermocline by about 5 metres. Such upwellings produce a "seesawing" of the thermocline and would provide for an alternate flooding of the Boughton Island scallop beds (20-26 metres deep) by warm and cold waters. Little is known about the frequency of the seesaw movements or for what periods they persist. However it is known that similar meteorological phenomena occurred earlier in 1946 and in other years.

Sudden warming and cooling of the environment of the scallops which would result from such hydrological phenomena would probably be inimical to scallops and have a more severe effect on the large than on the small animals. Furthermore the irregularity of their occurrence would account for the sporadic occurrence of the mortality if this is the effective mechanism. Further support of this hypothesis is found in recent communications from Woods Hole. Workers there have preliminary experimental data which place the lethal temperature of scallops at from 10° - 15°C.

e. Summary of Mortality Study.

The cause of scallop mortalities off the south coast of P.E.I. is still obscure. Of the several proposed explanations the writer is inclined to favour the last which is based on hydrographic changes even though the evidence is sketchy and circumstantial. Careful observations of the bed for a few summers and laboratory experiments to determine lethal temperature limits and "minute rate of mortification" in lethal temperatures (Fry 1947) may provide an explanation. Indeed this will be necessary as already pointed out if intelligent controls of fishing are to be instituted in this area.

VI A NOTE ON TEMPERATURE EFFECTS

The literature in zoological research, particularly marine zoological research, abounds with studies of temperature effects. Possibly this is because temperature data are easily collected, but there is no doubt about the importance of temperature in marine climates. For this reason one is inclined to look early in investigations for correlations between temperature and zoological phenomena. The present study is no exception and the preliminary results indicate many ways in which temperature may be important in the life of the scallop, and others in which it should not be (Part III, Section 5b(ii) and 5b(iii), Part V, Section 3d). By contrasting these results with those of studies in the Bay of Fundy area we are able to make certain speculations about the ecology of the scallop which the writer feels may be worthwhile.

In the Northumberland Strait area the success of spawning, settling, and growth of "larval" scallops in different years do not seem to be limited by the normal variations in water temperature as correlations between temperature and (1) strength of successive year classes and (2) amount of growth in the first year were lacking. However, there is an inverse correlation between average summer water temperatures and the annual growth of adults. Besides this there is a correlation between sudden changes in water temperature and mortalities of adults. Their survival is limited by catastrophic high temperature experiences which they suffer from time to time in summer months.

In the Bay of Fundy, on the other hand, recent studies (Dickie 1950) have shown a close direct correlation between the strengths of various year classes and temperatures at the time these year classes were spawned, but mortalities like those off P.E.I. have never been reported.

Bearing in mind the often-observed fact that young animals are more resistant to high temperatures than adults of

the same species, and the importance which has been ascribed to the height of temperature in development of eggs and sperms in the gonads, this evidence indicates that in the Bay of Fundy and the Gulf of St. Lawrence we are dealing with two areas which normally experience temperatures that are respectively near the lower (Bay of Fundy) and upper (Gulf of St. Lawrence) thermal tolerance limits for the survival of scallop populations.

Cognizance of these contrasting conditions is important to the investigator because it leads directly to an understanding of the reasons why factors which control the activity of the animal should be different in the two areas. It should permit proper orientation and better planning of future ecological and physiological investigation.

VII GENERAL SUMMARY

1) In the summer of 1946 a preliminary investigation of the scallop stocks off Boughton Island, P.E.I., was undertaken.

2) The Prince Edward Islanders use a variation of the standard Digby drag which is designed to bring up less debris and the technique of handling the drags differs somewhat from that off Digby. Methods for shucking and handling the catch are almost the same in both places.

3) Commercial catches were sampled for study of size-frequency distribution. Part of the sub-commercial-sized population was sampled by a special small-mesh drag.

4) Studies of size- and age-frequency composition show considerable variations in the strengths of various year classes. In 1946 the 3- and 7-year-olds were relatively scarce.

5) Growth rate studies show that P.E.I. scallops grow more slowly and reach a smaller final size than those from the Bay of Fundy and Georges Bank. Comparison of growth in different years show an inverse relationship between growth and average summer water temperatures. Prince Edward Island water temperatures may be too high for optimal growth.

6) There was no clear relationship between temperature and growth from the time of settlement until the formation of the first winterring, indicating that some factor other than temperature must be important in controlling the first season's growth.

7) Analysis of catch records indicates that fishing at P.E.I. in 1945 and 1946 was intense and that up to 70% of catchable stocks were removed each season. In 1945 scallops were abundant and total landings were high. In 1946 they were scarce, partly because fishing in 1945 had removed more than were replaced

by recruitment, and partly because of a serious 1946 summer mortality of stocks. The 1946 total landings were low.

8) Observations on the 1946 mortality indicate that it removed up to one third of the fishable stocks in about two weeks. It was serious enough to upset predictions of potential catches and showed the uselessness of the size limit as a conservation measure in that area.

9) Evidence to date indicates that the mortality was caused by southeasterly storms which shifted the level of the thermocline and flooded the beds by warm water whose high temperature was lethal to the scallops.

VIII FURTHER WORK SUGGESTED

This report attempts to point out some of the factors producing major changes in the scallop populations off the southeast coast of P.E.I. Some suggestions have been incorporated which may be helpful in future investigations of reproduction, growth, recruitment of commercial stocks and of both fishing and natural mortality. Further work along such lines is necessary before any recommendations for the improvement of fishing practice can be made.

For an understanding of the main problems the investigational program should include:

(1) Continued sampling of the population for size-frequency distribution to provide a basis for accurate prediction of the relative abundance of commercial stocks available. Careful strip census, tagging, and collection of detailed catch data are important for transforming these predictions of relative abundance into predictions of absolute abundance.

(2) Some method should be devised for studying and enumerating the youngest age groups. Examination of gonads and plankton tows should be made to determine the time of spawning and the distribution of larvae. Such records for several successive years should then be compared and correlated with hydrographic changes. This should give a clearer understanding of the reasons for success and failure of particular year classes and supply information important for predictions of fishing stocks.

(3) Annual examination of the older stocks and studies of commercial landings with simultaneous hydrographic observations are desirable for evidence of the cause of future mortalities. Collections of preserved, dead, dying and healthy animals for laboratory study, as well as an exhaustive study of the thermal tolerance of scallops, should be followed to provide a better basis for interpreting field observations on mortalities.

(4) Further studies of annuli to supplement present information on growth rate and recruitment are recommended. There is

still some uncertainty about the position of the first annulus.

(5) Observations on fishing effort and abundance for accurate estimates of the intensity of the fishery and of the effects on the population should be continued. The Boughton Island area is particularly well suited to a study of this kind because:

(a) The numbers of units fishing the beds are small and changes are readily detected.

(b) The entire bed is small and regularly covered by the fishery making interpretation of observations by the investigator relatively easy.

(c) Scallops from other grounds are not landed in south-eastern P.E.I. ports simplifying the collection of reliable catch statistics.

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APPENDIX

Shell diameters (heights judged from shell annuli) attained by Boughton Island scallops of various ages by end of successive years' growth and the growth increment for each year. Sample taken in August 1946 (see table 2).

		Year of Growth							
		1st		2nd		3rd		4th	
Specimen No.	Age	Growth	Size	Growth	Size	Growth	Size	Growth	Size
		1945							
1	1	21	21						
12	1	24	24						
		1944		1945					
2	2	21	21	13	34				
3	2	20	20	12	32				
4	2	17	17	23	40				
		1943		1944		1945			
5	3	19	19	11	30	13	43		
6	3	13	13	14	27	18	45		
7	3	18	18	13	31	16	47		
8	3	19	19	17	36	11	47		
11	3	14	14	15	29	16	45		
13	3	18	18	14	32	17	49		
17	3	19	19	18	37	16	53		
18	3	19	19	19	38	17	55		
		1942		1943		1944		1945	
9	4	14	14	13	27	7	34	16	50
10	4	14	14	11	25	15	40	14	54
15	4	16	16	10	26	18	44	19	63
16	4	18	18	14	32	14	46	12	58
19	4	12	12	15	27	13	40	16	56
20	4	11	11	16	27	16	43	14	57
21	4	12	12	13	25	15	40	14	54
22	4	15	15	11	26	17	43	10	53
23	4	18	18	9	27	13	40	17	57
24	4	20	20	16	36	16	52	14	66
25	4	18	18	16	34	16	50	13	63
26	4	17	17	15	32	9	41	16	57
27	4	17	17	19	36	14	50	13	63
28	4	16	16	18	34	15	49	11	60
29	4	17	17	20	37	13	50	11	61
30	4	15	15	16	31	19	50	15	65
31	4	17	17	16	33	19	52	11	63
32	4	20	20	20	40	11	51	16	67
34	4	13	13	19	32	18	50	19	68
35	4	15	15	23	38	10	48	16	64

APPENDIX (Continued)

Specimen No.	Age	Year of Growth: 1st Growth	1st Size	2nd Growth	2nd Size	3rd Growth	3rd Size	4th Growth	4th Size	5th Growth	5th Size
		1942		1943		1944		1945			
37	4	20	20	21	41	14	55	14	69		
38	4	16	16	24	40	14	56	11	67		
39	4	21	21	17	38	14	52	13	65		
40	4	18	18	18	36	16	52	13	65		
41	4	19	19	18	37	12	49	16	65		
42	4	20	20	17	37	18	55	12	67		
43	4	22	22	14	36	18	54	12	66		
44	4	16	16	14	30	18	48	15	63		
45	4	20	20	13	33	10	43	17	60		
46	4	17	17	16	33	16	49	14	63		
47	4	19	19	17	36	14	50	14	64		
48	4	17	17	17	34	17	51	11	62		
49	4	14	14	18	32	17	49	14	63		
50	4	16	16	17	33	15	48	14	62		
53	4	17	17	20	37	17	54	14	68		
54	4	22	22	17	39	17	56	11	67		
55	4	22	22	17	39	16	55	13	68		
65	4	14	14	20	34	15	49	16	65		
68	4	18	18	21	39	20	59	11	70		
69	4	18	18	26	44	14	58	14	72		
77	4	17	17	20	37	17	54	13	67		
92	4	13	13	16	29	22	51	24	75		
93	4	13	13	17	30	18	48	15	63		
95	4	12	12	14	26	17	43	24	67		
		1941		1942		1943		1944		1945	
33	5	19	19	10	29	17	46	13	59	11	70
36	5	16	16	13	29	16	45	16	61	9	70
51	5	7	7	12	19	13	32	15	47	13	60
52	5	15	15	12	27	20	47	13	60	11	71
57	5	17	17	11	28	20	48	15	63	14	77
61	5	14	14	11	25	23	48	16	64	10	74
63	5	17	17	16	33	23	56	11	67	8	75
64	5	12	12	15	27	19	46	15	61	13	74
66	5	21	21	18	39	17	56	9	65	11	76
67	5	15	15	12	27	17	44	13	57	13	70
70	5	16	16	12	28	19	47	11	58	13	71
71	5	16	16	14	30	22	52	11	63	13	76
72	5	11	11	17	28	15	43	16	59	15	74

APPENDIX (Continued)

Specimen No.	Age	Year of Growth 1st Growth	1st Size	2nd Growth	2nd Size	3rd Growth	3rd Size	4th Growth	4th Size	5th Growth	5th Size	6th Growth	6th Size	7th Growth	7th Size
		1941		1942		1943		1944		1945					
80	5	19	19	16	35	21	56	8	64	13	77				
83	5	6	6	14	20	25	45	14	59	13	72				
89	5	9	9	14	23	20	43	15	58	13	71				
94	5	15	15	16	31	19	50	15	65	13	78				
96	5	18	18	24	42	17	59	14	73	10	83				
99	5	13	13	11	24	20	44	15	59	14	73				
100	5	13	13	20	33	17	50	17	67	14	81				
104	5	18	18	16	34	23	57	14	71	9	80				
106	5	6	6	12	18	25	43	19	62	17	79				
		1940		1941		1942		1943		1944		1945			
56	6	9	9	18	27	15	42	16	58	12	70	10	80		
58	6	17	17	20	37	17	54	12	66	10	76	6	82		
59	6	7	7	14	21	18	39	17	56	11	67	9	76		
62	6	11	11	11	22	21	43	17	60	12	72	11	83		
76	6	5	5	13	18	21	39	14	53	10	63	8	71		
79	6	13	13	16	29	10	39	11	50	10	60	14	74		
81	6	18	18	12	30	12	42	10	52	11	63	9	72		
87	6	19	19	18	37	14	51	7	58	12	70	13	83		
90	6	14	14	15	29	17	46	20	66	9	75	6	81		
91	6	14	14	16	30	14	44	14	58	12	70	11	81		
97	6	6	6	14	20	15	35	18	53	9	64	11	75		
98	6	13	13	14	27	16	43	15	58	12	70	9	79		
105	6	17	17	24	41	14	55	13	68	8	76	8	84		
107	6	15	15	16	31	18	49	18	67	14	81	8	89		
116	6	17	17	20	37	17	54	18	72	14	86	6	92		
132	6	14	14	17	31	15	46	22	68	16	84	11	95		
138	6	19	19	22	41	27	68	13	81	9	90	7	97		
139	6	17	17	27	44	25	69	14	83	9	92	8	100		
		1939		1940		1941		1942		1943		1944		1945	
60	7	16	16	14	30	21	51	11	62	11	73	5	78	7	85
85	7	15	15	15	30	19	49	14	63	11	74	3	77	2	79
102	7	12	12	14	26	20	46	14	60	12	72	7	79	7	86
103	7	12	12	20	32	24	56	13	69	7	76	7	83	6	89
108	7	13	13	8	21	17	38	25	63	18	81	14	95	7	102
112	7	19	19	20	39	17	56	18	74	12	86	9	95	7	102
113	7	9	9	10	19	24	33	18	51	18	69	12	81	14	95

APPENDIX (Continued)

Specimen No.	Age	Year of Growth 1st Growth	1st Size	2nd Growth	2nd Size	3rd Growth	3rd Size	4th Growth	4th Size	5th Growth	5th Size	6th Growth	6th Size	7th Growth	7th Size	8th Growth	8th Size	9th Growth	9th Size	10th Growth	10th Size
		1939		1940		1941		1942		1943		1944		1945							
125	7	14	14	14	28	18	46	23	69	14	83	11	94	6	100						
130	7	6	6	14	20	23	43	28	71	16	87	10	97	6	103						
131	7	17	17	25	42	17	59	9	68	12	80	8	88	8	96						
137	7	17	17	23	40	20	60	17	77	9	86	7	93	3	96						
		1938		1939		1940		1941		1942		1943		1944		1945					
117	8	10	10	16	26	21	47	21	68	8	76	9	85	7	92	7	99				
119	8	19	19	11	30	21	51	17	68	14	82	8	90	7	97	5	102				
122	8	17	17	17	34	15	49	12	61	14	75	12	87	10	97	9	106				
126	8	4	4	12	16	28	44	24	68	16	84	8	92	6	98	5	103				
133	8	15	15	16	31	19	50	19	69	13	82	10	92	6	98	5	103				
		1937		1938		1939		1940		1941		1942		1943		1944		1945			
110	9	12	12	16	28	16	44	25	69	11	80	11	91	6	97	6	103	2	105		
118	9	15	15	16	31	17	48	17	65	18	83	14	97	4	101	5	106	4	110		
127	9	13	13	14	27	16	43	17	60	11	71	12	83	10	93	5	98	6	104		
136	9	12	12	20	32	13	45	13	58	24	82	9	91	8	99	5	104	8	112		
		1936		1937		1938		1939		1940		1941		1942		1943		1944		1945	
121	10	11	11	10	21	12	33	19	52	14	66	13	79	7	86	6	92	5	97	4	101
124	10	17	17	14	31	22	53	21	74	19	93	7	100	5	105	4	109	4	113	1	114
134	10	15	15	12	27	13	40	13	53	14	67	12	79	11	90	8	98	5	103	4	107
Average Size		15.38		31.21		48.12		63.21		75.70		85.90		95.04		101.92		106.29		107.33	
Average Growth			15.83		16.91		15.09		12.49		10.20		9.14		6.88		4.37		1.04		