FISHERIES RESEARCH BOARD OF CANADA

MANUSCRIPT REPORTS OF THE BIOLOGICAL STATIONS

No. 420

Title

Growth of the giant scallop

(*Placopecten grandis* (Sol.)), 1932

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GROWTH IN THE GIANT SCALLOP (*Placopecten grandis* (Sol.))

by

J.A.Stevenson. Queen's University, Kingston, Ontario.

Report for 1932.

CONTENTS:

INTRODUCTION.

(a) Facilities and time of investigation:-

The investigation providing the material for this report was undertaken at the suggestion of Dr.A.G.Huntsman, at the Biological Station at St. Andrews, N.B. during the summer of 1932.

(b) Statement and significance of the problem:-

1. Purposes.

Since the year 1921 the scallop fishery of Eastern Canada, particularly of the Fundy area, has increased greatly in economic importance, largely due to the commercial exploitation of large scalloping areas discovered about that time off the west coast of Nova Scotia in the Bay of Fundy (Margaretville to Brier Island). Notwithstanding the relative importance of the fishery, very little work appears to have been done upon the life-history and growth-rate of the scallops. If the fishery is to be conducted to the best advantage in the future knowledge of the life-history and of the various factors influencing the growth of the scallops in their natural habitat is essential, in order that methods of conservation may be used most effectively. The nature of the Canadian scallop-fishery is such that conservation is found to be necessary, as the past history of this fishery has shown that scalloping areas can be, and have been fished out comparatively easily within a short space of time. If, for instance, it is desired to protect a certain area from over-fishing until such time as it shall have recuperated; a knowledge of the growth-rate of scallops in that vicinity is necessary in order that the necessary period of protection may be determined.

The present report is concerned only with the growth-rate of the scallops under varying conditions.

The chief purposes of this investigation fall into five groups:-

1. The correlation of certain growth-lines upon scallop-shells with definite periods of time, and the forming, in this way, of a basis of age-determination of shells from different areas.
2. The determination of the age to which scallops live.
3. The determination of the age at which scallops in different areas attain the legal size of 4 inches.
4. The determination of the average rate of growth per unit of time for (a) The whole of Eastern Canada
   (b) Various localities on the east coast, exhibiting different environmental conditions.
5. The correlation of the growth-rate with environmental conditions in different areas.

2. General Natural History.

The Giant Scallop (Placopecten grandis Solander), which is the species under discussion, is a bivalve inhabiting comparatively deep water, being found in all depths ranging from low-tide mark down to 150 fathoms. It appears to be most abundant, in Canadian waters, between 10 and 45 fathoms (Moore(4)).

After it has passed the larval stage, it settles onto the bottom of the sea, where it lies on the somewhat flatter, lower valve of its shell, for the rest of its life. Upon settling on the bottom, the young scallop generally anchors it self by a byssus of two or three short threads, which may persist up till the time the scallop has attained a size of about three inches. Such a specimen was seen by the author off Grand Manan Island. The older scallops, however, never appear to be anchored by such a byssus, remaining free on the bottom. Judging from the dragging results (Moore (4)) the type of bottom preferred is sand or sand and gravel, although scallops may be taken on practically all bottoms, excepting, possibly, oozy mud.

The food of the Giant Scallop consists largely of plankton, the examination of many stomachs from L'Etang Harbour and the St. Croix River showing such forms as Pleurosigma, Distephanus and Tintinnids to be predominant.

In the adult state, scallops are almost unique among Pelecypods in being able to swim freely through the water, by the alternate opening and rapid closure of the valves, the consequent expulsion of water at each snap causing the animal to progress by a series of jerks. If environmental conditions in one particular area are unsatisfactory, the scallops are thus capable of moving elsewhere. This is a very important factor in the study of the growth of the animals. We may for instance, have a specimen from one locality, which shows growth-lines on its shell that are representative, perhaps, of conditions entirely different from those obtaining in the area where captured.

The valves of <u>Placopecten</u> are unequal in shape and intensity of colouration, the upper valve being considerably more convex than the lower, and also generally more heavily pigmented. Examination shows that both the upper and the lower valves are also marked with definitely arranged striae and grooves. These are found to be of two types: radiating and concentric. The radiating striae have their focal point at the umbo, although some extend only a short distance from the edge of the shell towards the umbo. These striae are very numerous and fine, being about one millimetre apart at the edge of the shell, and considerably closer at the umbo.

The concentric grooves are very much fewer in number than the radiating ones. They vary somewhat in distinctness, from fine, hardly discernible lines up to very conspicuous "check marks". The fine lines are comparatively abundant all over the shell, and are not placed at regular intervals. The coarser "check marks", however, are unmistakably regular in position upon the various shells. In all specimens examined, it was found that the distance between the concentric grooves, or

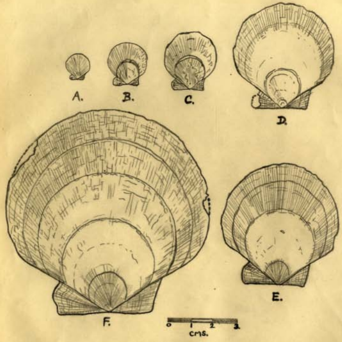


Figure 1. Typical scallop-shells, showing rings of growth.

"rings" was greatest near the umbo, gradually diminishing towards the edge of the shell (Figure 1.).

In a large majority of the shells examined, it was found also, that the colouration upon the upper valves was most intense on the edges of the rings nearest the umbo. This fact aided very considerably in the detection of these rings, and the separation of them from the less conspicuous, irregularly placed finer lines.

In some specimens, when the shells were held up to the light, it was found possible to detect the rings, which showed very clearly by transmitted light, often when they were indistinct by reflected light. This method was only applicable to the thinner shells that were able to transmit light. It was applied with success to a sample of thin shells from Chester, N. S.

As the scallop grows, the shell increases in size by the deposition of new material at its edges. This deposition takes place quite evenly around the edge of the shell, which thus extends away from the umbo. Now if anything occurs that would affect the rate of deposition of the shell in this manner, the event is likely to be recorded along the entire edge of the shell, being later discernible as a more or less distinct ring that corresponds to the shape of the shell when it was formed. Marks like this have been found definitely to correspond to increased or retarded growth-rate under known conditions in several species of molluscs, including Pecten (Belding (1)). It is therefore comparatively safe to assume that such concentric marks in Placopecten, corresponding as they do to the general contour of the shell, are caused by a change in the growth-rate, more or less sudden as the case may be, due to a change in the environmental conditions under which the scallops are living.

(c) Review of Literature:-

1. Growth in Bivalve molluscs.

The growth of certain commercial bivalve molluscs has been quite exhaustively treated by several investigators. Weymouth (9) on the Pacific Coast, and Belding (1) on the Atlantic Coast have both shown conclusively that a constant relation exists between the rings of growth and periods of retarded growth in the Pismo clam (Tivela) and the Bay Scallop (Pecten irradians)during the winter-time. A similar state of affairs has been found in the soft-shell clam (Mya) by Newcombe (5), the Oyster (O.edulis)by Orton (6), and many other species. There is however, practically no literature upon the growth of Placopecten. Drew (3) noted the general appearance of the rings of growth upon the shells; but went no further. Borden (2) working at St. Andrews, examined over three hundred scallop-shells, and measured the distances between the lines of growth of upwards of three hundred specimens of scallops from Fundy waters. Her results showed that, as mentioned above, the interlinear spaces were widest near the umbones, and diminished in width towards the edge of the shell.

It might be assumed that due to their close systematic relationship, growth in Placopecten and Pecten (irradians) would be similar. Whereas Belding (1) has demonstrated that Pecten seldom lives more than two years, there is every reason to believe that Placopecten may attain an age well over ten years.

Now the Giant and Bay Scallops live in entirely different habitats -- the former in deep water, the latter in the sub-littoral zone just below low-tide mark. These differences, then, in the two forms, make it evident that a study of the growth of Placopecten, to be properly conducted must be undertaken as an entirely separate problem from that of the growth of Pecten. Thus, assumptions from the known facts regarding the growth in Pecten, must be soundly based if they are to be applied to Placopecten.

2. Methods employed in the study of Molluscan growth.

The various methods employed by investigators in this field fall into three main groups:-

(a) The age-group method.

(b) The annual ring method.

(c) The experimental field method.

The present investigation is concerned with (a) and (b), particularly with the question of the validity of (b) in the case of Placopecten.

In the age-group method, large numbers of specimens are taken at definite intervals, and measured. It is generally found that any one sample taken at one time from one locality shows certain predominating size-groups. By comparing the modes of each size -- or age-group at different times, the amount of increase can be noted and an estimate of the growth-rate under various conditions can be arrived at.

The annual-ring method is concerned with the study of rings or lines of growth corresponding to periods of retarded metabolic rate in the animals. An estimate of the growth-rate can be obtained by measuring the distances between the rings, each of which represents a year's growth.

EXPERIMENTAL RESULTS.

(a) Material Used:-

Five samples of scallop-shells were examined as follows:

Sample No. 1. Empty shells, valves separate. Part of the Grand Manan commercial catch for the winter of 1931-32. Dragged on the Duck Island beds, with commercial drags (4-inch mesh), shortly before January 29th, 1932. Depth: 9-10 fthms. Bottom: sand and shells.

Sample No. 2. Empty shells, valves separate. Part of the Grand Manan commercial catch for the spring of 1932. Dragged in the vicinity of Duck Island, with the commercial drags (4-inch mesh), during the latter part of March and the early part of April, 1932. Probably from the same beds as Sample No. 1.

Sample No. 3. 42 living scallops, of all sizes, dragged in L'Etang Harbour with a rope drag, on August 2, 1932. Depth: 5-15 fthms. Bottom mud and stones.

Sample No. 4. Empty shells, valves separate. Part of the Chester, N.S. commercial catch for the winter of 1931-32. Dragged in Mahone Bay.

Sample No. 5. Empty shells, valves separate. Part of the Digby, N. S. commercial catch for the winter of 1931-32. Dragged off Digby with the regulation 4-inch mesh drags, probably during the late spring, 1932.

The four localities mentioned above; Grand Manan, Mahone Bay, L'Etang and Digby; were chosen as representative of differing temperature conditions. In L'Etang harbour, the average temperature may be regarded as high. Digby is lower; and Grand Manan, around which considerable "mixing" of the cold and warm strata takes place, is lower still. Mahone Bay may be regarded as showing the lowest temperatures of the four regions. (8).

With the exception of Sample No. 3, the material examined consisted entirely of the upper or convex valves of the shells. A comparison was made between the upper and lower valves for distinctness of the lines of growth, and total length. It was found that whereas the lines of growth in upper and lower valves of the same animal (Sample No. 3) were equal in number whenever it was found possible to count them on both, those on the upper valves were generally found to be more clearly marked, due primarly to a deposition of pigment along the inner edge of each line, not found in the lower valves to any appreciable extent.

It was also found that the lower valves were often worn so much by contact with the sea bottom, that it was impossible to discern any lines at all.

The average total length of the upper valves was found to be about 2 m.m. greater than that of the lower valves.

In some specimens, particularly from L'Etang and Grand Manan, the upper valves were considerably riddled by the boring sponge Cliona, rendering it somewhat difficult to discern the rings. In others, the rings were completely covered, particularly in the vicinity of the umbones, by coralline growths. Such specimens were disregarded in the examination of these rings.

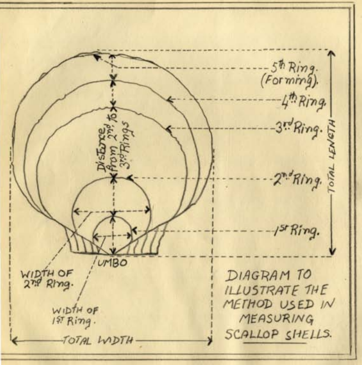


Figure 2. Methods of measurement.

It is to be noted that Samples No. 1,2,4, and 5 were representative commercially marketable scallops, hence possessed very few specimens of under 4 inches diameter. They are thus not representative of the scallop population as a whole upon the beds from which they were taken.

(b) Methods used.

Figure 2 shows the various methods of measurement employed. In practice, a pair of dividers, were used with a rule graduated in millimetres. The space upon the shell to be measured was marked off with the dividers, which were immediately placed upon the rule, indicating the measurement taken. This was noted down on a form previously prepared for filling in.

In the measurement of total length, the shell was placed directly upon the rule, concave side down, with the umbo resting upon the scale at one end, and the opposite edge of the shell at the other. The reading at the umbo (100m.m. for convenience) was then subtracted from the reading at the latter, giving the total length of the shell.

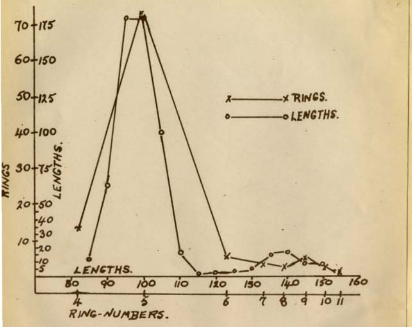
Weight measurements of living specimens will be discussed later.

Samples Nos. 1 and 2 furnished material for a preliminary study of the growth-rate by the age-group method; a study more suggestive than conclusive. The other samples were chiefly studied with regard to the rings of growth, sample No. 3 giving some data upon weight-increase.

(c) Criterion of growth.

Three criteria may be taken:-

1. Rings of growth, if annually deposited.
2. Length.
3. Weight.



ıre 3. Correlation between length-frequencies and ring-frequencies in Sample No: 1 Grand Manan.

1. The evidence seems to suggest that the rings of growth upon the shells of Placopecten are annual; but this has not yet been definitely proved. More investigation in this field is necessary, as the whole problem of the growth-rate in the scallop may almost be said to focus upon the establishment of the annual nature of these rings.

The following are the main reasons for believing that the rings on the shells of the scallops are annual:-

(i) Sample No. 1 was taken in mid-winter; out of a random sub-sample from this sample, consisting of 220 upper valves, it was found that in 218 (99.1%) the outermost ring of growth had just been formed, was partly formed, or was just about to be formed. This suggests that the ring was formed in mid-winter; and since the other rings upon the shells were similar, that they too, had been formed in mid-winter.

(ii) Sample No. 3 was taken in mid-summer and in 31 of the more definitely marked shells in the 42 constituting the sample, it was found that the distance from the outermost ring to the edge of the shell averaged 58% of the average width of the penultimate ring-space. In addition, this outermost space on the shells was composed of very much finer, translucent, and obviously more recently deposited material than the preceding ring-space. Thirty-one scallops is not a very large number upon which to base differences such as the above, but the following table indicates that these values are significant:-

Ring-space concerned	Number of specimens	Standard Deviation m. m.	Coeff. of Variability	Probable Error	Mean
Penultimate ring	31	4.56	44.2	3.08	P.E.x 3.35
Ultimate ring	31	3.15	52.9	2.12	P.E.x 2.81

Table I. Relation in width between ultimate and penultimate ring-spaces in L'Etang scallops.

It can be seen from these figures that considerable variability occurs.

(iii) In sample No. 1 a curve of the length-frequencies of the upper valves was taken, lengths being shown on the abscissa. Along the abscissa, at definite intervals determined by the measurements of the distances between the rings, each ring-number was marked, and a curve showing the ring-number was plotted. (Figure 3). It was found that the modes of this curve corresponded very closely with those of the length-frequency curve. This method of checking the validity of rings of growth as a criterion of growth has been used before (Scofield (7)) with success. It stands to reason that the dominant age-group in a sample when measured for length will also form the dominant age-group in the sample when measured for rings, if the rings are deposited at definite periods. Spawning is known to take place every year: this means that every year another age-group is formed. It is therefore natural to suppose that these "definite periods" are yearly.

(iv) In very many forms of molluscs it has been found that when the rings of growth are distinctly marked, they correspond to periods of slow growth during the winter. This would appear to agree with the above suppositions as to the time of origin of the rings of growth in Placopecten.

The above facts make it fairly evident, but by no means conclusive, that the rings of growth in Placopecten are deposited once a year, during the winter-time. This can only be proved, however, by actual experiment; and experimentation with Placopecten appears to present difficulties due to the inaccessibility of its natural habitat. It is possible that more than one ring may be formed in a year, due perhaps to unusual conditions. In the material examined, specimens were occasionally found in which two rings were situated very close together. Since there was some uncertainty in such cases as to why these rings should be placed close together, such specimens were disregarded.

2. Length has been used as a criterion of growth very widely. It is applicable to such animals as scallops, which are known to increase in length with age: and has been used in the present investigation with regard to (i) total size of the scallops, and (ii) the total addition per ring of growth in length of the shells.

3. Weight is a very important factor in the study of growth in animals, and is useful as a criterion of growth particularly with such forms as cannot well be measured in any other way for increase in size. Only Sample No. 3 furnished material for the measurement of weight in Placopecten; and since this sample was somewhat small, nothing very conclusive has been shown to exist in this field.

Length-frequencies

Lengths m.m.	Frequencies
76-80	1
81-85	16
86-90	64
91-95	182
96-100	180
101-105	100
106-110	17
111-115	1
116-120	1
121-125	3
126-130	5
131-135	15
136-140	16
141-145	9
146-150	6
151-155	1
Total	618

Ring-frequencies

Ring-number	Frequencies	Corresponding length
3	0	70
4	13	83
5	78	100
6	5	114
7	3	123
8	2	130
9	5	135
10	2	141
11	1	145
12	0	- -
Total	109	

Table II. Length and Ring-frequencies in Sample No. 1.

(d) Number of growth-rings:-

If it be correct, as it very probably is, to assume that the rings of growth are deposited once annually, the maximum number of rings to be found upon one shell from a given locality will indicate the maximum age in years to which the scallops can grow under the prevailing conditions in that locality. The following maxima were found for the four regions under consideration:-

Chester, N.S.	15 rings
Digby, N.S.	12 rings
Grand Manan	12 rings
L'Etang, N.B.	13 rings

Shells possessing more than 11 rings were found to be rare except perhaps in the Digby sample (Sample 5), which contained quite a number of shells with 12 rings.

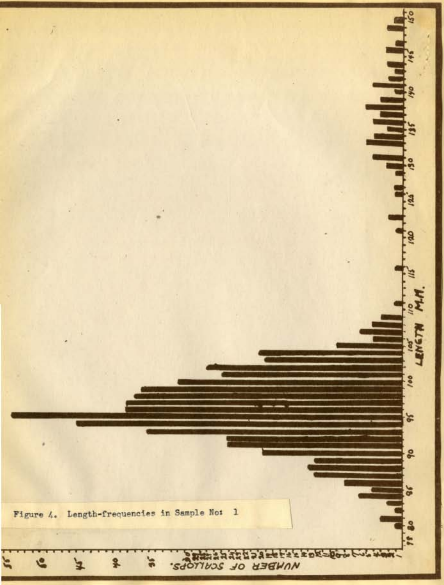


Figure 4. Length-frequencies in Sample No: 1

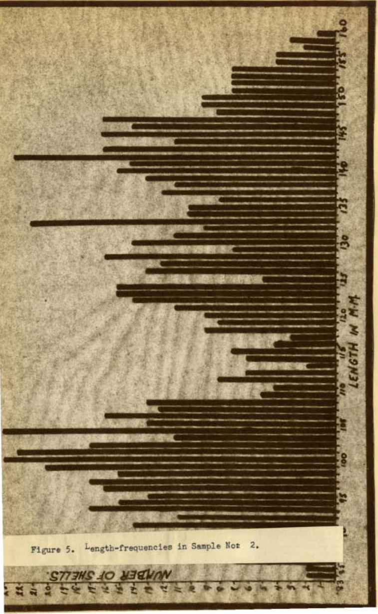


Figure 5. Length-frequencies in Sample No: 2.

In general 11 was the greatest number of rings found upon the shells in appreciable numbers. This applied to all four regions. If the rings are annual, it may therefore be assumed that the average span of life of Placopecten is about 11 years, occasionally being extended as far as fifteen. This is in marked contrast to Pecten irradians, which lives seldom longer than two years.

(e) Growth in Length.

1. Age-group determination of growth-rate.

Samples Nos. 1 and 2, from Grand Manan, were taken, it is believed, on the same scallop beds or not far apart. Sample No. 2 was dragged a little more than two months later in the season than Sample No. 1. If any growth took place during those two months (January to March), it is natural to suppose that it would be reflected in the positions of the modes in the length-frequency curves. The peak corresponding to the dominant age-group in Sample No. 1 will have moved up slightly in Sample No. 2. This was found to have occurred to a certain extent. Figures 4 and 5 show the length-frequency curves for the two samples. In Sample No. 1 the dominant age-group is very clearly shown: in Sample No. 2 it is not so clear, but still fairly unmistakable. It will be noticed that the peak of this age-group is at 95 m.m. in Sample No. 1, and at approximately 100 m.m. in Sample No. 2. It therefore seems probable that the difference of approximately 5 millimetres in the average lengths of this age-group was made in the two months, February and March, 1932. Again, in the smaller group towards the right end of the figure, a shift of approximately 3 millimetres can be perceived. In Figure 4, the mode is above 136 m.m. whereas in Figure 5, it is approximately above 139 m.m. It is natural to suppose that this age-group, being older, would not increase as much as the dominant one. This is, however, all the material that could be examined from this view-point. In order accurately to determine growth-rate by the age-group method, it is necessary to have regular samples taken from the same place throughout the year. The above example appears to suggest that this method could be used with Placopecten with a fair probability of success, especially with young specimens, which are still growing fast and, when belonging to one age-group, are more or less uniform in size.

Length m.m.	Sample 1	Sample 2
76- 80	1	3
81- 85	16	4
86- 90	64	33
91- 95	182	70
96-100	180	91
101-105	100	86
106-110	17	50
111-115	1	29
116-120	1	33
121-125	3	60
126-130	5	52
131-135	15	61
136-140	16	59
141-145	9	79
146-150	6	56
151-155	1	32
156-160	0	10
Totals	617	818

Table III. Length-frequencies in Samples 1 and 2.

2. Total lengths of shells at time of deposition of rings of growth.

In the measurement of the rings of growth, rings beyond the ninth were not considered because in a large number of cases they were found to be somewhat too indistinct and narrow for accurate measurement.

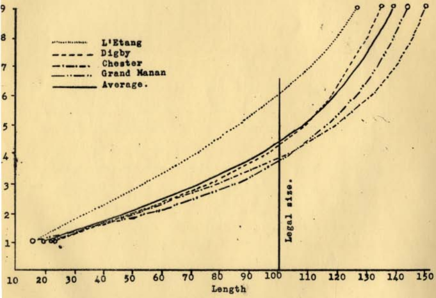
All the samples were examined. Measurement was made around the shells from the umbones along the median line of the shell to each ring. Figure 6 shows the resulting curves for the four localities considered, and the average curve for the whole.

	L'Etang, N.B.	Grand Manan	Digby, N.S.	Chester, N.S.	Average for whole
Number examined	42	200	101	200	(543)
1st ring	16.4	15.7	23.2	22.5	19.4
2nd "	34.9	57.1	50.7	52.0	48.7
3rd "	54.6	87.4	76.4	80.1	74.6
4th "	71.9	104.5	95.5	103.1	93.7
5th "	86.5	117.1	108.9	119.7	108.0
6th "	99.9	126.6	118.5	132.1	119.3
7th "	111.4	134.4	125.7	140.5	128.0
8th "	120.6	140.5	131.2	146.7	134.7
9th "	127.6	144.9	135.4	151.2	139.8

Table IV. Average lengths of scallops for different regions at the times of deposition of the first nine rings of growth. Upper valves. Lengths in millimetres.

These curves are of double significance. They indicate the lengths of the scallops in different regions at the times the rings were deposited on the shell, showing clearly how growth is retarded as the mollusks become older. They also suggest the age at which the scallops attain the legal size of 4 inches (100 m.m.) in these different areas. It will at once be noticed that there is considerable variation in the positions of these curves. L'Etang scallops form one extreme, in which the growth is apparently very slow, but in which the slow growth persists

Figure 6. Average lengths at time of deposition of each ring.

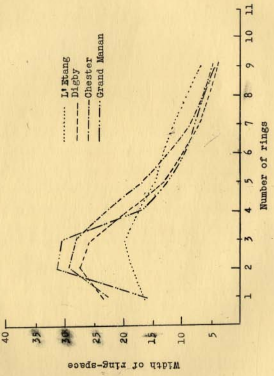


at an approximately constant rate after scallops from the other localities have begun to decrease the speed of their growth. Digby scallops appear to approximate the average very closely in their rate of increase, while both Chester and Grand Manan specimens grow considerably faster. The Grand Manan scallops apparently increase their length faster than the others up to the time of deposition of the fourth ring. After that, their rate of growth diminishes, and Chester scallops take their place. Thus in scallops from these four regions that possess an equal number of rings of growth above four, the largest will on the average be found to have come from Chester.

If it be assumed that the rings of growth are annual in nature, a very significant comparison may be drawn between these curves. A vertical line from the 100 m.m. point on the abscissa has been drawn intersecting the curves. The points on the ordinate corresponding to these points of intersection will therefore indicate the number of rings (years?) that were formed up to the time the scallop attained the legal size of 4 inches. It will thus be seen that L'Etang scallops would take six years, whereas Grand Manan and Chester scallops would take less than four years, to attain this size. Digby scallops would take about 4 ½ years.

This point is of vital significance in the conservation of the scallop-beds for the benefit of future fishery. From this it can be seen how important a bearing the establishment beyond doubt of the annual nature of the rings has upon the fishery. If it is known for certain how much time elapses before a young scallop attains the legal size, conservation methods can be applied for a predetermined definite period of time, with reasonable prospect of success.

Figure 7. Average lengths of spaces between rings of growth.



3. Growth of scallops per added increment.

A more graphic method of comparing the actual rate of growth of Placopecten in the four regions under discussion is shown in Figure 7, which indicates the average additions in length to the shells of the scallops, per ring-space. Very marked differences can be observed in these curves. In all but the L'Etang scallops the peak of growth was attained between the first and second rings. In the L'Etang sample, which is apparently characterised by slow growth, it was between the second and third rings. In all cases the additions in length for the first three spaces far exceeded any subsequent additions. The retardation of growth-rate is clearly shown in Figure 7. As in Figure 6, it can be seen that the L'Etang scallops came nearest to constant growth-rate. In Grand Manan scallops, the acceleration in the second and third spaces was greatest, but slowed up more than any of the others in the fourth space. In the Chester scallops, it can be seen that the growth was rapid at first, and tended to persist at a high rate.

	L'Etang N.B.	Duck Island Grand Manan	Grand Manan	Digby, N.S.	Chester, N.S.	Average for whole
No. examined	42	200	200	101	200	(743)
1st space	16.4	22.3	15.7	23.2	22.5	20.0
2nd "	18.5	21.7	31.4	27.5	29.5	25.7
3rd "	19.7	26.4	30.3	25.7	28.1	26.0
4th "	17.3	12.4	17.1	19.1	23.0	17.8
5th "	14.6	17.3	12.6	13.4	16.6	14.9
6th "	13.4	---	9.5	9.6	12.4	11.2
7th "	11.5	---	7.8	7.2	8.4	8.7
8th "	9.2	---	6.1	5.5	6.2	6.7
9th "	7.0	---	4.4	4.2	4.5	5.0

Table V. Addition in length of scallops shells from different localities per rings of growth. Lengths in millimetres.

Figure 8. Percent addition in length of spaces between rings.

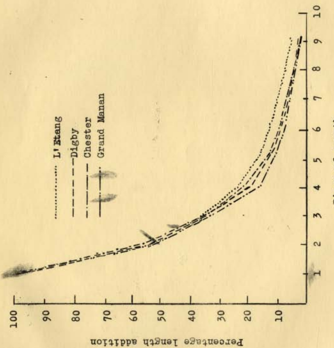
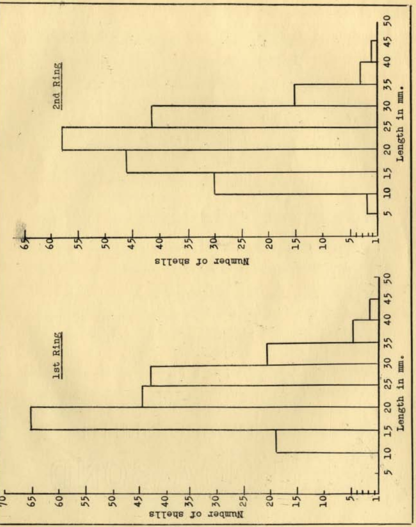


Figure 9. Length frequencies of 1st. and 2nd. ring spaces in sample No. 1.



Another method of indicating the same results is shown in Figure 8, in which the curves for the four regions are plotted, showing the average increase in length per ring as percent of the total length.

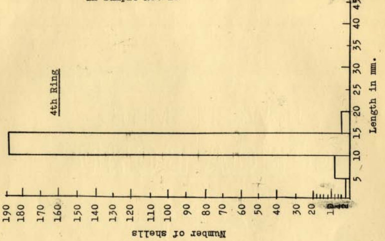
No. examined	L'Etang N.B. 42	Digby N.S. 101	Grand Manan 200	Chester N.S. 200	Average for whole (543)
1st space	100.0	100.0	100.0	100.0	100.0
2nd "	53.9	54.0	55.0	56.7	54.7
3rd "	36.1	33.6	34.6	35.1	34.8
4th "	24.1	20.0	16.4	22.3	20.7
5th "	16.9	12.3	10.8	13.9	13.5
6th "	13.4	8.1	7.5	9.4	9.6
7th "	10.3	5.8	5.9	5.9	7.0
8th "	7.6	4.2	4.3	4.2	5.1
9th "	5.5	3.1	3.0	2.9	3.6

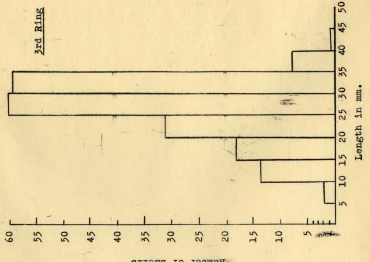
Table VI. Average percent addition in length per ring for the first nine rings, for scallops from different localities.

It will be noticed in Figure 8 how closely the curves for the four regions correspond for the first three rings of growth.

Tables V and VI are concerned only with the average growth of scallops per ring. The average growth is in certain cases not a very exact criterion of the typical growth for a particular region. A certain amount of variation between individuals is bound to occur; and in order to obtain a clear impression of the type of growth occuring in any one locality, it is necessary to know how great this variation is, and in what direction it occurs. For the purpose of obtaining such data, the obvious course in this instance is to observe the length-frequencies not only of the whole

Figure 10. Length frequencies of 3rd. and 4th. ring spaces in sample No. 1.





scallops themselves, but also of each ring of growth upon their shells.

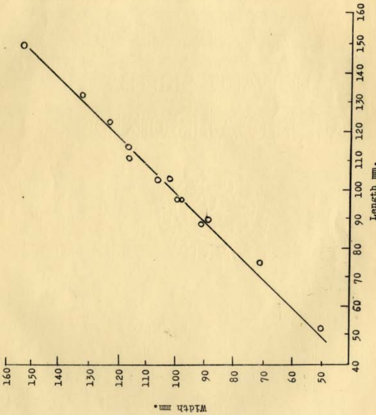
To illustrate the point, a single age-group, characterised by the possession of five ring-spaces, and by the approximate mean total length of 95 mm., and consisting of two hundred upper valves, was measured for length-frequencies of the different ring-spaces. The values obtained are shown in Table VII and Figures 9,10 and 11.

	RING-SPACES.				
	1st.	2nd.	3rd.	4th.	5th.
0-5 mm.	-	-	-	2	-
6-10 mm.	-	2	2	8	3
11-15 mm.	21	30	13	186	48
16-20 mm.	65	46	18	4	103
21-25 mm.	48	58	32	-	41
26-30 mm.	38	45	60	-	5
31-35 mm.	21	15	59	-	-
36-40 mm.	5	3	7	-	-
41-45 mm.	2	1	1	-	-
Coeff. Var.	28.2	26.1	25.5	12.7	20.6
Totals:	200	200	200	200	200

Table VII. Length-frequencies of spaces between rings. Upper valves.

The variations shown in these figures may be ascribed possibly to two causes: indistinctly defined rings, and the possibility of inaccurate measurement; and variations in living conditions resulting in varied growth-rate, upon the scallop-beds themselves. Since uncertain specimens were discarded, it is believed that the latter is the chief source of variation. It is interesting to note the decrease in the coefficients of variability for each ring, from the first to the fourth. The high coefficient of variability for the first ring-space may be ascribed to the extended spawning-season of the scallops, which would result in marked differences in the amount of growth during the first

Figure 12. Length-width relationships in Placopecten grandis.



year. The coefficients for the second and third ring-spaces are also high. It is possible that the scallops when young are more susceptible to changes in environmental conditions. The coefficient for the fourth ring-space is only about half of that for the third. The evidence seems to point to the fact that this fourth ring-space was deposited in the year 1930, which was a very exceptional year for temperatures. It seems remarkable that the coefficient of variability for the fifth ring-space should again be high. This possibly due to the fact that the fifth was the outermost ring, and in some specimens had not yet been formed, while in others it was fully formed.

4. Length-Width Relationship.

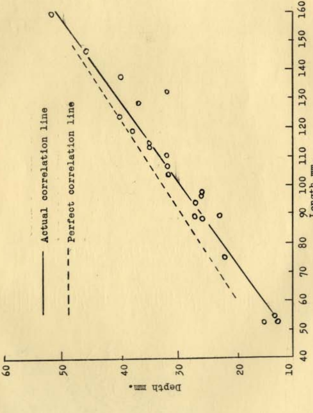
The relation between total length and total width of Placopecten shells was found to be very constant for all four areas considered. Taking the L'Etang sample (NO:3) as a typical example, the values shown in Table VIII and Figure 12 were obtained.

Length.	Width.
52.5	49.5 mm.
52.5	49.5 mm.
75	71 mm.
88	91 mm.
89	89 mm.
96	99 mm.
96	98 mm.
103	106 mm.
103	102 mm.
110	116 mm.
114	116 mm.
123	123 mm.
132	132 mm.
146	154 mm.
157	166 mm.

Table VIII. Length-Width relationships in L'Etang scallops.

The curve in Figure 12 is almost linear. In general, it may be said that as the scallops become older, their width very slightly exceeds their length. This is particularly so with the

Figure 13. Length-depth relationships in Placopecten grandis



Chester sample (No:4). Otherwise length and width are approximately equal. The curves for the other three regions so nearly approximate that of the L'Etang specimens, that it was considered sufficient to use only these as an example.

5. Length-Depth Relationship.

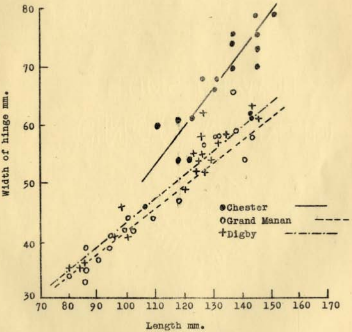
Since measurements to determine this value could only be made upon whole scallop-shells, (both valves joined), they were confined to sample 3, which consisted of living scallops. The total lengths (umbo to opposite edge) and depths (greatest perpendicular distance, when the shell is closed, from the exterior of the upper to the exterior of the lower valve) of all the 42 scallops in the sample were recorded, and a curve plotted (Figure 13). Table IX gives a series of the measurements taken.

Length	Depth
52.5	15 mm.
52.5	13. mm.
75	22 mm.
89	27 mm.
89	23 mm.
88	26 mm.
93	27 mm.
96	26 mm.
96.5	26 mm.
103	32 mm.
106	32 mm.
110	32 mm.
113	35 mm.
113	35 mm.
118	38 mm.
123	40 mm.
128	37 mm.
132	32 mm.
137	40 mm.
146	46 mm.
159	52 mm.

Table IX. Length-Depth relationships in L'Etang scallops.

Considerable variation from the average was found. For example, tow specimens of a depth of 32 mm. were respectively 103 and 132 mm. in length. In general, it may be said that although there was an increase in depth as the L'Etang scallops increased in length

Figure 14. Length-hinge-line relationships in Placopecten.



It remains to be seen whether the same applies to scallops from other areas.

6. Length-Hinge line Relationship.

A means of comparison, more of systematic than commercial interest, was found in an examination of the relative lengths of the hinge of scallops of given total lengths from different areas. It was noted that scallop-shells from some places appeared to possess a much broader hinge-line than scallops from others. To illustrate this graphically, the total lengths of scallops from Chester, Digby and Grand Manan were plotted against the lengths of their hinge-lines, the resulting curves being shown in Table X and Figure 14. It can be seen from these curves in

GRAND MANAN, N.B.		DIGBY, N.S.		CHESTER, N.S.	
Length	Hinge-Line	Length	Hinge	Length	Hinge
80	34	79	36	106	46 mm.
85	33	83	36	110	60 mm.
86	35	85	37	117	54 mm.
86	39	95	41	118	61 mm.
90	37	98	46	121	54 mm.
93	39	100	41	121	61 mm.
94	41	120	49	126	68 mm.
99	42	123	55	130	66 mm.
100	44	124	52	131	68 mm.
102	42	125	54	136	76 mm.
109	44	126	62	136	70 mm.
118	47	126	55	136	74 mm.
127	57	126	58	143	61 mm.
131	58	127	52	143	62 mm.
131	58	129	54	144	79 mm.
137	66	131	57	145	70 mm.
138	59	134	58	145	76 mm.
141	54	143	63	145	73 mm.
143	58	146	61	150	79 mm.
Means:	46.68		50.9		66.21 mm.
P.E. of Mean	± 6.7		±5.9		±6.0

Table X. Length-Hinge line relationships for three areas.

The Chester scallop's hinge-line was on the average much wider than that in the others. That this difference is a significant one is shown in the probable errors of the means included in the above

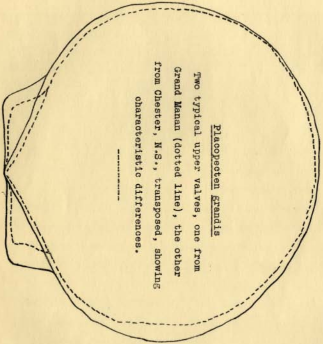


Figure 15. Relative shapes of Chester and Grand Manan scallops.

Figure 15 clearly shows this characteristic. An outline of a typical Chester scallop, drawn around the shell, is superimposed upon a similar outline of a Grand Manan scallop of approximately the same length. The great difference in the lengths of the hinge-lines is apparent; also the slightly broader shell of the Chester specimen. It would be futile at the present time to attempt to account for these differences. Suffice it to say that Figure 14 shows them to exist.

(f). Growth in Weight.

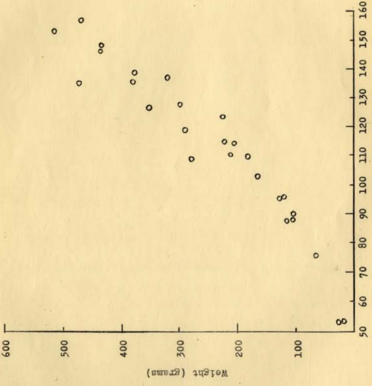
Since Sample No: 3 was the only one that consisted of living specimens, it formed the basis of all weight measurements taken. This sample was composed of only 42 animals; hence few conclusions can be drawn until further material of this type has been examined.

In weighing the scallops alive, it was essential first to remove all the water from their shells. Dessication is perhaps the most efficient method of doing this: but for roughly comparative purposes, as in the present case, it was considered sufficient to hang them umbo uppermost until they ceased dripping. The shape of their shells, and the arrangement of the body-organs within them made it possible for a very large percentage of the water to drip out. The specimens were then weighed upon a torsion balance to the nearest gram.

1. Weight-Length Relationship.

Weight, as obtained by the above method, was plotted against length, in the L'Etang scallops: and Figure 16 shows the resulting approximate curve, obtained from the figures in Table XI. As in the lengths-depths curve, considerable variation from the mean was found. In this case it is possible that this was largely due to experimental error (varying quantities of water in the shells); but this cannot be the sole cause. In general,

Figure 16. Weight-length relationships in <u>Placopecten</u> <u>grandis</u>.



it is seen that increase in weight is very rapid in proportion to the length after a total weight of about 80 grams has been attained. This is a typical weight-length curve, and is found in similar form in very many groups of animals.

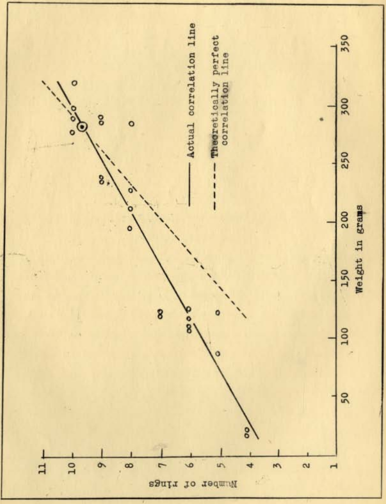
Length. mm.	Weight. grams.
52	18
52	20
75	68
87	114
88	108
89	107
95	125
96	127
103	164
109	281
110	212
110	183
114	205
115	222
119	290
123	228
127	351
128	300
135	472
136	379
137	322
139	376
146	441
147	440
154	525
157	470

Table XI. Length-Weight relationship in L'Etang scallops.

2. Weight-Ring number Relationship.

Weight was also plotted against the number of ring-spaces upon the scallop shells in Sample No: 3. The resultant curve was very similar to that in Figure 16, except that there was a suggestion of retardation in the weight increase after the deposition of the ninth ring. Growth at this stage appears to be slowest in the scallops, and such retardation is to be expected. The variation from the mean is very great in some specimens. There is, however, a definite correlation, as indicated by the similarity in the direction of the curve and that of the line representing a perfect correlation.

Figure 17. Weight-ring-number relationships in Placopecten grandis.



Perhaps if more material were examined from this view-point, a more definite curve would be obtained.

No: of Ring-Spaces.	Weight. grams.
4	18
4	20
5	87
5	127
6	107
6	108
6	114
6	125
7	120
7	222
8	212
8	228
8	195
8	286
9	237
9	291
9	287
9	237
10	322
10	278
10	290
10	300

Table XII. Weight-Ring-space number relationships.
L'Etang scallops.

From the above figures (Tables XI and XII) it appears, from the wide variation that occurs, that weight cannot be used with much success as a criterion of growth in L'Etang scallops. All the specimens in Sample No: 3 were taken within a radius of about half-a-mile, and there is no reason to suppose that the individuals constituting this sample had migrated to L'Etang Harbour from a number of different regions in which varying conditions, which might possibly have accounted for the above variations in the scallops, obtained. L'Etang Harbour is a comparatively secluded inlet of the sea, and it is reasonable to suppose that these scallops had spent their whole lives there - a supposition strongly supported by their apparently characteristically slow growth (Figures 6 and 7). If this is so, the apparent variations in weight occurred under more or less identical conditions: and if under approximately identical conditions the weights of two scallops do not increase similarly, it stands to reason that weight cannot be taken as a criterion of growth. Forty-two specimens is, however, too small a number upon which to base conclusions. More material is necessary before such can be done.

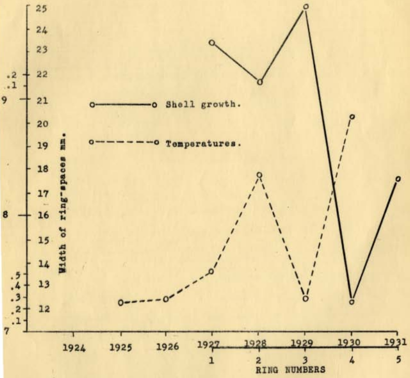
(g). Temperature and Growth in Scallops.

Two hundred upper valves, all characterised by the possession of five ring-spaces, were taken from Sample No: 1. These constituted shells belonging to one age-group. The average distances between each ring were determined for all of the 200, and a graph drawn representing the distance per ring against each ring. The ring-numbers were placed upon the abscissa. Monthly temperatures are taken regularly at the sea-bottom at Station 5 in the Bay of Fundy. This point is situated between the Wolves and Grand Manan, and is not very distant from Duck Island, where Sample No: 1 was taken.

The average bottom-temperatures for the six months June-November, as determined once a month, for the years 1925-1931 were obtained from the data available. Another curve was drawn, showing these average temperatures for each year. The months June-November were chosen as being probably those months in the year during which growth in scallops might be expected to be most active.

The two curves thus obtained were superimposed, in such a way as to cause the year 1930 to coincide with the 4th, ring-space, 1929 with the 3rd., etc: which, if the rings of growth are annually deposited, would be correct. It is to be noted (Fig: 18) that in every case shown, that when the growth of the shells was small, the corresponding temperature was high, and vice versa.

Figure 18. Possible correlation between growth and temperature in Grand Manan Scallops (Sample No.1).



It is interesting to note, too, that the year 1930 was an exceptional year for temperatures throughout the Fundy area. In that year the temperatures were generally much higher (Biological Station records). The 4th. ring-space on the shells of this single age-group would, if the rings are annual, correspond to the year 1930. In practically every one of the shells examined, the 4th. space was exceptionally narrow, in only one or two cases exceeding 15 mm.

Number of ring-space:	1st.	2nd.	3rd.	4th.	5th.
Average length of ditto in 200 shells:	22.3	21.7	26.4	12.4	17.3 mm.

A. Sample No: 1. Growth of one age-group per each ring deposited. Upper valves of two hundred shells.

Year:	1925	1926	1927	1928	1929	1930	1931
Bottom temps: Degrees C.	7.25	7.28	7.52	8.36	7.28	8.84	--

B. Averages of bottom temperatures taken at Station 5, for the six months June-November, in the years 1925-1930.

Table XIII. Comparison between growth and temperatures in Grand Manan scallops.

It is unfortunate that such scanty data on the temperatures prevailing around Grand Manan should be available. It must be remembered that the above data upon temperatures refer to an area about six miles distant from the area from which the scallops were taken. The unusual temperature conditions during the year 1930 were widespread, and it is possible that they may have prevailed around Duck Island. However, little can be concluded from the above, which only serves to suggest that the growth of the scallops is not so rapid at a high as at a low temperature. The latter suggestion is supported somewhat when a comparison between the growth and temperatures of the different regions considered in this report is made.

It can be seen from Figures 5 and 6 that the scallops from Chester, N.S. show on the whole the most active and sustained growth. Next, in order, come those from Grand Manan, Digby and L'Etang, the latter showing the slowest growth. The waters of Mahone Bay are on the average colder than those of the other three regions, which increase in temperature in the order of Grand Manan, Digby and L'Etang (8). Thus it is seen that the fastest-growing scallops come from the coldest area, and the slowest-growing from the warmest of these areas.

All animals have a characteristic optimum temperature, at which their metabolic processes proceed at maximum efficiency, and above or below which this efficiency falls off, its degree depending largely upon the proximity of the temperature to the optimum. In view of this, it appears that the optimum temperature for the growth of scallops, to judge from the above data, is low - possibly corresponding to the temperatures in Mahone Bay. If not this, then the higher temperatures encountered over the beds are above the optima for the growth of the organisms that form the basic food of the scallops. Insufficient material has been examined as yet to warrant many conclusions.

SUMMARY

(a) Since the validity of certain "rings of growth" upon the shells of scallops as "annual rings" is fundamental to a study of the growth of the molluscs, an attempt was made to show that they are deposited once a year, and can hence be used as a means of age-determination. That such an assumption is justifiable is very strongly supported by the evidence accumulated throughout the summer. Working on this basis, the following more important results were obtained.

(b) If the rings are annually deposited, then since the

maximum number upon the shells of scallops from Chester, N.S., was 15; Digby, 12; Grand Manan, 12; L'Etang, 13; the corresponding ages were the same number of years. Generally scallops with more than eleven rings were rare.

(c) Again assuming the rings of growth to be annually deposited, the age of a scallop at the time it attains the legal size of 4 inches will correspond to the number of rings between the umbo and a point four inches away upon the median line of the shell. The following values were obtained from measurements of 543 upper valves; Chester, 3.75; Grand Manan, 3.6; Digby, 4.3; L'Etang, 6.0. The average for all four areas was 4.5.

(d) (i). The average addition in length to the shells of scallops from all four areas for each ring was determined from measurements taken from 743 shells. In general, growth-rate increased until the second or third ring had been deposited, then decreased gradually.

(ii). The curves obtained from measurements of the additions in length for each ring indicate that maximum growth-rate was attained shortly before or after the deposition of the third ring of growth. Growth-rate in Chester scallops was apparently high and sustained; in Digby scallops, not so high nor so long-sustained; in Grand Manan scallops, very high for the 2nd and 3rd rings, with a very rapid decrease subsequently; and in L'Etang scallops, very low, but sustained for a long period.

(e) The evidence accumulated suggests that the higher the average temperature of an area inhabited by scallops, the slower they grow. It is considered that this may be due to a low optimum temperature for the growth either of the food of the scallops, or of the scallops themselves.

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The numbers in the foregoing list of references correspond to those in the text.

ACKNOWLEDGEMENTS

The author wishes gratefully to acknowledge the assistance provided by the Biological Board of Canada, and by Dr. A. G. Huntsman, director of the St. Andrews, Biological Station, in obtaining the material upon which this report is based; and also most sincerely to thank Dr. John Stanley, Mr. G. C. Toner and Irene Toner of Queens University for their most valuable suggestions and assistance in its compilation.

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