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The Causation of Diatom Maxima.

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THE CAUSATION OF DIATOM MAXIMA

by

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The Causation of Diatom Maxima

The investigation of this subject began in July 1924, and upon which two period reports have been submitted, was continued during July and August, 1926 at the Biological Station. The same general method as previously reported was used and unless otherwise stated will be understood to apply to this report.

The work done during the summer may be sub-divided into the following parts:

(a) The determination of the periods of diatom maxima from the measurement and counting of material taken with No. 18 net in weekly tows at Station No. 6 from August 1, 1925 to August 1, 1926, and in the monthly tows at Station No. 5.

(b) The measurement of the rapidity of the growths and the abundance of Aurelia flavidula in the waters adjacent to the Biological Station.

(c) Cultures.

1. To test the effect of adding the various ingredients of Allen's Miquel solution separately to summer surface water containing diatoms.

2. To test the growth properties for planktonic diatoms of sea water taken from different depths at the same station in Passamaquoddy Bay.

3. Preliminary work to test the effect of the duration of light on the growth of diatoms by the use of artificial light.

During the winter the work began with artificial light at St. Andrews was continued along similar lines at the Biological laboratory at the University of Toronto.

A. The determination of Periods of Diatom Maxima.

The jars containing the tows made with No. 18 plankton net at Station No. 6 from August 1, 1925 to August 1, 1926 were placed side by side on a long table for examination. It was apparent at once that the diatoms were very few in number in the autumn and winter tows because they scarcely gave a trace of colour to the mass of material which was small and for the most part copepods. In the spring tows, the diatoms increased rapidly from early March and reached their greatest abundance in early July. The comparison of the volume of the tows according to the height of the material in the jars was not very satisfactory because the amounts were so small during the greater part of the year and the presence of the copepods very misleading. It was

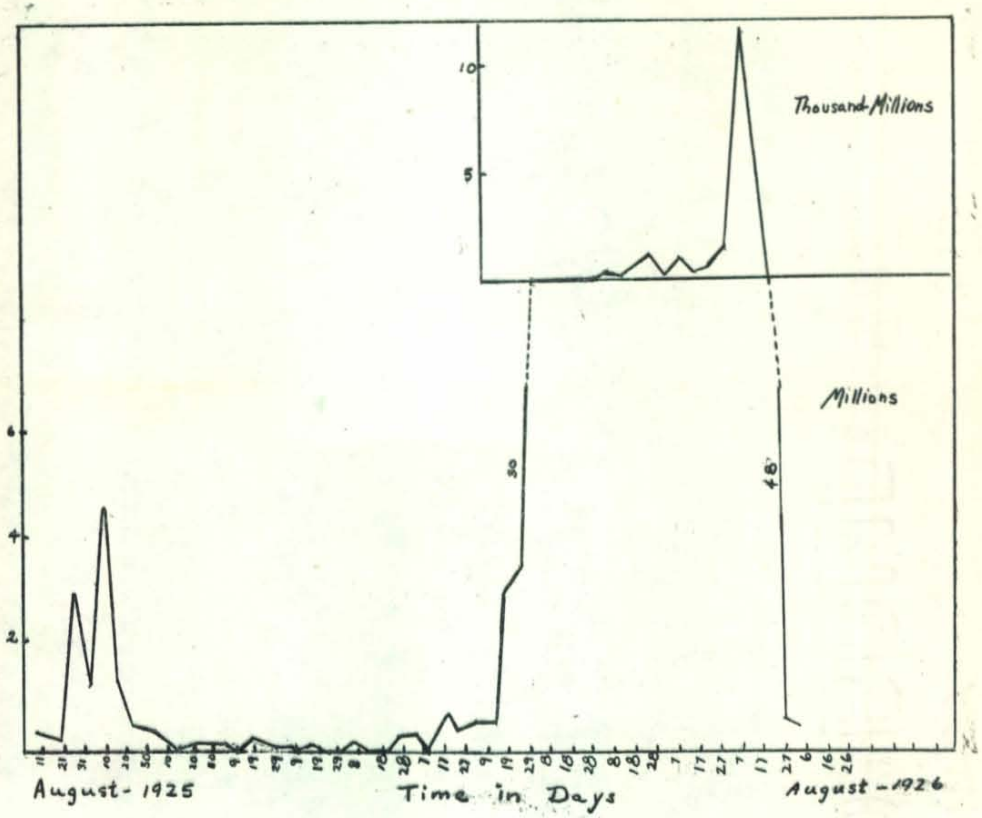
thought advisable to modify the method of counting previously used to provide for counting separately each frustule of the chains found so abundantly in the spring tows and thus show more accurately the great multiplication which took place in the spring waters. The total number of diatoms in each tow was computed as follows: The volume of the liquid in each jar was found by comparing it with a jar of the same size calibrated with a paper scale which showed the volume in cubic centimetres. The contents of the jar were then thoroughly stirred and a small quantity drawn off quickly with a pipette sufficient to fill a counting cell of the Rafter type of capacity .17 c.c. The number of diatoms in the cell were then counted. The different genera were recorded and the counts of each tabulated. When the amount of material was great, $\frac{1}{2}$ c.c. was drawn off and diluted until it could be counted conveniently and the dilution factor used in computing the total number of diatoms in the tow. Experience in the use of the counting cell showed that the average of a number of counts made from the same material differed so little from the first counts that the added accuracy was not commensurate with the time employed. The possible sources of error in this method of estimating the number of diatoms are great. They begin with the manner in which the tows are taken. In an estuary such as the St. Croix the amount of material might differ widely at different stages of the tide. It would differ also with the condition of the surface of the water governing the ease and uniformity with which the tows could be made. Then in such a laborious method of counting, allowance must be made for error in handling the material, in agitating the contents of the jar, in diluting and even in counting. The computations made form the counts are recorded in Tables I and II expressed to the nearest five thousand diatoms.

Table I--Station No. 6

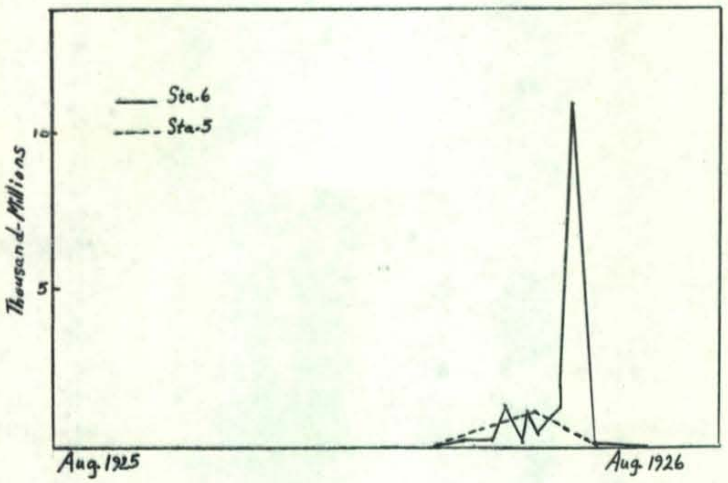
Date	Number of Diatoms	Time of Tide
1925		
Aug. 6	395,000	4.5 hrs. flood
" 19	290,000	5.5 " "
" 26	2,955,000	5.0 " "
Sept. 2	1,280,000	5.0 " ebb
" 9	4,615,000	3.5 " "
" 16	1,490,000	high
" 23	560,000	5.5 " flood
Oct. 1	406,000	high
" 7	275,000	0.5 " "
" 14	35,000	0.5 " ebb
" 21	115,000	3.0 " flood
" 28	100,000	high
Nov. 4	135,000	3 hrs. "
" 11	50,000	3 hrs. ebb
" 18	185,000	1.0 " "
" 25	115,000	2.0 " "
Dec. 2	105,000	3.5 " flood
" 9	45,000	4 hrs. ebb
" 16	115,000	1.75 " "
" 24	45,000	4.70 " "
" 31	65,000	5.5 " flood
1926		
Jan. 6	160,000	low
" 13	45,000	
" 21	65,000	4.5 hrs. ebb
" 27	250,000	5 hrs. flood
Feb. 3	335,000	4.5 " "
" 10	60,000	4.5 " ebb
" 18	700,000	5.5 " "
" 24	430,000	5 hrs. "
Mar. 4	620,000	1.5 " flood
" 11	600,000	5.25 " ebb
" 17	2,935,000	1 hr. "
" 25	3,405,000	1.25 " "
" 31	30,780,000	2.75 " flood
Apr. 7	60,280,000	2.5 " ebb
" 14	61,390,000	0.75 " "
" 23	98,395,000	2.0 " "
" 28	99,260,000	high
May 5	203,720,000	5 hrs. flood
" 13	203,390,000	2.5 " ebb
" 26	1,343,060,000	5 hrs. flood
June 3	263,470,000	5.5 " ebb
" 9	1,059,670,000	5.5 " flood
" 16	358,545,000	5.0 " "
" 23	778,895,000	5.0 " ebb
" 30	1,459,375,000	5.5 " flood
July 8	11,782,590,000	low
" 21	48,800,000	0.5 " flood
" 28	585,000	3 hrs. ebb

Table II--Station No. 5

Date 1925	Number of Diatoms	Time of Tide
Aug. 13	895,000	1.5 hrs. ebb
Sept.18	20,000	2.5 " flood
Oct. 30	220,000	3.25 " ebb
Nov. 19	19,500	3.0 " flood
Dec. 16		
Jan. 11	25,000	1.5 " ebb
Feb. 13		
Mar. 12	225,000	0.5 " ebb
Apr. 14	28,520,000	3.25 " flood
May 18	656,575,000	1.5 " "
June 14	1,111,130,000	low
July 15	157,130,000	high



Graph I Showing the number of diatoms taken with No. 18 plankton net at Station No. 6 from August 1925 to August 1926.



Graph II Showing a comparison between the number of diatoms taken with No. 18 plankton net at Stations No. 5 and No. 6 from August 1925 to August 1926.

The counts recorded in Table I and shown in Graph I indicate a small but distinct maximum at Station No. 6 in the early autumn of 1925 and a very marked increase in the following spring culminating in early July. It is to be regretted that the boat used for these nettings was incapacitated and no tow was taken between July 8th and July 21st, 1926 which would have determined whether the diatoms were increasing or decreasing between these dates. At Station No. 5 which is situated out in Passamaquoddy Bay and not in the estuary, the two maxima were distinct in the counts, the autumn later and the spring earlier than in the river. Since the tows were only taken monthly, the exact peaks may have been missed and the general trend only can be indicated by the counts.

The time of the tide taken from the plankton records was introduced in the tables as a possible explanation for the great variation in the numbers of diatoms taken from week to week at the apparent season of maximum. The tows of May 26th, June 3rd and June 9th, 1926 might be cited as examples, the smaller tow of June 3rd being taken at ebb, while the other two were taken at flood tide.

To include further data to test out W. H. Pearsall's theory that diatom maxima follow periods of heavy rainfall referred to in the last report, the total precipitation in inches recorded for St. George, N. B., the nearest point of observation likely to be similar to St. Andrews was taken from the meteorlogical observations for Canada as follows:

1925

May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1.83	3.58	2.46	2.68	4.31	8.16	5.31	2.57

1926

Jan.	Feb.	Mar.	Apr.	May	June	July
5.70	4.94	4.28	2.39	2.00	2.63	1.73

The high maximum of July 1926 followed the rainiest period of the late spring.

The Genera of Diatoms Abundant in the Tows

Chaetoceros predominated in August, September and October, 1925 and in June and July 1926. Coscinodiscus was next in numbers to Chaetoceros in late September and in October and more abundant than any other in late October, November, December and January. In February Rhizosolenia, with Biddulphia and Skeletonema predominated, the latter two being most abundant and about equal in amount during March. Towards the close of March two species of Thalassiosira became very abundant and during April formed the bulk of flora.

Chaetoceros began to appear in May but was less abundant than Thalassiosira. By June 3rd, Chaetoceros debile and Chaetoceros sociale were in the lead and formed nearly all the great mass of diatom material in June and July.

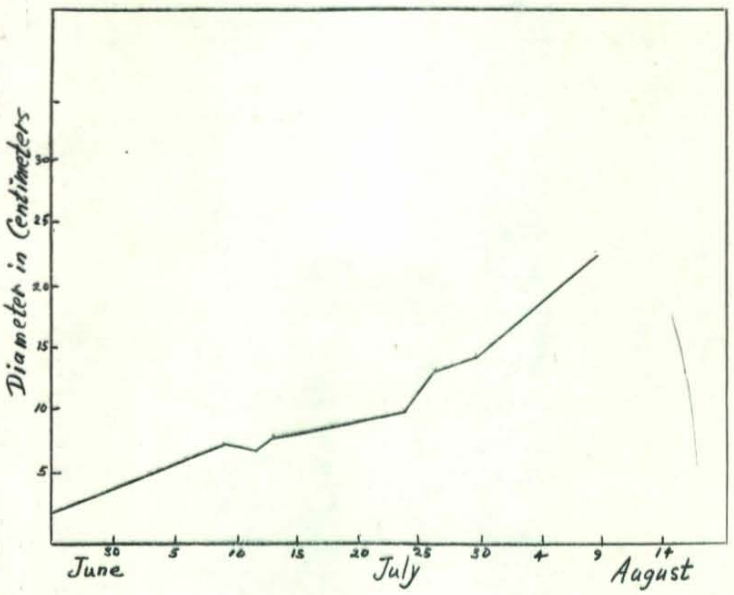
B. Measurements of Aurelia flavidula.

A large number of Aurelia flavidula taken near the wharf and in tows in the river adjacent to the station were measured during the summer. The first specimens were taken at Station No. 6 on June 24th and averaged 2.04 centimetres in diameter. The largest specimen was taken on August 10th and measured 28 centimetres. At that date, which was the last recorded all the jelly fish were in good condition. On September 29th, the jellies were still abundant as the plankton records stated a large number were thrown out of the tow at Station No. 6. No record was kept of the time they were last observed.

Table III records the number of specimens taken on each date and their average diameter. The results are shown graphically in Figure III.

Table III.

Date 1926	No. of Specimens	Average diameter in centimetres
June 24	9	2.04
" 30	15	4.26
July 3	8	5.10
" 8	50	6.94
" 9	20	7.57
" 12	11	7.00
" 13	11	8.10
" 24	4	10.5
" 26	26	13.9
" 30	24	15.0
Aug. 4	15	19.4
" 10	6	23.4



Graph III Showing the average measurements of Aurelia flavidula during July and August 1926.

Culture I

Date: June 28, 1926.

Purpose: To test and compare the effect of the addition of each ingredient of Allen's Standard Miquel solution separately to summer surface water, on the growth of diatoms introduced into it.

Notation and Content: I_1, control, filtered sea water; I_2 unit nitrate; I_3 ½ unit nitrate; I_4 unit phosphate; I_5 ½ unit phosphate; I_6 unit silicate; I_7 ½ unit silicate. Doubly filtered sea water measured from the same sample to the amount of 250 c.c. was used for each jar and each was inoculated with 2 drops of fresh concentrated plankton in which Chaetoceros was the most abundant germs.

Position: All the jars were placed in a pan of running sea water on the roof in full sunlight.

Preparation of the Chemical ingredients: Reference was first made to the work of Allen and Atkins done at the Plymouth laboratory to ascertain the amounts of each ingredient considered necessary to produce the best growth. For the nitrate and phosphate, the amounts in Allen's Standard Miquel were taken as the units. For the silicate, an attempt was made to get 0.55 mg of SiO_2 per litre in solution since Atkins found that amount to be present in the culture solutions of Mitzschia closterium in the Plymouth laboratory. As a source of SiO_2, K_2SiO_3 was used and since half the weight of the salt is SiO_2, 1.1 mg per litre would be required. At first, 100 c.c. of distilled water was used to dissolve 1.1 grams of K_2SiO_3. It seemed to have little effect; an additional 100 c.c. was taken. The following day 100 c.c. of filtered sea water was added and thoroughly shaken. Since a large amount of the salt still remained undissolved, 100 c.c. more of filtered sea water was used and the whole solution boiled. The small remaining precipitate was filtered off and the clear saturated solution diluted as though all the salt had dissolved to make 1.1 mg per litre.

Detailed observations on Culture I.

The first inoculation failed to grow, the cause very likely being an unavoidable rise in temperature of the water in the cooling pan to 21.5°C on June 30th. On July 6th, a second inoculation of 5 drops of fresh plankton to each jar was made. The growth in the days which followed was very small and when all the jars were arranged in a row for a final examination on July 19th there was no apparent difference in the amount of growth. Examination of sample taken every two days from the thoroughly agitated cultures showed the diatoms in the normal Miquel in I_2 to be in a more healthy condition than in any of the others. The addition of the phosphate seemed to inhibit very slightly healthy growth and the silicate showed no difference from the

control. Counts made of the number of diatoms in each sample are recorded in Table IV. The diatoms were tabulated as living and dead, this being deemed advisable in view of the heavy inoculation used.

Table IV

Jar	No. of Diatoms	Day of Month July 1926 8	10	12	14	16
I_1	Living	140	79	44	X	XX
	Dead	188	234	114	224	30
I_2	Living	13	26	40	67X	X
	Dead	147	288	238	229	169
I_3	Living	38	33	70	15X	X
	Dead	252	297	181	99	141
I_4	Living	50	95	37	XX	XX
	Dead	246	230	261	306	43
I_5	Living	52	25	16	22	X
	Dead	163	306	295	214	156
I_6	Living	77	21	35	18X	X
	Dead	177	143	122	177	30
I_7	Living	110	134	59	12X	X
	Dead	86	229	72	237	

Sign X indicates patches of bottom living forms too dense to count but very abundant in the culture.

Culture II

Date: June 26, 1926.

Purpose: To test the growth properties of sea water taken from different depths at Station No. 492 in Passamaquoddy Bay.

Notation and Content: II_1 surface water; II_2 water from 5 metres; II_3 water from 10 metres; II_4 water from 28 metres. Each jar contained 250 c.c. of doubly filtered water and was kept in a cool dark place for two days and then inoculated with 2 drops of fresh concentrated plankton.

Position: The jars were placed in a row in a pan of running sea water on the roof.

Detailed observations on Culture II.

As in Culture I, the first inoculation was killed and a second one necessary. Samples were taken every two days and the counts made were recorded in Table V. Although the volume of growth was small it showed a graded series from II_1 to II_4 the bottom water producing the best culture.

Table V

Jar	No. of Diatoms	Day of Month July 1926 8	10	12	14	16
II_1	Living	0	0	0	0	700
	Dead	101	14	76	94	6
II_2	Living	15	13	17	128	688
	Dead	146	100	98	220	108
II_3	Living	26	50	41	258	942
	Dead	232	191	56	291	167
II_4	Living	67	90	195	894	1750
	Dead	69	140	171	166	146

Cultures III and IV

Date: July 21st

Purpose: To repeat and extend experiment III.

Notation and Composition: Samples of sea water were taken from the surface, 5 metres, 10 metres and 28 metres at Station No. 492 and from the surface, 5 metres, 10 metres and 30 metres at a point 2 miles north of Station No. 9. Each sample was carefully filtered and 250 c.c. of it was placed in a jar and inoculated with 4 drops of fresh plankton. Each set was numbered from 1 to 4.

Position: The eight jars were placed in two rows in the first pan of running water on the roof.

Detailed observations.

The weather was exceedingly warm for several days and the water bath rose to 17°C. The diatoms did not multiply sufficiently to permit of a satisfactory comparison and the series was discontinued. The water was refiltered and stored in a cool, dark place until new inoculation could be secured.

At this time the diatoms in the sea water were very scarce. The great maximum of early July was over and the suddenness of the falling off was remarkable. The plants which were taken in the tows looked plasmolysed and lacking vigor and this condition may have been responsible for their failure to reproduce in Cultures III and IV.

Culture V

Date: July 28th

Purpose: To raise planktonic diatoms suitable for inoculating the samples of sea water unsuccessfully treated with fresh plankton in Cultures III and IV.

Notation and Composition: One and a half litres of Allen's Miquel solution in fresh filtered sea water was prepared and divided betweeen six jars numbered from V, to V_6. A fresh plankton tow with No. 18 net was found to contain a great many copepods but few diatoms. To separate the former from the latter the material was poured onto a shallow dish one half of which was darkened and the other illuminated with an electric light. Twelve drops of phytoplankton from the lighted side of the dish forsaken by the copepods was used as inoculation for each jar.

Position: V_1 and V_2 were placed in the north window: V_3 and V_4 in a pan of running water on the roof and V_5 and V_6 were suspended from the breakwater.

Detailed Observations.

The jars were observed and sampled until August 9th when it was apparent that no material suitable for culture purposes was present in any of the jars. So small was the amount of growth that a sample drawn from a jar in which the contents had been thoroughly agitated, revealed no diatoms to count. If however, a sample were drawn from the settled material a few diatoms could be found. Samples taken in this way showed that the Chaeloceros chains did grow to a small extent in jars V_3 and V_4 on the roof but none were found living in V_1 and V_2. Bottom living Naviculae appeared in all the jars. A small number of living chains were found in the jars suspended from the breakwater.

Aurelia Cultures

Date: June 30th

Notation and Composition: Two quart jars each containing 4 grams of Aurelia flavidula to 500 c.c. of fresh sea water were prepared to grow diatoms as food for copepods.

Position: Both were placed on the roof.

Detailed Observations.

In seven or eight days fine healthy Chaetoceros chains were found present in both jars and a few frustules of Nitzschia closterium were first observed. The cultures were allowed to run until July 22nd but did not produce as rich growth as had been observed in the smaller quantity in the Aurelia cultures.

Whether the additional quantity in the cultures or the warm days of early July were responsible for the difference could not be tested out by further experiments.

Miquel Cultures

Date: July 23rd

Purpose: To test whether N. closterium would develop as soon as planktonic forms if given more favourable conditions of light and temperature.

Notation and Composition: Three pint jars numbered 1, 2 and 3 each contained 250 c.c. of sea water. To the first was added Allen's Standard Miquel; to the second, double the amount and to the third 4 times standard Miquel.

Position: The three jars were placed in the north window of the laboratory.

Detailed Observations.

In five days, three days earlier than it had appeared on the roof, N. closterium was found in both jars 1 and 2. It continued to grow in jar 1 more abundantly than any other form until the last sample was taken on August 9th. In jar 2, the diatom was less abundant than in jar 1. Jar 3 did not produce N. closterium.

This experiment would lead one to think that the conditions in the north window of the laboratory were more favourable for the growth of N. closterium than the more intense light and lower temperature of the roof garden bringing the growth on several days earlier. This conclusion is also borne out by previous experiments with both Aurelia and Miquel cultures.

Artificial Light Experiments

Culture I

Date: August 3rd

Notation and Composition: The jars were numbered from 1 to 4 and each contained 250 c.c. of Allen's normal Miquel solution and were inoculated with 4 drops from a good Nitzschia closterium culture.

Position: All the jars were placed in a row in front of two 300 watt electric light bulbs at a distance of thirty inches. A piece of common window glass was placed in front of the bulbs at a distance of 9 inches to cut down the heating effect. All daylight was carefully excluded and the temperature of the room at that distance from the bulbs was fairly uniform and about 20°C. very similar to the temperature of the laboratory in which the diatom used as culture inoculation had been growing. Jars 1 and 2 were exposed to light day and night; jars 3 and 4 were covered at alternate twelve hour periods. The light intensity at a distance of 30 inches from the bulbs was measured by Professor Klugh and found to be .9° of full noon June sunlight.

Duration and Temperature: The experiment was run from August 3rd to August 16th. The temperature of water in a jar at the same distance from the light taken five times daily, varied from a maximum of 22.9°C at 10.30 p.m. on August 8th to a minimum of 19.2°C at 10.30 a.m. on August 14th but usually remained about 21°C.

Detailed Observations.

Samples were taken and examined microscopically on August 3rd, 6th, 9th, 10th, 12th and 14th. At no time did Nitzschia closterium become abundant. Very small Naviculae began to appear in the seond jar as early as August 9th and since these bottom forms grow in patches counting cannot be reliable and can give only a general idea of what was happening in the jars. By August 14th when the last sample was taken a unicellular green alga was growing in all the jars along with many bottom living diatoms. The counts made are recorded in the following table.

Jar	Diatoms	Day of Month August 1926 6	9	10	12	14
1	Nitzschia	0	1	0	0	4
	Navicula	0	0	6	11	210
2	Nitzschia	0	3	0	0	9
	Navicula	0	56	11	47	281
3	Nitzschia	0	1	0	0	3
	Navicula	0	0	4	0	5
4	Nitzschia	0	2	1	0	0
	Navicula	0	0	10	0	few

Conclusion.

Study of this table, meagre as it is, shows that light is a factor of prime importance in the growth of diatoms. The small amount of light that the jars were receiving made the growth possible. When it was reduced to one half scarcely any growth at all was produced. The jars exposed to the light all the time were much more than twice as productive.

Culture II

Date: August 16th

Notation and Composition: There were six jars numbered from 1 to 6. Each contained Allen's Normal Miquel solution, inoculated with 4 drops from a culture jar containing a small diatom which appeared in the previous experiment and, in fact, in all the culture jars at that time. It has not been identified. It resembled a small Navicula or Acnanthes brevipes. It often was found in pairs.

Position: It was determined to place the jars this time close to the light. The first pair was placed at $\frac{1}{4}$, the second at 1/3 and the third at $\frac{1}{2}$ the distance used in culture I. In order to avoid any shading they were arranged as shown in the sketch. Jars 1, 3 and 5 were covered with cans to exclude the light for alternate twelve hour periods.

Duration and Temperature: The experiment lasted from August 16th to August 31st. To control the temperature and keep it as uniform as possible a small metal tube was bent to the shape of the row of jars. A small hole was bored in the tube above each jar to let a stream of water flow down over the jar to cool it. By controlling the supply entering the tube and by maintaining the right size opening the temperature was kept from varying more than 1. to 1.5°C in the whole series. It was more difficult to keep the temperature accurate in the jars which were covered but for a simple arrangement of this type, one could hardly hope to maintain any smaller variation. The water ccoling bath kept the temperature from 15 to 16.5°C.

Detailed Observations.

This experiment was set just before I left St. Andrews and cared for by the kindness of Dr. Leim. No samples were taken but the contents of the jars were preserved. Since the diatoms the jars contained were all bottom living forms and in dense patches no counts could be made. Judging from the volume on the bottom of the jars, those covered half of the time produced better results than those exposed all the time to the light. The third jar produced the best culture of diatoms. The plants in the first and second jars close to the light seemed less healthy than those in the more remote jars.

Culture III

Date: December 3rd

Notation and Composition: There were six jars numbered from 1 to 6. Each contained 250 c.c. normal Miquel and were inoculated with 5.6 drops of fresh plankton received from Halifax on December 3rd.

Position: They were arranged in the same way as the jars in Culture II on August 16th. This experiment was carried out in the basement of the Biology Laboratory at the University of Toronto. The jars were arranged on a bottom of a shallow sink and the jets of water flowed over the jars from small rubber tubes controlled with pinch cocks and leading from a reserve jar resting on a small shelf above the taps and jars to maintain an even flow. The electric light bulbs were two in number each 500 watts and placed at the end of the sink side by side. A sheet of thin window glass protected them from the splash of the water jets and cut down the heat effect of the bulbs. Jars 1, 3 and 5 were covered with tin cans as in Culture II.

Duration and Temperature: This experiment lasted from December 3rd to December 16th. The temperature was difficult to maintain uniform throughout the series. The greatest difficulty was found with the cans which were covered which tended to warm up although a small stream of water ran over them. The daily range of the temperature of the water in the cooling system was at least 3°C depending upon the amount being used in the building. The temperatures ran high during the night and on Saturdays and Sundays the average daily range was from 8°C to 12°C.

Detailed Observations.

Bottom living diatoms began to show colour at the base of the jars as early as the third day. Under the microscope they looked like small Naviculae. There were two species--one a little larger than the other about equally abundant. They were present in all jars throughout the experiment. On December 9th the contents of each jar were thoroughly stirred and a sample drawn off for examination was recorded as follows:

Jar 1 The sample contained 2 large healthy-looking Naviculae, many patches of minute Naviculae and many protozoans but no planktonic diatoms.

Jar 2 The contents of this jar did not grow so tightly to the bottom. The minute Naviculae were there in abundance and one chain of Chaetoceros containing 4 frustules was found. It was somewhat deformed being slightly twisted with the spines still present but apparently living.

Jar 3 In this sample 4 Coscinodiscus were found and the rest were bottom forms.

Jar 4 Five frustules of Chaetoceros surrounded by protozoans and very unhealthy-looking were all this sample contained apart from an abundance of Naviculae.

Jar 5 This sample contained a short chain of Chaetoceros, pale in colour, one small Coscinodiscus and a small patch of unicellular green algae. The Naviculae were abundant.

Jar 6 This one contained a small deformed, spineless Chaetoceros chain, 2 Coscinodiscus and many Naviculae.

Examination was made at intervals until December 16th when it was plain that the bottom forms were predominant and the planktonic form gone. They were unsuitable for counting and the set was destroyed. The volume of growth as seen with the naked eye was as follows on December 11th--maximum--Jars 1 and 4--minimum--Jars 3 and 5.

The intensity of light in the position at distances of 7.5, 10 and 15 inches from the two 500 watt bulbs was suitable for the bottom forms but unsuitable for the planktonic forms.

Culture IV

Date: December 3rd

Notation: Jar 7--A single jar containing 250 c.c. of Normal Miquel was inoculated strongly from the fresh plankton of December 3rd and left on the tray behind the jar at about 20 inches from the bulbs and had no cooling spray. The base of the jar was kept cool by the water from the tubes continually running over the tray and the temperature was therefore fairly uniform but higher than the jars close to the light.

Detailed Observations.

The samples from this jar were taken irregularly. It was considered merely as an auxiliary for inoculation purposes and revealed so many different types of life that it became a curiosity as compared with the other jars. Samples were drawn directly from the bottom where the growth seemed most abundant. It did not develop the adherent bottom layer which was apparent in the jars of Culture III.

On December 8th It contained Chaetoceros, Nitzschia and a few Actinoptychus from which the chromatophores were escaping.

On December 11th — The growth had increased much since the last examination and the diatoms were healthy looking for diatoms grown under culture conditions. Skeletonema was the most abundant. Chaetoceros was present in moderate amount. There were many Nitzschia of two or three species and a chain of 14 frustules of Acnanthes. There was also some of Coscinodiscus which looked less healthy than the rest.

On December 14th — Skeletonema was still dominant and in fine chains. There were some healthy-looking Rhizosolenia, Chaetoceros and Acnanthes.

On December 29th — The planktonic diatoms were fast disappearing. The Skeletonema was caught in patches of benthic Naviculae. The Acnanthes chains which were so vigorous in the last examination were fading and breaking up. Radiolarians were very abundant.

On January 4th — The condition was unchanged except for a few minute N. closterium.

On January 11th — N. closterium had multiplied around the edges of dense patches of another diatom which showed signs of dominating the culture. It was a long, slender greenish brown frustule which resembled N. delicatissima but was less slender and sharp at the ends. The appearance of this diatom may be explained by the fact that the temperature of this jar had been about 17°C for several days.

On January 16th — The unidentified form mentioned on January 11th formed dense patches throughout the whole culture and was apparent as thick dark brownish masses to the naked eye. Subsequent observations did not reveal any marked change in the culture.

Culture V

Date: December 16th

Notation and Composition: This experiment was a repetition of Culture III and was inoculated from Culture IV which contained many healthy planktonic diatoms.

Duration and Temperature: It lasted until January 4th and the temperature varied from 9°C to 11°C.

Detailed Observations.

The results were very similar to those obtained with Culture III. The planktonic forms soon perished but the bottom forms found the conditions quite favourable and it was difficult to detect any marked difference in the amount of growth in the jars. The second, fourth and sixth jars had the most abundant growth and the fifth seemed to have the minimum.

Culture VI

Date: January 17th

Notation and Composition: There were four jars numbered 1 to 4. Each contained 250 c.c. of Standard Miquel Culture and was inoculated with 3 drops from a culture containing N. closterium grown at the High School of Commerce. The culture seemed in healthy condition and had been growing under a sky-light in a cool place since December 3rd when it was inoculated with fresh plankton from Halifax.

Position: All the jars were placed at a distance of 10 inches from the two 500 watt bulbs in a row in front of them. The first jar was raised on a small wooden block and the rest were placed on the shallow sink and were cooled by jets of running water.

Duration and Temperature: The experiment lasted until January 28th. The temperature of each jar was taken three times daily and the water taps adjusted to keep a difference of about 4°C. The first jar which was uncooled by a water jet varied from 25°C to 27°C; the second from 21°C to 23°C; the third from 18°C to 20°C and the fourth 13°C to 17°C. On January 23rd, one bulb was found to be burned out and was not renewed for forty-eight hours and the temperature of the whole series was changed, the higher temperatures were reduced about 7°C.

Detailed Observations.

A covering of bottom living Naviculae spread over each jar and is not recorded at all in the table of counts for this culture. It developed first in the warmest culture. The higher temperatures also stimulated the growth of the Nitzschia colosterium used for inoculation and a large number of frustules were found in the second jar as early as the third day. Both long frustules and short ones were found and the short small frustules were very active, an observation seldom made in previous cultures of this species. By January 23rd, the sixth day, the Nitzschia in the first jar appeared dead while in the jars with the lower temperature were reaching their maximum and contained healthy-looking plants. By January 28th all except the fourth jar, contained only dead N. closterium and the

plants in that jar were quite unhealthy looking. The bottom living Naviculae evidently found the conditions favourable and many dead N. closterium were found caught in the dense patches loosened from the bottom of the jar.

Table VII contains the counts that were made from day to day. The general conclusion reached from this experiment was that a temperature in the neighborhood of 18°C was most favourable for cultivating this diatom when exposed to the intensity of light received from two 500 watt bulbs. Since the culture was of such short duration the light may have been too intense.

Table VII

Jar	Diatoms	Day of Month January 1927 20	21	22	23	27
1	Nitzschia	2	49	43	12	1
2	"	289	228	45	44	4
3	Nitzschia	58	20	285	40	34
	Skeletonema	5	0	0		
4	Nitzschia	33	77	360	219	52
	Skeletonema	0	115	0	0	0

Culture VII--Part A.

Date: February 19, 1927

Purpose: To find the optimum intensity of light for Nitzschia spp. growing at a temperature of about 18°C.

Notation and Composition: Six jars containing Standard Miquel were prepared and were inoculated from a jar containing the best N. closterium then available. The plants had been growing at a distance of 20 inches from the light. There was also present another diatom which has been mentioned in Culture IV as a species of Nitzschia resembling N. delicatissima.

Position: The jars were placed at 7.5, 10, 15, 20, 25 and 30 inches from the two 500 watt bulbs, the jars in the nearer positions being cooled with a jet of running water. The first jar was closest to the light and the sixth farthest.

Duration and Temperature: The cultures were allowed to grow until March 15th and throughout the whole time the temperatures were read and the taps adjusted to regulate the cooling jets, twice daily,

three times if possible. Occasional variations as great as 3°C could not be avoided as had been demonstrated by a temperature control run for two weeks previous to beginning the experiment since the temperature of the cooling stream varied considerably with the amount of water being used in the building.

Detailed Observations.

In five days a faint trace of brownish growth was apparent on the bottom of each jar showing a tendency to cling to the jar. Samples taken on the fifth and sixth days revealed N. closterium present in all the jars but in much smaller numbers than N. delicatissima. It was most abundant in the sixth jar farthest from the light. In eight days N. closterium had almost disappeared from the jars except the sixth. The other species of Nitzschia flourished in all the jars but was most healthy looking in the fourth, fifth and sixth. By March 3rd, the maximum volume of growth had been reached in the first and second jars and from that time, the colour faded slightly and the condition became unchanged as long as the culture lasted.

The last microscopic examination was made on March 11th when N. closterium was found only in the sixth jar among a rich growth of the other Nitzschia. This culture was the best of the whole series, and was the farthest from the light and kept up its maximum until March 15th when the culture was destroyed.

It was evident from this experiment that the light intensity at 30 inches was the most favourable for both species of Nitzschia and that the experiment should be extended by setting up a series at greater distances. Since this could be done most conveniently with a smaller bulb instead of increasing the distance, the experiment was postponed until equipment could be obtained.

Culture VII--Part B.

Date: April 1927

Purpose: To extend the work of Part A.

Notation and Composition: There were four jars in the set each containing the same culture medium and kind of diatoms used in Part A.

Position: The jars were placed at 13.5, 18, 22.5 and 27 inches from a 200 watt electric bulb, the first jar being nearest to the light.

Culture VIII

Date: March 21st

Purpose: To test the effect of the duration of light on such diatoms as grown in culture VII.

Notation and Composition: There were four jars containing Standard Miquel inoculated from Jar No. 6 of Culture VII.

Position: The jars were placed side by side at 30 inches from the same source of light as used in the previous experiment. Jars No. 1 and No. 2 were covered half the time to exclude the light and jars No. 3 and No. 4 were exposed continuously to the light.

Duration and Temperature: The culture lasted until April 11th. The temperature throughout the time was about 18°C.

Detailed Observations.

In five days N. delicatissima was appearing abundantly in the samples taken from the jars continuously exposed to the light, and soon became rich brown growth on the bottom of the jars. Two days later, a faint trace of brownish deposit was seen in jars No. 1 and No. 2. The plants were equally healthy in appearance in all the jars and differed only in abundance. When the experiment was closed, there was no apparent difference in the volume of growth in members of each pair but a distinctly greater amount of growth in jars No. 3 and No. 4 than in jars No. 1 and No. 2.

One might conclude that the amount of growth was roughly proportional to the light received, the interruption of its reception merely retarding the rapidity of multiplication.

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THE CAUSATION OF DIATOM MAXIMA

by

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March, 1928

THE CAUSATION OF DIATOM MAXIMA

Report of the work done at St. Andrews in July and August, 1927

I General outline

(a) Plankton measurements and counts.

(b) Measurements of Aurelia flavidula.

(c) Culture experiments briefly outlined.

II Determination of Periods of diatom maxima at Station No. 6 and Station No. 5, including tables, graphs, and comments thereon.

III Determination of the rapidity of growth, and the time of disappearance of Aurelia flavidula.

IV Culture experiments in detail.

V Summary and conclusions

VI Literature.

1. Outline of the Work accomplished during July and August, 1927 at the Biological Station

The investigation of the cause of diatom maxima at St. Andrews was continued during the summer of 1927. The routine work of counting the numbers of diatoms in samples from the weekly hauls and tows made with No. 18 net at Station No. 6, was carried out in the same way as in previous summers and brought up to date. Counts were also made of samples of the material taken at Station No. 5 during 1926 and 1927, and all the previous tows taken with No. 18 net at this station which had not been previously counted were completed. Full details of this work are recorded in the tables and graphs which follow.

Measurements of the diameter of large numbers of Aurelia flavidula were made frequently throughout the summer, and a report made on its abundance and disappearance in the autumn.

The culture of diatoms under artificial light of measured intensity and at known temperature as begun in the biological laboratory in Toronto during the winter of 1927 was continued in the darkened basement of the laboratory at St. Andrews. The same general procedure of using an electric light bulb on the local circuit was followed. In front of it or around it culture jars were placed, and at the same time kept cool and fairly uniform in temperature by water from jets flowing over them in a thin film. With streams of sea-water as a cooling agency, it was possible to obtain lower and more uniform temperatures, than it had been with the water supply in the laboratory in Toronto. The space around one bulb was so limited that only a few jars could be included in each experiment, and since each had to run at least ten days, the number of experiments tried was all too few. Reference was made to the results obtained during the winter in deciding upon the size of the bulb to be used and the distance which would produce maximum results. The purpose of these experiments was to obtain more information on the factors which contribute to the normal development of planktonic diatoms. As mentioned previously in this investigation, light, temperature, salinity, and food supply are obviously the great factors, and if one or more are controlled, the effect of varying the others may be studied. Instead of using the Miquel culture medium as employed by Allen, fresh jelly-fish was introduced as the food material except where the natural food dissolved in the water was to be tested.

During July, several sets of cultures were set up, all of which were for the purpose of growing in jars diatoms present in the plankton at that time. At first when the temperature was kept low, and artificial light used, planktonic forms existed, but did not multiply to any great extent. The bottom forms, which previously had always appeared and overrun the cultures, were checked, but when the cultures were removed to the warm laboratory, they developed very quickly, and were most abundant in the jars which had received the highest illumination in the basement. To still keep a low temperature such as the planktonic forms have in the sea, and to increase the light, a series

of jars containing jelly-fish was placed on the breakwater, but the results were quite as unsatisfactory as in the basement.

It must be remembered, when studying these results, that for some reason yet unexplained, diatoms are at this time at their lowest ebb in the estuary. The chains looked unhealthy and worn out in the fresh plankton tows. I, therefore, searched very carefully for signs of resting spores, especially in the Chaetoceros chains by comparing the fresh material with drawings in reference books, but was unable to find any. The decrease from the very large maximum of June is so rapid that one would expect to find preparation in nature for this sudden unfavorable condition for further development.

During the first week of August, a marked increase in diatoms was noticed in the tows taken at Station No. 6, and became larger from day to day until about August 13th, when a decrease again took place. The species which formed the bulk of each tow was identified as Chaetoceros constrictum. Jelly-fish cultures were inoculated with this fresh material, and grown both in the basement and in the north window of the laboratory at a temperature of about 19°C. with good results. In fact, this species remained more normal, and multiplied more extensively than any planktonic form previously cultured. When one remembers that 19°C. is from five to seven degrees higher than the sea water at Station No. 6 at this time of year, it must be concluded that this species can withstand a considerable rise in temperature without apparent ill effects.

It was, therefore, considered to be suitable material for inoculating surface and bottom water samples from Station No. 6, and also testing a series of water samples taken at regular intervals at different depths at Station No. 492 during the year. All of these samples were to be treated in the same way with good inoculation under uniform light and temperature conditions to find out if possible what different food material was present at different seasons in the water. Ten representative samples were chosen, five from the surface and five from the bottom. The results are given in detail in a table which follows, and show, in the spring and summer samples, direct contrast to the results obtained with fresh water samples taken either at Station No. 6 and Station No. 5 during the summer.

Time was insufficient to repeat this last experiment, and one cannot draw conclusions without further data. It is quite possible that chemical changes of great importance take place in the water in the stored samples. The sample which was stored longest showed the greatest variation.

II. The Determination of Periods of Diatom Maxima in the St. Croix Estuary and in Passamaquoddy Bay

Samples were counted from all the plankton tows and hauls made at Station No. 6 from August 4, 1926, to August 17, 1927, and at Station No. 5 from August 1924 to August 1927, except from August 1925 to August 1926, which had been reported last year. The procedure followed was exactly that of the previous summer, and graphs were constructed

from the counts obtained.

In 1925, a volumetric method of finding the periods of diatom maxima was used, but discarded last year as unreliable, because the large numbers of copepods and peridinians present at certain seasons in the material was misleading as to the quantity of diatoms. It was particularly ineffective when applied to the hauls, because the whole mass of material was less than in the tows. Instead of measuring the height of the settled material in the plankton jars, the contents of each was poured into a graduate of suitable size, and allowed to settle over night, and the volume read to the nearest cubic centimetre. This method was used for the hauls only, merely, for comparison with the results obtained from the counts.

Table I--Station No. 6--Tows and Hauls

Number of Diatoms in Thousands

Date 1926	Tows	Hauls	Time of Tide
Aug. 4	510	35	2 hrs. ebb
" 11	1,690	470	1 " "
" 19	3,720	160	3 " "
" 25	2,210	100	4½ " flood
Sept. 2	6,920	160	2 " "
" 8	1,180	225	3½ " ebb
" 15	23,290	835	5 " "
" 23	13,450	1,195	2 " "
" 29	635	145	4½ " "
Oct. 7	1,080	70	4 " flood
" 14		70	4½ " ebb
" 27		95	4½ " flood
Nov. 3		10	¼ " ebb
" 11	57	20	1½ " flood
" 18	170	35	5¼ " "
" 24	65	10	low
Dec. 1	100	125	1¼ " ebb
" 9	80		3 " flood
" 15	50	30	3 " ebb
" 22	65	25	½ " "
" 29	200	35	5½ " "
1927			
Jan. 5	140	30	3 hrs. flood
" 12	130	65	4¼ " ebb
" 19	155	20	3¼ " flood
Feb. 7	157	100	4¼ " "
" 16	435	175	4¼ " "
" 23	780	230	low
Mar. 2	525	540	3 " ebb
" 9	1,630	570	5¾ " "
" 17	5,465	240	high
" 23	9,310	740	low
" 30	294,200	12,170	1 " ebb
Apr. 5	260,215	58,350	1 " flood
" 22	853,000	1,380	5¾ " "
" 27	1,059,000	173,805	3 " ebb
May 4		119,645	¼ " "
" 11	1,694,000	59,575	high
" 26	52,975	4,175	2½ " ebb
June 4	29,175	5,210	1½ " flood
" 9	39,625	8,305	2 " "
" 16	682,940	108,355	4 " "
" 23	2,603,670	70,125	low
July 7	949,385	18,260	4½ " flood
" 21	1,630	925	5 " ebb
" 28	3,675	160	5¼ " flood
Aug. 4	38,000	2,015	5 " "
" 10	45,175	3,255	1 " "
" 17	650	1,640	¼ " ebb

Table II--Station No. 6--Hauls

Date 1926		Volume of settled material in c. c.
July	28	1.0
Aug.	4	1.0
"	11	1.0
"	19	2.0
"	25	2.0
Sept.	2	1.75
"	8	2.0
"	15	1.5
"	23	1.75
"	29	2.0
Oct.	7	2.0
"	14	3.0
"	27	4.0
Nov.	3	0.5
"	10	0 1
"	18	0.5
"	24	1.0
Dec.	1	0.5
"	15	0.25
"	22	0.5
"	29	0.1
1927		
Jan.	5	1.0
"	12	1.5
"	19	0.5
Feb.	7	0.75
"	16	0.75
"	23	0.5
Mar.	2	1.0
"	9	1.5
"	17	0.75
"	23	1.0
"	30	5.0
Apr.	5	15.0
"	22	2.0
"	27	35.0
May	4	25.0
"	11	20.0
"	26	4.0
June	4	3.0
"	9	4.0
"	16	22.0
"	23	12.0
July	7	16.0
"	21	3.0
"	28	1.0
Aug.	4	5.0
"	10	2.0
"	17	1.75

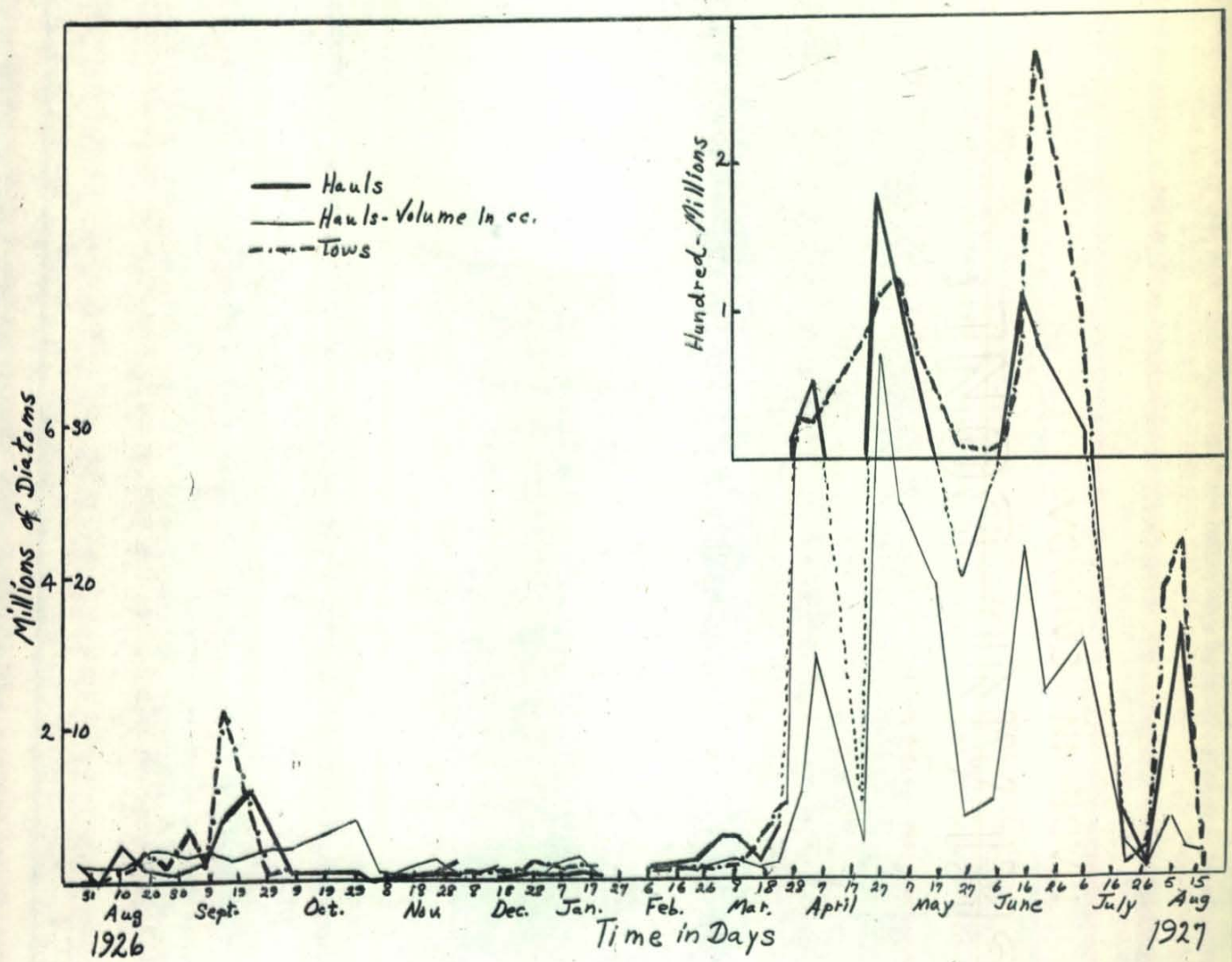


Fig. I Graph showing the autumn and spring maxima of diatoms at Station No. 6, as determined by the numbers counted in both tows and hauls, and by the volume of material in the hauls.

Table III--Station No. 5--Tows

Date 1924	Number of Diatoms in Thousands	Time of Tide
Aug. 12	1,835	2½ hrs. ebb
Sept. 16	11,285	low
Nov. 12	775	5½ hrs. flood
Dec. 11	405	5¾ " "
1925		
Jan. 16	90	4½ " "
Mar. 20	735	1 " "
May 11	96,705	low
June 16	242,260	¾ hrs. "
July 13	27,065	5½ " ebb
Aug. 1925 to July 1926	previously reported	
1926		
Aug. 17	1,555	½ hr. flood
Sept. 14	4,480	4 hrs. "
Nov. 13	290	4½ " ebb
Dec. 10	20	2 " flood
1927		
Jan. 13	80	3 " ebb
Feb. 11	245	3 " "
Mar. 10	865	1¾ " "
Apr. 25	1,223,530	4 " "
May 14	1,968,940	high
June 22	168,375	2½ hrs. "
July 20	6,640	2½ " flood
Aug. 17	5,000	low

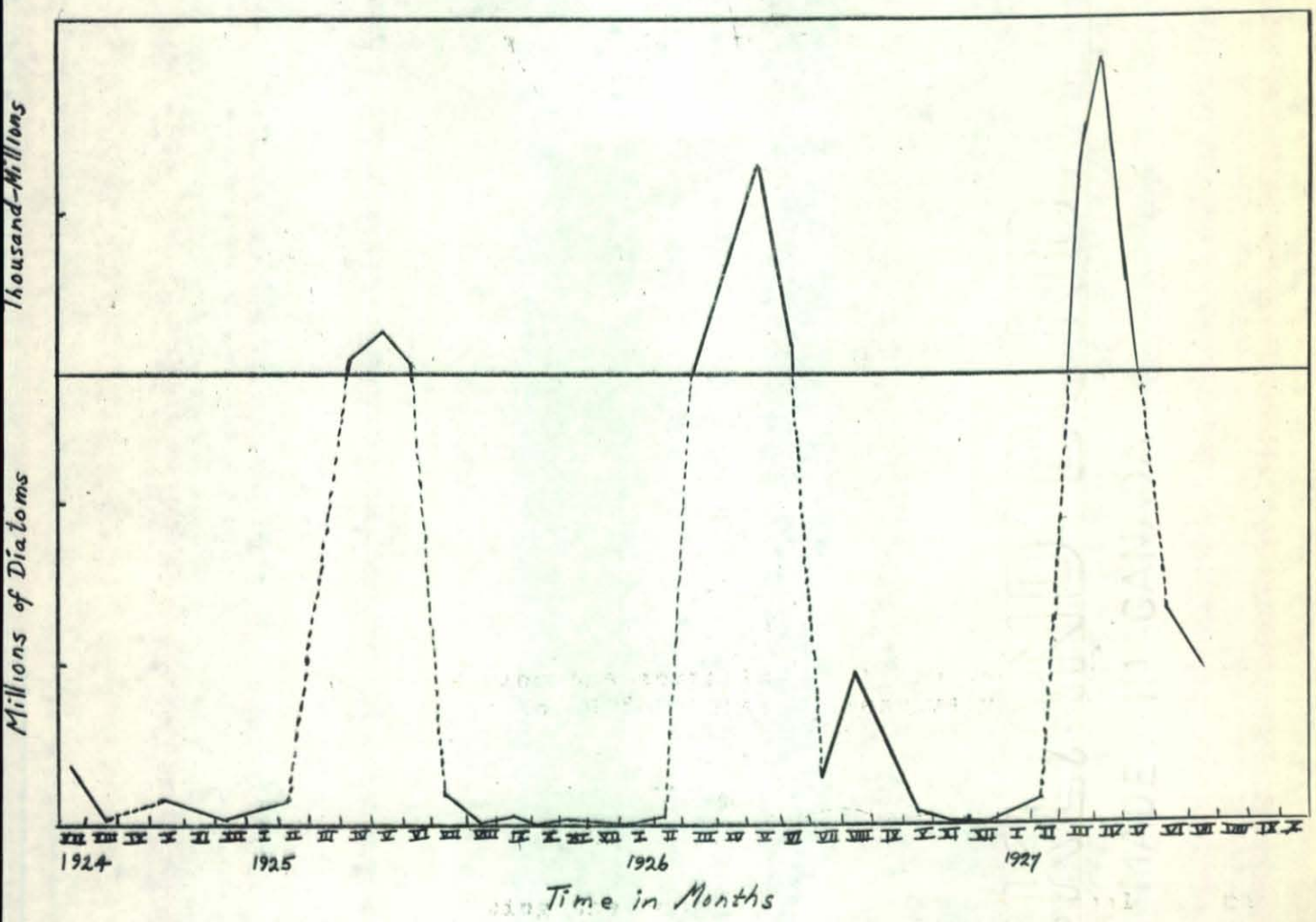


Fig. II Graph showing the comparison between the annual maxima at Station No. 5 for three successive years.

The counts recorded in table No. I and shown in graph No. I indicate a small but distinct maximum of diatoms in the St. Croix River at Station No. 6 early in September. It decreased quite suddenly and very little diatom material was taken in the nets throughout the whole winter. About the middle of March, rapid growth began reaching a maximum for the summer in the hauls in April, and in the tows in June. The two graphs show the same general characteristics throughout the year with the three prominent points of maxima within a week of each other. When one considers the great disturbance of the water of the St. Croix estuary due to the high tidal fluctuation in this region, and the irregularities possible in the amount of material taken especially in the tows, it is not surprising that there is a variation in the amount of material taken even on the same day in the tows and in the hauls.

The amount of material in the tows was so much greater than in the hauls that it was necessary to divide the computations made from the counts of each sample by 10 to be able to include them on the same graph with the hauls.

The time of tide at which the nettings were made is included in both tables I and III, but the results are so irregular that no conclusion can be reached as to the effect on the amount of material by taking it at any particular time of tide. It would seem that the great difference in the number of diatoms counted in the hauls of April 5th and 22nd must be due to some irregularity, since as great variation did not occur again in the tows. The decrease, however, in the later part of May and again in July was common to both.

It is interesting to compare the periods of maxima and minima with the amount of rainfall in the St. Croix basin. For this purpose, reference was made to the total amount of precipitation reported in the meteorlogical report of Canada for St. George, N. B., which is as follows:

1926

July	Aug.	Sept.	Oct.	Nov.	Dec.
1.73	1.93	5.03	14.70	4.62	3.95

1927

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
3.19	3.08	4.18	2.80	1.72	3.69	4.31	7.56

The sudden maximum of September was coincident with a marked increase of precipitation. The very marked increased rainfall in October, however, apparently produced no maximum. Other conditions such as sunlight and possibly temperature may have been sufficiently unfavourable to offset the effect of the rainfall. The heavy precipitation of March is coincident with the first rapid growth of Spring. Both tows and hauls showed a marked decrease at the time of the scanty precipitation of May.

The June maximum occurred when the rainfall was much increased and the sunlight at its maximum. The sudden decline of July was the most marked of the year and the greater rainfall of this month did not produce an increased food supply in time to prevent the almost complete disappearance of the diatoms. In previous summers, the month of August has also been a period of little diatom production, but in this case there is a very prominent and sudden maximum also accompanied by much increased precipitation. The falling off in July is the only exception. The light may be too strong, the temperature unfavorable, or the food supply so depleted by the rapid and very great spring growth, that the rainfall was insufficient until August to restore favorable conditions. There may be, during July, a greater demand upon the diatoms as food for copepods and other planktonic forms which would decrease their numbers in the nettings.

Hutchinson (8) in his paper on the Biohydrographical investigation of the sea adjacent to the Fraser River mouth, shows that a reduced salinity due to river water mixing with the sea water produces a diatom maximum at two different points, one above the river mouth, and the other below. He does not believe that salinity is a limiting factor apart from indicating the amount of dilution due to river water. Rainfall in the St. Croix basin especially in the early spring, when it includes interior washings from the melting snows would have the same effect in the water of the estuary.

Table No. II records the numbers of diatoms present in the tows made at Station No. 5 with No. 18 net for two years. Graph No. II includes all the data from the counts from August 1924 to August 1927, --the counts for the middle of the graph being recorded in the tables of last year's report.

This graph shows that the spring maximum at this station occurred at approximately the same time in each of the three years. Each year showed a small but distinct autumn maximum occurring in different months, that of 1924 being in November, that of 1925 in October, and that of 1926 in September. Since the tows were only taken monthly instead of weekly, and the fluctuations are often very sudden, lasting occasionally only a few days, only very general conclusions may be drawn from such data.

It is interesting, however, to observe that the points of summer maxima and minima fall about two weeks later than in the river at Station No. 6. The autumn maxima of 1924 and 1925 occurred one month later than in the river and that of 1926 about the same time.

If we consider the inflow of water from the St. Croix as a possible source of food supply to production diatom growth, it is reasonable to expect that its effect would not be felt as early in the bay at Station No. 5 as in the estuary of the river at Station No. 6.

The volumetric method of finding the maximum production is less reliable than the counting. Apparently, from the graph, the autumn maximum was reached in October, whereas the counts plainly showed it to take place in September. The volume of the spring material showed far

less increase than the counts indicated. This can be explained by the fact that the species abundant in the spring are composed of very delicate, small frustules, which pack closely together, and also comprise almost the total bulk of the material taken in the nets. The general picture presented by the volume in the spring hauls is like that presented by the counts made from the hauls, but the extremes are less pronounced.

If one were to measure the plankton present in the water as a food supply for copepods or other marine animals, the volumetric method would give a more satisfactory result than the counting of the diatoms. As an indication of rapid growth or decline, the more laborious counting method seems to be necessary.

The Genera of Diatoms Abundant in the Tows and Hauls.

At Station No. 6, the August tows of 1926 showed a considerable variety of genera with Chaetoceros most abundant. The total volume of diatoms was small. Peridinians were abundant, and copepods present in small numbers. In September, Chaetoceros was the most abundant genus, and Coscinodiscus was increasing in quantity. Through October, November, December, and January, Coscinodiscus was the most prominent genus, but of course, the whole volume was very small. Actinoptychus and Biddulphia were also present in limited numbers. In February, Chaetoceros again assumed the lead, and maintained its place until the end of March, when Thalassiosira became more abundant. Throughout April, the tows were composed almost entirely of only four species: T. nordenskoildii, T. gravida, C. sociale, and C. debile. During May, June, and early July, Chaetoceros formed the bulk of all the tows, and then quite suddenly, almost entirely disappeared. In August, C. constrictum was in marked proliferation, and lasted for about two weeks and then rapidly decreased.

The report made upon the material taken at Station No. 5 showed a very similar order of appearance and diminution in the same species as taken at Station No. 6, but the changes from one form to another took place about one month later. There was, too, a less marked minimum in the summer than in the St. Croix estuary.

Careful examination was made of fresh material taken daily during the August abundance, in search of evidence of the formation of spores as a preparation for the period of decline, which experience has shown always follows hard upon such a marked proliferation. No resting spores could be discerned in any of the fresh material. There was evidence of rapid fission and what looked like auxospore formation in the material taken on August 1st, when the increase was becoming very rapid.

The only record I have of resting spores being found in the summer material examined, was made of a Chaetoceros chain found in the June tow at Station No. 5. One would conclude, then, the plants were not preparing for unfavourable conditions by the preparation of resting spores and sinking to the bottom. It is more probable that the diatoms were being devoured rapidly by marine animals.

Copepods in the larvae stages were found on August 1st, when the diatoms were on the increase, and later as the plants were decreasing copepods were so abundant in the fresh tows that it was hard to separate them from the diatoms which were being used for inoculation.

Table IV--Measurements of Aurelia flavidula

Date 1926	No. of Specimens	Average diameter in centimetres
June 30	15	5.9
July 4	5	4.3
" 6	18	8.0
" 11	8	8.8
" 12	15	8.9
" 14	15	8.8
" 19	20	10.2
" 21	16	10.9
" 26	15	15.7
" 28	13	15.5
Aug. 4	4	18.2
" 5	23	18.0
" 8	9	20.8
" 16	16	21.0
" 17	8	20.9
" 19	26	21.4

Measurements of Aurelia flavidula.

A study of table IV and the records from which the table was compiled, show that the jelly fishes grew most rapidly between July 21st and July 26th, the increase in average diameter being from 10.9 to 15.7 centimetres. In previous summers, nearly all the specimens measured were taken from water close to the dock in calm weather. The measurements here recorded were made most often from material brought in when tows were made for fish eggs or when the specimens could be obtained out in the river at some distance from the docks. The measurements on July 6th, 11th and 12th, were made of specimens taken near the dock; that of July 14th, of specimens brought in from a tow and the results were the same. On July 29th, 137 jellies were thrown out of the nets taking a tow for fish eggs showing that a vast school must have been encountered at that time. There was no noticeable increase in numbers observed about the dock on that particular date. By August 5th, the Aurelia were easily broken up, and many were sexually mature. On August 11th, the largest jelly fish found during the season was measured to be 30 centimetres, the minimum on the same day was 14 centimetres. On August 17th, it was recorded that many specimens had torn edges. This was likely due to their heavy mature condition, which made it difficult for them to withstand the rough, stormy weather of August 14th, 15th and 16th.

I am indebted to Captain Rigby for the following report upon the disappearance of the jelly fishes: "They began to thin out early in September, and gradually decreased until the end of October." This behaviour is a repetition of what has been observed previously.

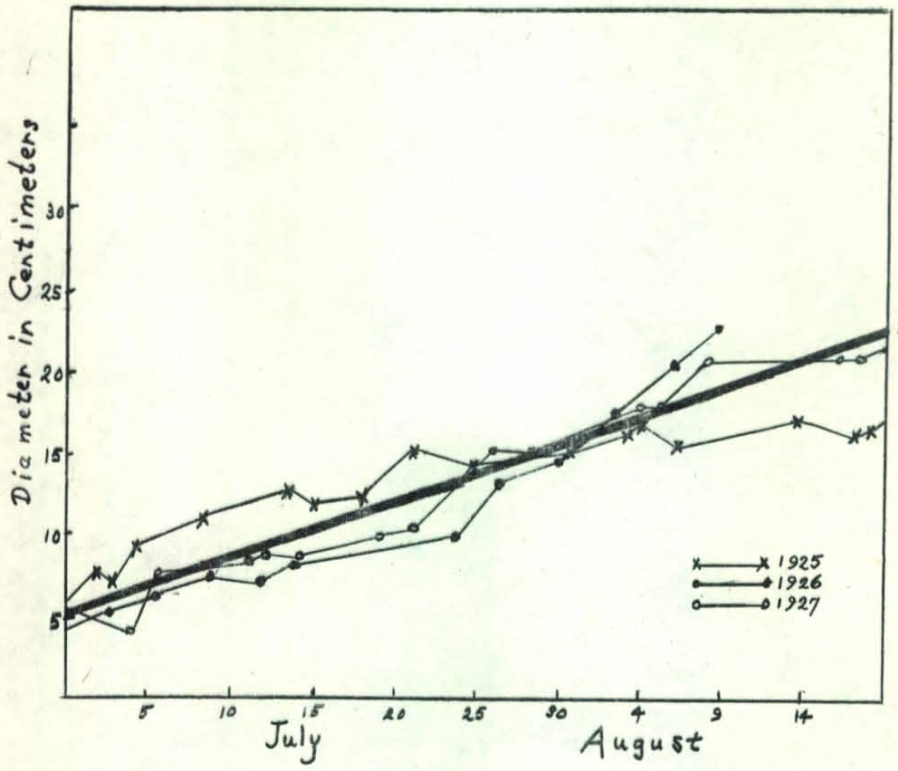


Fig. III Graph showing the rate of growth of Aurelia flavidula for three successive years.

CULTURES

Culture I--Part A.

Date: June 30, 1927.

Purpose: To grow planktonic diatoms in a culture of jelly fish under artificial light at as low temperature as could be obtained with streams of sea water flowing over the jars.

Notation and Content: Four jars numbered 1, 2, 3, and 4, were sterilized and filled to 250 c. c. with fresh sea water strained through No. 5 net. To each was added two grams of fresh jelly fish dried on filter paper and cut radially, and then broken up as finely as possible with a glass rod in a small beaker containing a little of each of the measured samples of water.

Position: The jars were removed to the darkened basement and cooled with streams of sea water until the evening of July 5th, when it was first possible to turn on the electric light to begin the experiment proper. During the first four days, the jelly fish was disentegrating slowly in the dank cool basement.

The source of illumination was a 300 watt bulb. Jar 1 was placed at 13.5 inches, jar 2, at 18 inches, jar 3, at 22.5 inches, and jar 4, at 27 inches from the light after each had been inoculated with two drops of fresh plankton from No. 18 net.

Detailed observations:

I. The plankton used for inoculation was examined, and it was found to contain the genus Chaetoceros in abundance, including a great variety of species, C. debile, C. decipiens, C. boreale, C. sociale, C. teres, and C. densum, being present. The following were present in small amounts: Pleurosigma, Leptocylindrus, Acnanthes, Thalossiosira, and Coscinodiscus.

II. The temperature of each jar was found by stirring the whole contents vigorously a moment with the thermometer. A temperature chart in °C. was kept as shown in the table to follow. Then streams of water were adjusted with an arrangement of pinch cocks as used in Toronto the previous winter, to keep the temperature as nearly uniform as possible in all the jars. Practice in adjusting the streams of water flowing over the jars made it possible to keep the variation in temperature throughout the series within $\frac{1}{2}$°C., which previous experiments showed to be satisfactory.

III. Samples were taken from each jar every two days for examination. The contents were agitated thoroughly by rotating the jar in the hand, and then a small amount was drained off quickly and transferred to a small vial. Observations were made at once to ascertain the condition of the diatoms before they became plasmolysed to any great extent.

The results in the tables show them reported as living or dead;--by living, the writer means containing coloured and fairly healthy-looking chromatophores; the dead chains were empty and plasmolysed. Unfortunately, the second jar was broken on July 7th, just after the

first sample had been taken.

Table V

Date	Time	Temperature			
		Jar 1	Jar 2	Jar 3	Jar 4
June 30	6.00 p. m.	13.5	13.5	13.5	13.5
July 5	4.00 p. m.	12.8	12.8	12.8	12.8
	6.30 p. m.	12.8	12.0	12.0	12.8
	10.00 p. m.	12.5	12.5	12.4	12.4
July 6	8.10 a. m.	12.5	12.5	12.5	12.5
	11.00 a. m.	12.2	12.2	12.2	12.2
	5.30 p. m.	13.0	13.0	13.0	13.0
July 7	8.10 a. m.	13.0	13.0	13.0	13.0
	3.00 p. m.	12.5	12.5	12.5	12.5
July 8	8.30 a. m.	12.2	broken	12.2	12.2
	2.15 p. m.	12.5		12.5	12.5
July 9	9.00 a. m.	13.0		13.0	13.0
	1.30 p. m.	12.5		12.6	12.8
July 10	9.00 a. m.	13.8		13.8	13.8
	6.00 p. m.	13.8		13.8	13.8
July 11	2.00 p. m.	14.0		14.0	14.0
July 12	8.45 a. m.	15.0		14.8	14.5
	5.00 p. m.	14.2		14.5	14.2
July 13	9.00 a. m.	14.0		14.0	14.0
July 14	8.30 a. m.	15.0		15.0	15.0

Table VI--Culture I

Day of Month--July, 1927

Jar	Diatoms	7	8	9	11	12	14	Totals
1	Living	16	33	10	33	14	8	114
	Dead	90	38	64	1	33	56	282
								396
2	Living	55	broken					
	Dead	194						
3	Living	3	15	38	39	21	10	126
	Dead	20	29	100	40	58	126	373
								499
4	Living	15	21	4	82	29	14	165
	Dead	18	38	29	30	39	133	287
								452

The samples contained Chaetoceros almost entirely. C. debile and C. sociale formed the greater part. The early samples contained long chains similar to those in the fresh plankton and there was evidence that they were multiplying. As time went on, the chains were broken up, and part of the frustules became dead. Finally, only a few, perhaps one or two, showed any appearance of life.

The totals indicating the amount of multiplication in the whole series showed that the growth was very small, almost negligible, and of no great difference as regards the response to the stimulus of light. The jar closest to the light had the smallest number of total living diatoms, and the one farthest, the greatest number. It is to be regretted that the second jar was lost, because it made the most promising beginning. There were no signs of bottom living diatoms in any sample taken.

Culture I--Part B.

Date: July 14th.

Purpose: To test the effect of raising the temperature and increasing the light intensity to that of the north window of the laboratory on the cultures in I, Part A.

Observations:

July 17--Jar 1--There was a faint tinge of brown deposit on the bottom of the jar. It resembled Navicula when examined under the microscope.
Jar 3--No brown deposit, but a sample showed a few broken Chaetoceros chains, some Navicula, and one fine, very healthy looking patch of C. sociale.
Jar 4--Resembled jar 3, but showed less variety.

July 23--Jar 1--Contained a very rich culture of large, deep brown coloured Navicula. The sample indicated a culture of a single species.
Jar 3--A similar culture in less abundance.
Jar 4--Much less than jar 3.

The whole series was well graded in amount from the greatest in jar 1, to the least in jar 4.

July 28--Jar 4 contained a rich brown culture which about equalled that in jar 1 at its maximum, which was passed several days before.

Conclusions: The exposure to greater light intensity during the early days in the basement prepared the way for more rapid development when other conditions were made favourable.

The higher temperature in the laboratory and light intensity of the north window position brought up the bottom living forms which have always developed easily under these conditions.

The basement conditions were apparently a preventative as far as they were concerned and such that the planktonic ones existed, but did not multiply to any great extent.

Culture II

Date: July 6th.

Purpose: To grow diatoms for inoculating new cultures.

Notation and Content: There were two jars, A and B, each containing 250 c. c. of fresh sea water filtered through No. 5 net, to which two grams of freshly broken up jelly fish was added. No inoculation was made, apart from what the sea water contained.

Position: Both were placed in the north window of the laboratory.

Detailed Observations:

July 11--Both jars showed a distinct brownish deposit in the bottom of the jars, which, when sampled and examined under the microscope, showed the following:

Jar A--(1) Fine, long chains of C. debile. Some spines were gone, and the chromatophores were rather pale in colour, but the chains were growing. (2) A small number of frustules of C. sociale and C. decepiens. (3) A few broken chains of T. gravida which appeared quite healthy. (4) There were also many small frustules which looked like rapidly growing patches of deformed planktonic chains. They have appeared each previous summer, and I cannot be sure of their origin. They may be small Navicula but the little outgrowths would more closely resemble broken chains of Skeletonema or Chaetoceros. The filaments which extend out from the cells may be mucilagenous secretions to meet unfavourable conditions, such as was offered as an explanation for a similar condition as reported in the Depths of the Ocean. Page 317.

Jar B--This culture resembled A very much, but had in addition a number of patches of large Navicula frustules, and one healthy Coscinodiscus.

July 12--There was little change in the gernera in either of the jars apart from the appearance of N. closterium in a very healthy condition. Jar B contained more of the latter than A.

July 14--Jar A was almost a culture of a single species, that being patches of the fine broken chains mentioned in the observation of July 11th. Jar B was rich in N. closterium and contained a few patches similar to the contents of Jar A.

July 17--Jar A contained a culture fading in colour. Its chains were dense and dwarfed; the colour unhealthy. Jar B revealed a good N. closterium culture also past its maximum. Both the small inactive N. closterium and the long active forms mentioned in previous accounts of this species, were present.

July 23--Both cultures were still rich, but faded somewhat in the depth of brown colouration.

Conclusion: This experiment repeated the results of each preceding summer, and showed that a jelly fish culture could, if exposed to sufficient light and warmth, produce a rich growth of neritic diatoms in five days from the spores or frustules in the water at the time that the jelly fish was added. The cultures furnished inoculation for later experimentation.

Culture III

Date: July 11th.

Purpose: To test the effect of aerating cultures with a current of air sufficient to keep the liquid in gentle motion as nearly as possible like that of tidal and current movement in the sea.

Notation and Preparation: Six jars, numbered 1 to 6, were prepared, each containing 250 c. c. of strained sea water, and two grams of broken up jelly fish. All were then placed on the floor of the balcony in the sunshine to allow the jelly fish to disentegrate rapidly and dissolve in the water. On the following day, all the cultures had a milky appearance, but the jelly fish had not entirely dissolved. On July 14th, the solutions were filtered once through fine paper and then all the empty jars were heated for thirty minutes in the Arnold sterilizer to kill any bottom living diatoms which might have germinated during the three days. The jars were then cooled, the filtrate returned to them, and then all were cooled in a sea water bath till they reached 15°C., at which temperature all were inoculated with fresh plankton.

Position: Jars numbered 1 and 2 were placed on the light tower, and cooled with a stream of water.

Jars numbered 3 and 4 were placed at nine and sixteen inches respectively from a 300 watt bulb, on a tray in the darkened basement and cooled with streams of sea water.

Jars 5 and 6 were placed at the same distances, nine and sixteen inches from the same bulb, similarly cooled, and at the same time were agitated by having air bubbles sucked by a filter pump through a small glass tube which passed just below the surface of the liquid. The bubbles passed into the liquid rather rapidly--about four per second.

Temperature: Careful adjustment of the streams of water cooling the jars maintained a temperature through the series in the basement which did not vary more than .2°C. at any time when the readings were taken. The daily variation was much greater depending upon the outside variations in the estuary. The jars on the roof suffered many changes and could not be relied upon at all for results. The stream of water to the tower was very warm, the ground pipe being insufficiently insulated from the heating effect of the sun. The stream, before being directed over the jars, was cooling by passing through a keg of ice, but so rapid was the melting of the ice that the temperature became irregular during the renewing of the supply of ice. The records of temperatures while the experiment was running are shown in Table VII.

Detailed Observations:

1. The plankton used for inoculation contained: C. atlanticum, C. densum, C. debile, C. lacinosum, C. didymum, N. seriata, S. costatum, R. faeroensis, a great many bivalve larvae, and some copepods. The sample drawn off for inoculation was taken as far as possible from the diatoms only, and was four drops instead of the usual two drops, because the chains looked spent and were few in number.

2. The diatoms proved to be most abundant in jars 3 and 4. There was in no case much growth. Those in the agitated cultures were less healthy and much fewer than in the same series unaerated. The counts are shown in Table VIII.

Conclusion: The aeration of the cultures as carried out in this experiment did not produce as favourable condition for growth as that in the companion jars Nos. 3 and 4. The unsatisfactory range of temperature which the cultures in the jars numbered 1 and 2 suffered, could not be expected to produce reliable results. The method of cooling with ice was unsatisfactory unless a great deal was available, and since such was not the case, its use had to be discontinued.

Table VII

Date	Time	Basement	Tower	Weather
July 14	6.45 p.m.	15.0°C	16.5°C.	
	8.30 p.m.	15.5	17.5	
July 15	8.00 a.m.	14.0	16.0	
	9.00 a.m.	14.0	15.5	
	11.30 a.m.	13.5	17.0	Cloudy but warm
	12.00 noon		14.0	
	1.30 p.m.	14.0	14.0	
	7.00 p.m.	14.2	14.8	
July 16	8.30 a.m.	14.0	15.0	Rain
	11.00 a.m.	14.0	15.0	
	2.00 p.m.		18.0	
	3.15 p.m.		14.0	Clearing
	7.00 p.m.	13.0	18.0	
July 17	9.00 a.m.	14.5	15.5	Cloud and fog
	6.15 p.m.	13.0	14.0	
July 18	9.15 a.m.	13.8	16.5	Hot--ice all day
July 19	9.00 a.m.		17.0	
	11.00 a.m.	14.0	13.5	Cloudy
	2.30 p.m.		16.0	Sunshine
	3.15 p.m.		13.5	
	4.30 p.m.		13.0	Much ice required
	6.00 p.m.		14.5	
	7.00 p.m.	14.5	15.0	
	11.00 p.m.		16.0	
July 20	8.30 a.m.	14.8	15.0	Cloudy and rain but
	10.30 a.m.		16.0	ice required
	11.45 a.m.		14.5	
	3.30 p.m.		16.8	
	5.00 p.m.	14.5	14.2	
July 21	9.00 a.m.	13.5	18.0	Sunshine
	11.30 a.m.		15.0	Very warm
	1.45 p.m.	13.8	19.0	No ice available
	6.00 p.m.	14.8	20.0	
July 22	9.00 a.m.	14.2	16.0	Cloudy
	2.30 p.m.	14.0	16.5	
July 23	9.00 a.m.	13.0	16.0	Cloud and fog
July 24	2.50 p.m.	13.5		
July 25	11.00 a.m.	14.0		

Table VIII

Day of Month--July

Jar	Diatoms		17	20	22	25	Totals
1	Chaetoceros	living	2	4	8		14
		dead		9	12	6	27
	Skeletonema	dead	4				4
	Pleurosigma	dead	1				1
							46
2	Chaetoceros	living	0	0	14	0	14
		dead	3	0	4	5	12
	Thalassiosira	dead	0	0	4	0	4
							30
3	Chaetoceros	living	16	23	32	16	87
		dead	0	5	12	12	29
	Pleurosigma	dead	0	1	0	0	1
	Rhizosolenia	living.	0	1	0	0	1
	Thalassiosira	dead	0	0	5	0	5
							123
4	Chaetoceros	living	20	44	22	16	102
		dead	4	13	17	5	49
	Pleurosigma	living	0	0	1	0	1
		dead	0	0	0	1	1
							153
5	Chaetoceros	living	0	0	3	3	6
		dead	7	0	0	3	10
	Paralia (?)		0	4	0	0	4
	Pleurosigma	living	0	0	0	1	1
							21
6	Chaetoceros	living	0	0	0	2	2
		dead	0	0	0	0	0
	Pleurosigma	living	0	1	0	0	1
							3

Culture IV

Date: July 13th.

Purpose: To grow diatoms in jelly fish cultures in cooler water than had yet been tried.

Notation and Preparation: There were four jars in the series, and each contained 250 c. c. strained sea water with two grams of fresh jelly fish. The jars were placed for three days on the tower in

the sun to allow the jelly fish to dissolve, and then cultures 1 and 2 were filtered through fine paper and the jars sterilized to kill any bottom living diatoms contained therein, and the filtrate returned to the jars. Cultures 3 and 4 were left unfiltered. On July 18th, all were inoculated from plankton which contained many copepods, avoiding them as carefully as possible by drawing them to one side of the dish by a lighting device.

Position: All were tied to the breakwater so that the top of the cultures would be a uniform distance, about three inches, below the water level. The jars were thus kept at surface water temperature and in the sunlight, which could penetrate the top three inches of sea water. Samples were taken by raising the bottles, but not removing the cords from the breakwater. The contents suffered, therefore, no appreciable rise in temperature during sampling.

Detailed Observations: Counts were made as shown in Table IX.

		Day of Month--July			
		20	22	25	27
Jar 3	Living	20	23	10	3
	Dead	5	15	12	7
Jar 4	Living	23	5	39	50
	Dead	9	1	5	15
Jar 1	Living	00	33	8	lost
	Dead	0	6	0	
Jar 2	Living	20	11	15	0
	Dead	0	0	0	3

Samples on July 25th and 27th were taken directly from the bottom without the usual stirring taking place, in order to investigate what species might be growing, since it was apparent that no vigorous multiplication was taking place.

Conclusion: Even the colder temperature of the surface sea water did not produce a vigorous culture of diatoms. There was no marked difference in the abundance of life. Both of the unfiltered cultures developed a brownish deposit of bottom growth, which was not present with filtered cultures placed in sterilized jars showing that the latter method adopted was successful in eliminating the more hardy bottom living species which could even stand the high temperature of the light tower during the decomposition of the jelly fish.

Culture V

Date: July 26th.

Purpose: To test the effect of agitating a culture inoculated with bottom living diatoms by bubbling air through it.

Notation and Composition: The cultures in jars 3, 4, 5, and 6 of culture III were reinoculated from jar 1 of culture I, which contained a healthy growth of Navicula.

Position: Jars 3 and 5 were placed as before, nine inches from the light, and jars 4 and 6, sixteen inches from the light (300 watt bulb).

Temperature: Inoculation was carried out at 19°C., the temperature of the basement, and the jars were kept at that temperature throughout the experiment. The front pair of jars required a small stream of water to counteract the heating effect of the bulb. A temperature record made at least twice daily showed a maximum of 20°C. and a minimum of 17.5°C., but the usual record was 19°C.

Detailed Observations: The experiment lasted until Aug. 5th, a period of ten days, and in that time all the jars developed a brown deposit of diatoms. The front cultures developed more quickly, but did not produce any richer cultures than the back jars later produced. The agitated cultures were slightly less productive, that the controls and the bubbling did not prevent the diatoms from settling and growing to the bottom of the jar.

Culture VI

Date: July 28th.

Purpose: To produce cultures of diatoms for inoculation purposes.

Notation and Composition: Four jars composed this series. All contained 250 c. c. of strained sea water, and two grams of jelly fish left to disentegrate for two days in the sunlight. Two were inoculated with fresh plankton, in which C. constrictum and N. seriata were abundant, and the other two, with N. closterium from Culture II.

Position: All the jars were placed in the north window of the laboratory.

Observations: For the first five days, the Chaetoceros chains grew well. No N. seriata survived. Then N. closterium, and some large brown Navicula crowded out the planktonic chains. The Chaetoceros, however, during the early stages, was unusually vigorous, and healthy-looking, and its condition led me to believe that this species took more favourably to life in such cultures than any other planktonic form previously tried. The N. closterium progressed well and reached its maximum in eight or nine days.

Culture VII

Date: July 28th.

Purpose: To grow N. closterium under artificial light at a higher temperature than previously tried, as a comparison with conditions in Culture VI.

Notation and Content: Two jars were prepared at the same time and in the same way as those used in Culture VI, and were inoculated with N. closterium.

Position: Both were placed on a board under the 300 watt bulb, but were not cooled by any streams of water. The first jar was 10 inches from the bulb, and the second, 17 inches.

Temperature: A record was kept which showed a maximum of 25°C. in the nearer jar, and a minimum of 23°C. in the farther one, the average being 24.2°C. Such a small variation one may consider negligible.

Observations: In three days, the jar nearer to the light contained a very rich brown growth of N. closterium which was more abundant and more active when viewed under the microscope than the contents of the jars in the north window in Culture VI. In five days, the farther jar also contained a rich culture.

Conclusion: A temperature averaging about 24°C. and the artificial light at a distance of 10 inches from a 300 watt bulb with no intervening layer of glass, presented very favourable conditions for the growth of N. closterium. In fact, it was better than a north window exposure at the temperature of the laboratory which averaged about 20°C. This experiment simply demonstrated that N. closterium could be grown successfully in what had, heretofore, been waste space in the arrangement of the culture jars, and could be used as inoculation material, if necessary, for other cultures.

Culture VIII

Date: August 5th.

Purpose: To compare the growth properties of bottom and surface water taken at the same time at Station No. 6 by inoculating the water with diatoms to be grown under uniform conditions of light and temperature.

Notation and Content: There were four jars in this series, two sets of two jars each. The jars labelled "S" in each set contained 250 c.c. of surface sea water, and the jars marked "B" contained bottom water. The water for the whole experiment was carefully filtered and inoculated from good growing cultures and with fresh plankton. The inoculation was carried out when the water in the new jars was at the same temperature as that of the growing cultures, in order that the plants should suffer no harm from the transfer. Set I was inoculated with a bottom living species, thought to be Navicula, and Set II, with fresh plankton containing very vigorous and abundant C. constrictum.

The inoculation was sufficiently small, that it became lost in such a large quantity of water when a sample was immediately taken. Any later samples sufficient to be counted, would, therefore, indicate that multiplication had taken place.

Position: All the jars were placed at a distance of 9 inches from the 300 watt bulb, and the streams of water were regulated to keep the temperature as nearly 19°C. as could be obtained with such an apparatus. The aforementioned conditions had been found favourable for the growth of both these species of diatoms.

Temperature: The records in °C. are stated in the accompanying Table IX. On Aug. 7th, the sea water supply ran out for a few hours, and the temperature rose about 2° too high. A study of the table reveals that the variation which took place in the jars of each set throughout the duration of the whole experiment was too small a factor to be important.

Table IX

Date	Time	Temperature			
		Set I		Set II	
		S.	B.	S.	B.
Aug. 5	5.00 p.m.	18.0	18.0	18.0	18.0
	7.00 p.m.	18.5	18.0	18.5	18.5
	8.30 p.m.	18.8	18.8	19.0	19.0
	10.00 p.m.	18.5	19.0	19.0	19.0
Aug. 6	9.00 a.m.	18.0	18.5	19.2	19.2
	12.00 noon	19.0	17.0	19.0	19.0
	7.00 p.m.	20.2	20.0	20.8	20.8
Aug. 7	8.30 a.m.	21.0	21.5	21.8	21.8
Aug. 8	9.00 a.m.	19.0	18.0	18.0	19.0
Aug. 9	9.45 a.m.	18.5	18.8	18.0	18.0
	2.00 p.m.	18.0	17.5	19.5	18.0
	6.00 p.m.	19.0	20.0	19.8	19.5
Aug. 10	9.00 a.m.	17.5	18.0	18.0	18.0
	7.00 p.m.	18.8	19.0	17.5	19.0
Aug. 11	9.00 a.m.	18.0	18.5	18.8	18.8
Aug. 12	8.30 a.m.	19.5	19.0	19.0	19.0
	2.30 p.m.	19.8	19.0	20.5	20.5
	5.10 p.m.	19.2	19.0	20.0	19.0
	7.00 p.m.	19.0	19.0	19.0	19.0
Aug. 13	8.30 a.m.	19.0	19.0	18.2	18.6

Detailed observations: Samples were taken on Aug. 9th, 11th, and 13th, in the usual way, and counts made were recorded in Table X and graph figure IV.

Table X

			Day of Month--August		
			9	11	13
Set I	Surface	Living	76	139	636
		Dead	0	0	0
	Bottom	Living	388	805	1.524
		Dead	0	0	0
Set II	Surface	Living	0	4	0
		Dead	47	167	229
	Bottom	Living	71	430	827
		Dead	10	75	0

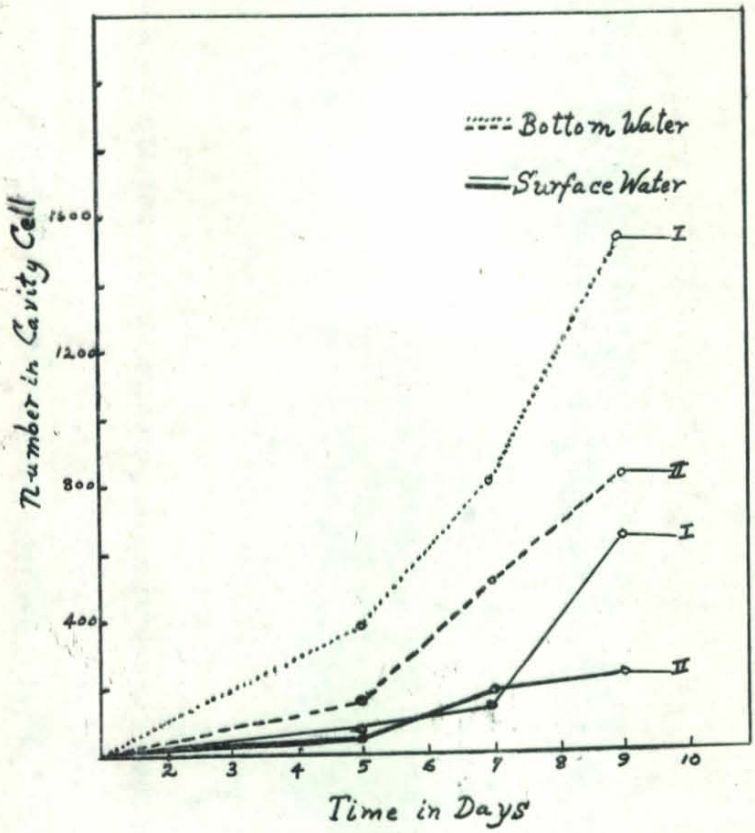
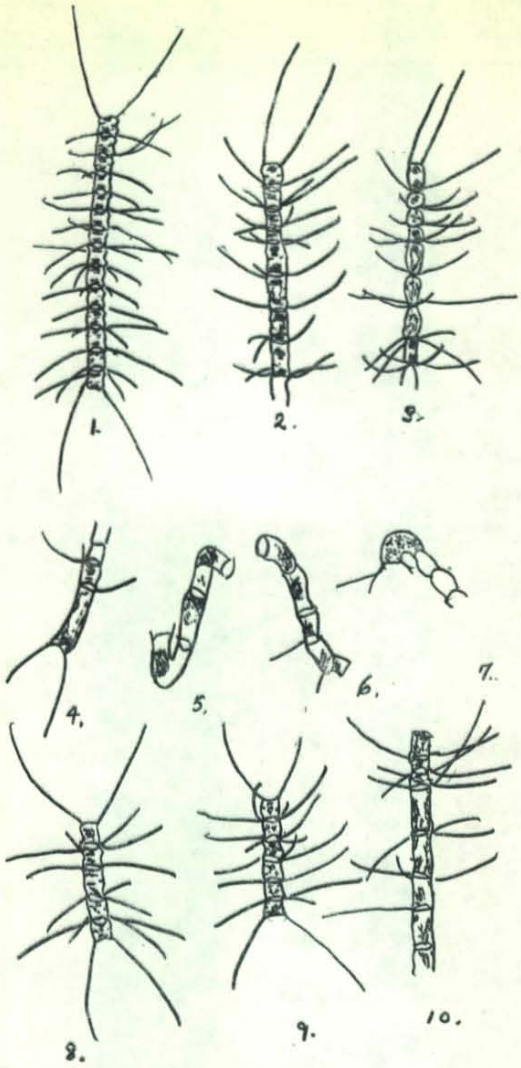


Fig. IV Graph showing a comparison between the productivity of surface and bottom water at Station No. 6.



Length - 20-24 μ.
Width - 14 μ.

Plate I Chaetoceros constrictum.

1. Normal chain from fresh plankton.
2. Normal chain with newly divided frustules.
3. The same chains in lateral view.
4.)
5.) Deformed chains grown in
6.) surface water in Culture VIII.
7.)
8.)
9.) Chains grown in bottom water in
10.) Culture VIII.

The counts recorded of Set I are reliable only in the most general way because bottom growing forms are very difficult to use as in indication of the productivity of a culture. They cling to the bottom gather in patches, and the counts may be quite variable from the same sample. There is sufficiently great difference, however, between the bottom and surface samples to indicate distinctly more favourable conditions in the latter. This agrees quite well with the results obtained in Set II for which the counts should be quite reliable.

In addition to greater numbers of diatoms being found in the bottom samples, the chains were in much better conditon. Drawings were made of chains of C. constrictum found in both surface and bottom water on August 12th, and are shown in the accompanying plate.

We must conclude that the bottom water in both sets produced better cultures than the surface water.

Culture IX

Date: August 5th.

Purpose: To investigate further the conditions under which C. constrictum would grow in cultures.

Notation and Composition: There were two jars, each containing 250 c.c. of strained surface water, to which two grams of fresh jelly fish had been added on the previous day, and left to disentegrate in the sunlight. Both were inoculated with fresh plankton in which C. constrictum predominated.

Position: The jars were placed on a box above the row of jars in Culture VIII, and were then thirteen inches from the 300 watt bulb.

Temperature: The reading was taken daily the same time as Culture VIII and ranged from 19°C. to 21°C., the average being 20.3°C.

Detailed Observations: Counts were made of samples taken on August 9th and 11th, and then the culture was destroyed to make room for the large one set up on August 13th.

C. constrictum flourished in both jars, and produced more new chains than any other species. It seemed to find the light sufficient, and the temperature favourable. All were healthy cultures when destroyed at the seventh day.

Table XI

	Diatoms	Day of Month--August	
		9	11
Jar 1	Living	105	134
	Dead	10	0
Jar 2	Living	169	175
	Dead	15	0

Culture X

Date: August 13th.

Purpose: To compare the growth properties of samples of surface and bottom water taken at different seasons at Station No. 492.

Notation and Content: It was decided that there would be insufficient room about the 300 watt bulb to accommodate all of the samples which had been carefully stored in the dark, cool basement throughout the year. Ten representative ones were chosen to show seasonal differences. Since the water had been carefully filtered before being stored, 250 c.c. was poured into each sterilized culture jar and the jars labelled with the date of each sample and marked "S" to indicate surface water, and "B" for bottom water. The bottom samples came from a depth of 28 to 30 metres. The dates of the samples chosen are detailed in the accompanying table. Inoculation was carried out very carefully. Fresh plankton containing C. constrictum in fair abundance was used. Five drops of plankton was used for each jar, which was insufficient to supply enough diatoms to count in a sample taken at once. The plankton was not rich enough to allow the use of the usual amount of two drops.

Position: The jars were placed in a circle about the 300 watt bulb at a distance of nine inches. The light intensity in this position was measured by Professor Klugh to be 1.1% of full noon June sunlight, or to have a gram calorie value of 1.771. A very gentle flow of water dropping in front of the jars cooled the air and the tray behind a cylindrical glass jar which enclosed the bulb to protect it from the splashing water, and to cut down the heating effect; to keep the temperature in the whole series of cultures very close to 19°C. The temperature was recorded three times daily, and fine adjustment of the jets made if required. The temperature record was kept, but since it was even more uniform than that in experiment VIII, has been omitted in detail from this account.

On August 17th, the jars were placed a little closer together, and two more added. They contained surface and bottom water freshly taken at Station No. 5. The bottom sample came from a depth of 90 metres, that station being well out in deep water in Passamaquoddy Bay.

Detailed Observations: Samples were taken at intervals of two days, and careful counts made. The sample of August 28th, from the bottom water of Station No. 5, contained patches too dense to count. The results are summarized in Table XII, the total number of diatoms found being recorded. They are also shown in graph No. 4.

Table XII

7 July 21 1926		Sept. 7 1926		Nov. 13 1926		Feb. 10 1927		Apr. 25 1927		Aug. 17 1927	
. S.	B.	S.	B.	S.	B.	S.	B.	S.	B.	S.	B.
65	43	13	18	15	34	15	34	36	19		
170	60	21	22	7	6	7	6	84	12		
143	77	11	39	26	29	26	29	98	4	17	31
204	69	20	40	12	28	12	28	52	12	17	29
121	38									25	many

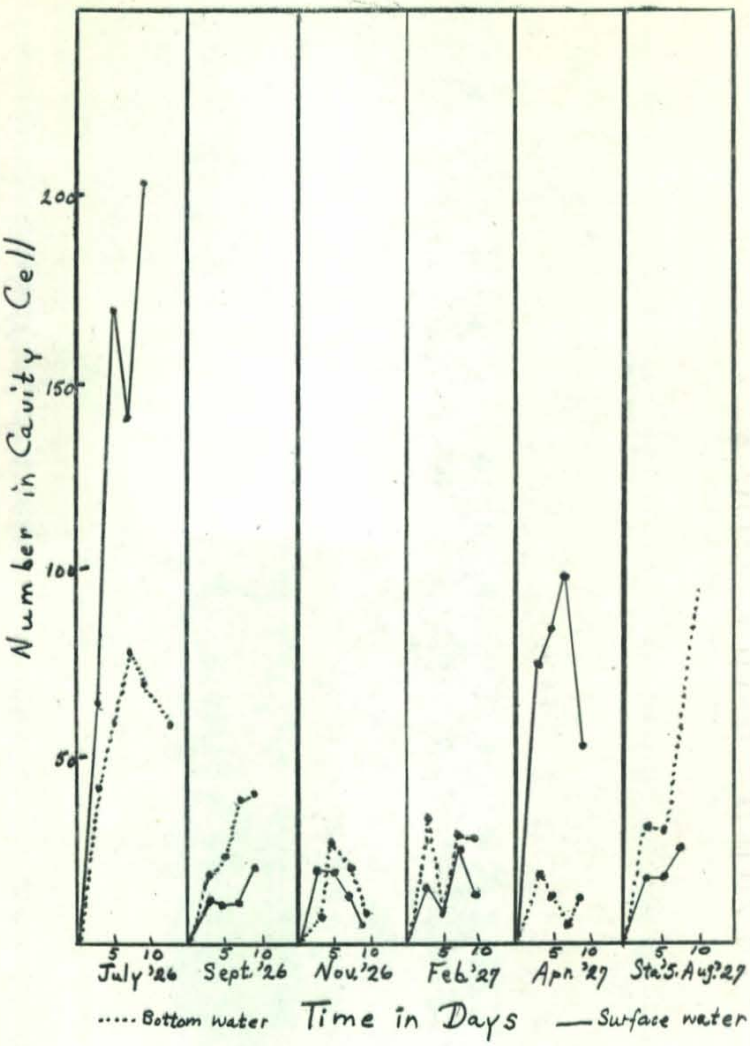


Fig. V Graph showing a comparison between the productivity of surface and bottom water at Station No. 492, taken at different seasons of the year.

The results of experiment X as shown by a study of the counts recorded in the table, were quite unlike those obtained in experiment VIII, except for that of the last pan of jars added on August 17th. The fresh samples of water brought in on August 17th from Station No. 5 out in Passamaquoddy Bay produced results very similar to the fresh samples from Station No. 6, the bottom water being decidedly more productive than the surface water. The deep water at 90 metres at Station No. 5 would suffer less disturbance than the water at Station No. 6, where the tide rise is very high, and the water less deep. The rest of the jars in Culture X contained water which had been stored for several months, varying from twelve, in case of the sample of July 21, 1926, to three in that of April 25, 1927. The fall and winter samples showed little difference between the surface and bottom water, but both the summer and spring samples were decidedly more productive in the surface waters. One might expect this in the spring sample, which was taken at a time when the diatoms were multiplying most rapidly in the upper layers of water, but it is quite the contrary in July, when the diatoms in the regular tows were at their minimum for the year in the surface tows. Further work must be done to either verify these results or to search for an explanation of them.

What takes place in the composition of sea water when stored, has not, as far as I know, been chemically explained. Changes of great importance may go on during the period of storage, and may be more marked in the richer bottom water than in the surface waters. Atkins (2) writes in his recent paper of white glass bottles effecting the phosphate content of stored sea water, and has changed the containers to green glass. The samples mentioned in this paper were stored in white glass "Perfect Seal" quart jars.

Summary and Conclusions:

I A distinct autumn maximum and a very great spring maximum in the production of diatoms occurred in the St. Croix river in 1926 and 1927. The extent of these maxima was very similar to that of the maxima of 1925 and 1926. Both periods of autumn maxima occurred when the jelly fishes were breaking up and disappearing, and when the rainfall was increasing. The spring maxima occurred during the months of fairly abundant precipitation, and when the light intensity was on the increase.

II There was the usual July death of diatoms. They disappeared with great suddenness for some unexplainable reason, and no solution as to what became of them was found. Just as suddenly as the spring maximum disappeared, a small summer maximum of genus Chaetoceros took place. The species which multiplied so rapidly was not present to any noticeable extent in the earlier tows, and after a few days' proliferation, just as suddenly disappeared.

III C. constrictum multiplied more rapidly and produced more healthy-looking chains in cultures than any other planktonic diatom yet grown.

IV Fresh samples of bottom water from both Stations No. 5 and No. 6, were more productive of diatoms than surface water taken at the same time. If the phosphate content is, as Atkins (2) believes, the limiting factor in growth, this is what we should expect after the surface waters had been depleted during the spring and summer maxima. The bottom water at this season would be too cold to suffer any upwelling except from tidal disturbance.

V Stored samples of bottom and surface water taken at different seasons of the year at Station No. 492, where the tidal effect was less than in the river gave contradictory results. The surface water in both spring and summer were more productive than the bottom water. It is quite likely that storage changed the chemical composition of the samples to a great extent.

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