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FISHERIES BRANCH

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# CONTRIBUTIONS

TO

# CANADIAN BIOLOGY

BEING STUDIES FROM THE

## BIOLOGICAL STATIONS OF CANADA

## 1915-1916

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1917

## THE BIOLOGICAL BOARD OF CANADA

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# PREFACE.

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The series of nine biological papers, included in the present publication, comprises a selection of the researches completed by various members of the scientific staff, last season, and includes some work done in previous seasons at the two Canadian Biological Stations, at St. Andrews, New Brunswick, and at Departure Bay, British Columbia.

Several very important investigations might have been included, but are not really complete at this date; two bearing directly upon the utilization of certain fish-products for food; but they will be published in the next volume of "Contributions." The question of a serial publication, or of the issue of separate papers as they reach completion, has occupied the attention of the Biological Board, especially in view of the fact that some researches can be completed earlier for publication than others, and yet are held back in order to appear in the same volume with papers which for various reasons cannot be hastened. About twenty trained scientific workers from eight different Universities have during the past season attended one or other of the Stations, and all engaged in marine and fishery studies of special interest, and in most cases of direct value practically and scientifically.

Purely scientific problems, while not neglected, have not formed a prominent feature in the biological investigations at the stations under the Board, and on many occasions there has been official recognition of the value to the Government of the researches undertaken. This appreciation of the practical bearing on the great fishing industries of Canada, of their work, has been a great satisfaction to the staff. Most of them carry on their work without recompense from the Government, and in no case has adequate recompense been possible. The main reward has been the satisfaction which original discovery in Science affords, the satisfaction of adding to man's knowledge of Nature and her resources, and of solving the pressing problems which the great industries on our seas and inland waters offer for solution to trained scientific experts.

During the year 1915 Dr. Johan Hjort, Director of Fisheries, Norway, continued the comprehensive survey of the waters of the Gulf of St. Lawrence and the Maritime Provinces shores which he had commenced the year before. Such a fishery survey, having special reference to the herring, cod, etc., had been considered by the Biological Board in 1909, and the Board had decided to enlist, if possible, the skilled aid of Dr. Hjort, or some Norse expert to be selected by him, and, as Chairman of the Board, I wrote to Dr. Hjort on the subject. Professor E. W. McBride, who was then the representative of McGill University on the Board, followed up my communication, and Dr. Hjort replied recommending a qualified junior member of his scientific fishery staff; but, owing to certain conditions involved, the proposal remained in abeyance. Two years later the proposition was revived by the Biological Board, who laid the matter before the Hon. the Minister because of the fact that the ordinary appropriation available was too limited to allow of a large expenditure upon such a fishery expedition. No final decision was reached until 1914, when the scheme took practical shape and Dr. Hjort, in the fall of that year, began his researches. During his second season (1915) in Canada he carried out a very elaborate series of investigations, and several members of the Biological staff took part, including Professor Willey, Dr. A. G. Huntsman, Dr. J. W. Mavor, and Commander Anderson and other officers of the Naval Service Department.

A series of voluminous memoirs, most of them fully illustrated, is now in the printer's hands, and the results of this important Atlantic Fishery Expedition will be of permanent interest and value.

As in previous volumes of the Biological Contributions, I give a brief *resumé* of the several papers which follow, for convenience of reference, and to afford a ready means of knowing some of the main points set forth by the authors.

1. The Winter Plankton, St. Andrews, 1914-15.—*(Professor McMurrich.)*

Previous Plankton investigations have been carried on in summer; but in view of the importance, as a source of nutriment for marine fishes, of the minute organisms floating in the sea, it appeared desirable to study these organisms in winter, as well as during the warmer months of the year, and Mr. Arthur Calder, a permanent officer of the St. Andrews Biological Station, made collections from September, 1914, to May, 1915. About twenty stations were visited regularly and suitable plankton nets used at the surface and at a depth of three fathoms. The depth and temperature (of the air and water), and the condition of the tide, were recorded on each occasion. Professor McMurrich points out that the collections at three fathoms depth showed greater abundance than near the surface; but the finer net used at the latter level may have influenced the result. The author grades the occurrence of the different species identified by him as "abundant," or "frequent," or "occasional," or "rare," and a study of the synoptical table, at the end of the paper, gives at a glance the comparative results. Among the microscopic plant-forms, the sub-globular *Coscinodiscus* (four species) is most constant, but it increases in abundance as spring comes on. Next, but much less constant, is *Biddulphia*. *Chaetoceras,* four or five species, occurs throughout the winter near the surface; but *Thalassiosira* and *Rhizosolenia* become suddenly most abundant in May and April. *Ceratium* and *Peridinium,* several species, were not frequent.

Curiously enough, some familiar animal forms seemed to be absent in winter, such as the Foraminifera, Radiolarians, and Infusorians, a few of the latter only occurring. Similarly Hydroids, and Echinoderm larvae, were rare in contrast to their frequency in summer. Higher animals, e.g., worms, mollusks, and the like, were rare, one *Sagitta* being taken on January 1st, and a number of Plutei, and Holothurian ova and larvae, in April and May. Minute crustaceans form, as a rule, a most abundant element in the zoo-plankton, and the Copepods or water-fleas appeared during the winter to be most constant, very few of the Cladocera being taken (viz. a species of *Podon* about the middle of October at three fathoms depth; *Temora, Harpacticus, Zaus, etc.,* being abundant or frequent, but Calani, species of which the rarest forms were *Parathalestris Jacksoni,* not before recorded in west Atlantic waters, and a single *Halithalestris*. Larval crabs and allied forms were rare, no lobster fry occurred; but Tunicate larvae were secured early in November and January, and Appendicularians in October. Only a few fish eggs and one small shore fish (pelagic stage) were obtained.

The winter plankton in these waters would not appear to be so abundant or varied as anticipated; but it may be that, by using modified nets and by more extended work, areas of plentitude may be discovered to which the schools of young fish resort for feeding purposes.

2. Diatoms and Lobster Rearing.—*(Professor MacClement.)*

Professor Knight's laborious researches have shown that efforts to rear lobsters through the young stages in hatching ponds have been hampered by several difficulties, one of the most serious being the diatom pest. After hatching, larval lobsters crowd near the lighted surface layers of the water, until after four or five moults they seek shelter at the bottom. While under the influence of sunlight they become loaded with microscopic plants, the diatoms forming a feathery coat as it were, and so incommode the floating larval lobsters that they were observed to sink to the bottom of the boxes used in the experiments at Long Beach, Nova Scotia.

After a description of the structure of diatoms, and of the three or four species chiefly affecting young lobsters, the author dwells upon the two principal methods of combatting the pest, viz., by copper sulphate solution, which proved fatal when only 1½ to 2 parts in three million parts of water were tried; and a second method, i.e., the screening from direct sunlight of the rearing boxes. Under this latter method larval lobsters loaded with diatoms soon lost a great many of them, and they moulted earlier, viz., in nine days, whereas the lobster fry not shaded from sunlight did not moult until the thirteenth day. *Licmophora* was the chief pest, but a list of nineteen species of diatoms occurring in the boxes is given, and the relation of the plankton to the sessile diatom pest is interestingly explained.

3. The Scales of the Spring Salmon.—*(Dr. C. McLean Fraser.)*

After reference to other work on fish scales, as affording information on the growth of fishes, Dr. Fraser states that the rings of growth in the Spring Salmon or Quinnat are much more regular in arrangement than those of the herring scale, and closely resemble the growth in a twig of wood (in cross section); the rings being closer and more compact in winter (the "winter check"), whereas from late in April to late in November the rings are wider, like the looser texture of the summer growth in the twig. Dr. Fraser noticed between March 17th and April 22nd, and between November 27th and January 5th, there were in many specimens evidences of retardation of growth, as Einar Lea had also noticed in the Norwegian herring. Careful tests made by the author did not show any relation between the temperature of the water and the retardation or the acceleration of growth, and the "graphs" given in the paper fully confirm this negative result. Nor does variation in food-supply appear to explain the phenomenon. An exhaustive study of the growth of the fish was made from the time when the fry (1½ inches long), not yet provided with scales, descends to the sea.

At the end of the year the fish are 10 inches long usually and weigh about half a pound. Not all the fry descend the first year; but some remain, and acquire their scaly covering in fresh water. The summer rings are close together, so slow is the growth of the fish in fresh water, and the two types of fish are remarkably contrasted even when both mingle in the same schools in the sea. Thus, the fish which reach the sea from March to April in their first year, may be 20½ inches long and weigh 4 pounds or over; but the delayed fish are only 14 inches and of a weight of a pound. In the third year they are respectively 28½ inches and 14 pounds weight, and 23 inches and 6 pounds weight; while, in the fourth year, they are in length 33 inches and 30 inches, and in weight 22 pounds and 16 pounds respectively. The more rapid growth of the "sea type" indicates that the retention of the fry in ponds is a mistake, and based on lack of accurate knowledge of the peculiarities of the Pacific Quinnat Salmon. Four very graphic plates and two diagrams establish the important conclusions reached by Dr. Fraser.

4. ON THE LIFE-HISTORY OF THE COHO.—*(Dr. McLean Fraser.)*

The author points out that the increasing commercial value of the Coho or Silver Salmon *(Oncorhynchus kisutch)* in recent years justifies a thorough investigation of its life-history, rate of growth, etc. The spawning grounds are usually a short distance from the sea, and not at the head waters, as in the case of the Sockeye and the Spring Salmon. The eggs hatch in three months and the young fry wriggle up through the gravel early in April, and work down the rivers as the yolk is absorbed, and early in May many are near the mouth of their natal streams and creeks, but do not appear to migrate into the sea until the following March, or even later. The alevins measure 1½ inches; but when they are about to enter salt water (nearly a year old), they measure 2 to 2¾ inches about; and eight or nine months later are 10 to 12 inches long and of a weight of 12 to 14 ounces. When 2½ years old or thereabout, they may be 3¾ to 16½ pounds in weight, and from 18 to 31 inches long, so great is the variation in growth. They are now mature and make the short ascent to their spawning grounds.

Dr. Fraser proves that the opinion, which has been frequently expressed, that coho live for two or three years in rivers feeding on trout is absurd, and the reverse is much nearer the truth, for trout gorge themselves with coho eggs and devour the fry mercilessly. The Dolly Varden trout (*S. malma*) is the chief culprit. The mature coho feed actively until ready to ascend for spawning purposes; the shrimp-like Schizopods being their main food, but larval crabs, young herring, launce, and capelin, form also part of their diet. Dr. Fraser's investigations correct the conclusions of previous workers as to the migrations and development of the coho, and three points, with which his report concludes, are of the highest interest to practical fish-culturists, viz., that the hatching of coho in fish-culture establishments is most desirable to avoid the wastage due to trout-depredations; and, secondly, that the retention of coho fry in rearing ponds must bring the best results, as almost the whole of the fry hatched naturally remain for a year or more in fresh water before descending to the sea. Lastly, early coho fishing operations are a loss to the fishermen and the canners, as the coho vastly increases in weight during the summer of its third year.

5. INVESTIGATION OF OYSTER PROPAGATION IN RICHMOND BAY, P.E.I., DURING 1915.—*(Dr. Julius Nelson.)*

The author, who was long prominent as a State Expert in New Jersey, U.S.A., agreed to carry on some special work in 1915 on the Richmond Bay Oyster Beds, P.E.I., and obtained some very remarkable results. These are difficult to epitomise owing to the very detailed nature of the investigation. The decline and extinction of certain areas are due not to the elevation of the beds, geologically, or by annual accumulations of debris, but to other causes. If the coast has been sinking, as seems probable, the intrusion of colder northern water may have lowered the temperature and the salinity may have been affected. Too much stress, says the author, has been probably laid on salinity, for oysters can endure much variation in that respect; but temperature, oxygen, and currents, are of importance.

Ice and snow also are unfavourable. Shallow water is favourable for propagation; but, in winter, results in oyster destruction; hence man can aid by oyster culture, especially by transplanting young oysters from shallow flats to deeper water, before winter comes. The main cause of destruction of beds has been improper fishing. Were private culture general each man would conserve the oysters, and fish them properly.

Dr. Nelson calls attention to the fact that a large spawning oyster produces annually 60,000,000 eggs, and he estimates that an oyster bed readily produces ten to fifteen millions of young for each adult present. In five years a bed should be ten million times larger; yet beds are decreasing and decaying.

Unfavourable causes are noticed, viz.:—(1) Eggs must be fertilized within a quarter of an hour of ejection to undergo normal development; (2) Eggs may be prevented from settling by agitation in the water; (3) Floating enemies such as water-fleas, and the young of other shellfish, devour them; (4) Owing to the sweeping of the tide, twice daily, myriads of oyster fry are lost; (5) Slime, silt, etc., prevent the fixation of the spat to dead shells and other "cultch"; (6) Boring sea-snails, starfish, bottom fishes, etc., devour the oysters, and, lastly, man himself destroys them. Systematic plans of conserving oyster beds are then detailed, and the necessity of oyster leases urged. The methods adopted for testing the special areas examined in Richmond Bay are described, and the numbers of oyster larvae obtained in definite cubic quantities of water. The maximum found was two young oysters to one quart of water in Grand River. This small yield is contrasted with the profusion of oysters on more southerly areas as in New Jersey, where several hundred young oysters per quart of water was very usual. Some oysters shed their eggs towards the end of July, but the date varied in different localities, fry ten days old being got on August 5th, but it continued until September, some oysters becoming fixed spat as late as September 16th or 18th.

To prevent the formation of bacterial slime, a number of shells were coated with coal tar, as a fine catch of spat had fastened on the tarred bottom of a boat the previous season. The result showed only two-fifths as many fixed young as on the uncoated clean oyster shell. The smooth and the rough side were equal in results, and the left valve attracted twice as many as the right valve, though in gaping empty oyster shells, lying naturally on the bottom, the right valve always secures more spat. Further experiments are desirable, especially with cultch coated with a cement composed of equal parts of lime, sand, and cement, as used on European oyster beds. Dr. Nelson's conclusion is that 8,000 acres might be made productive in Richmond Bay, which covers 32,000 acres, and that a million bushels per annum could be produced were rational scientific methods adopted.

6. The Marine Algae of the Passamaquoddy Region, N.B.—*(Mr. A. B. Klugh, M.A.)*

Mr. Klugh covers in his paper the area from St. Stephen, at the head of navigation on the St. Croix River, to Grand Manan, and notes that the algal flora is boreal, but shows a marked "inside" or mainland shore division, and an "outside" division comprising the shores of what are called the West Isles, and due doubtless to the difference in salinity. The "outside" waters have a specific gravity of 1·0235 to 1·0242, and salt content of 3·201 to 3·280, as compared with the "inside" waters where the figures are—specific gravity 1·0226 to 1·0235, and salts 2·99 to 3·202, as Mr. Copeland found. Of the Cyanophyceæ Mr. Klugh names twelve species; the Chlorophyceæ 24 species; the Phaeophyceæ 23 species; and the Rhodophyceæ 26 species.

The features of the shores are shown in views on Plate viii, the gigantic *Laminaria longicruris,* the largest alga in this region, is well shown in a photo-figure, the specimen selected being five feet ten inches long, with a stipe 9 feet long. *Dermocarpa prasina,* and four other species of Cyanophyceæ, are recorded by the author for the first time in Canada. The habitat, and other interesting notes are given.

7. Serially Striped Haddock in New Brunswick.—*(Professor Prince.)*

Specimens of haddock with four to six transverse black stripes are frequently brought to the Biological Station, and the author compares them with other species showing metameric bars, in post-larval or older stages, and he concludes that they are ancestral in significance, and not protective or illustrative of mimicry and the like.

8. Notes on the Phyto-Plankton of the Bay of Fundy and Passamaquoddy Bay.—
*(Professor Bailey.)*

Professor Bailey continues his laborious studies of the microscopic plant-life of our Atlantic waters. He determines the species in gatherings made in successive months of the year, December excepted, and adds a list of diatoms secured in tow-nettings made by the *Prince,* the biological vessel belonging to the station at St. Andrews. He points out that non-planktonic species are frequently met with amongst neritic species secured far from shore, and the distinction is often, therefore, ill-defined. The gatherings in various months differ greatly, for while in January under twenty species were determined in the gatherings from St. Andrews to St. John, in August nearly eighty species were found. The *Prince* collections are similarly detailed, and interesting notes added including reference to a species of Thalassiothrix which is probably new to science.

9. The Geological Features of the St. Croix River and Passamaquoddy Bay.—
*(Professor Bailey.)*

In response to a suggestion made to Professor Bailey, he has prepared a condensed account of the geology of the site of the St. Andrews station and its environment. The Upper Devonian rocks of red sandstones and conglomerates of the St. Andrews peninsula contrast with the granites of the Maine shore opposite and of Dochet island above the station, and the Silurian strata extending from lake Utopia and St. George to Oak bay, both sides of the entrance and both sides of Waweig inlet. The interesting features, largely Pre-Cambrian probably, of the Western Isles are also indicated in the paper.

# THE WINTER PLANKTON IN THE NEIGHBOURHOOD OF ST. ANDREWS, 1914-15.

By Professor J. Playfair McMurrich, M.A., Ph.D., Professor of Anatomy in the University of Toronto.

With the object of determining the general character of the winter plankton in the vicinity of the Biological Station, St. Andrews, N.B., the caretaker of the station, A. B. Calder, was instructed to make collections of the plankton during the winter of 1914-15, and to preserve the material collected in formalin. Collections were consequently made at frequent intervals from the latter part of September, 1914, until the end of May, 1915, and in what follows, the results of a qualitative study of the collections are given. Acknowledgment must be made of the conscientious manner in which Calder fulfilled the task with which he was entrusted, the collections having been made with sufficient frequency to give an excellent idea of the character of the winter plankton, and the material being well preserved. Two collections were taken at each station in the majority of cases, one at the surface and one at a depth of about 6 metres (3 fathoms), and at each station the temperature of both the air and the surface-water was taken, and the condition of the tide noted. The only misfortune that occurred was the loss of the labels of some of the collections, chiefly of those made in the early autumn, so that these collections cannot be included in the table which forms an appendix to this report. Their omission, however, does not modify the qualitative character of the plankton as shown by the remaining collections.

In studying the collections, the volume of the material contained in each one was measured, and since nets of the same mesh were used throughout and the time of the towing was the same, i.e., twenty minutes for each collection, the amounts obtained indicate approximately the relative abundance of the plankton in the different gatherings of the series. Obviously, however, they furnish no indication of the absolute amount of material present in the water of Passamoquoddy bay, since no data were available as to the volume of water filtered through the nets during the towing. So many factors, uncontrollable in the series of collections under consideration, enter into the question of the determination of the absolute plankton volume, that it did not seem worth while to attempt an estimation of the volume of water filtered by the nets. The amounts obtained have, therefore, only a relative interest. One feature is, however, shown very clearly by the figures, namely, that with rare exceptions the collections from the 6-metre level were considerably larger than those from the surface. This may or may not have a bearing in the distribution of the plankton, since the conditions under which the collections at the two levels were made were not quite identical, the surface collections having been made with a net of finer mesh than that used at the 6-metre level. The greater fineness of the surface net may have caused so much diminution of flow through it, that much less water was actually filtered by it than by the 3-fathom net, in which case a less amount of plankton, even though its distribution were uniform at both levels, would be expected in the surface collection. In future series the conditions for the gatherings at the two levels will be made more uniform, and it is hoped that a definite result will be obtained as to this question of distribution.

Samples were taken of each collection and, so far as possible, the various forms observed in each were identified and recorded, an attempt being made to indicate the relative abundance of each form by estimating the frequency with which it occurred. Four classes of frequency were recognized and termed abundant, frequent, occasional, and rare, the last being employed when only one or two examples of a form were found in a sample, the other terms explaining themselves in a general way on this basis. In the table these terms have, for convenience, been indicated by the numbers 4–1, 4 standing for abundant, 3 for frequent, etc. Seasonal variations in the character of the plankton are revealed in this way, and a few remarks may be made upon these variations and on various forms occurring in the collection so far as they have been certainly identified.

## THE PHYTOPLANKTON.

Less attention was given to the phyto- than to the zooplankton, partly on account of the inaccessibility of the literature necessary for the identification of the forms, and partly because the Diatoms which form a major portion of it have already been discussed by Bailey.[1] The form occurring with the greatest constancy is the diatom *Coscinodiscus,* which is absent from but a few of the collections throughout the entire period which they represent. With the onset of spring, however, it becomes somewhat more abundant than in the winter months, behaving in this respect like other members of the phyto-plankton. Four different forms of the genus have been recognized, which, with the aid of Rattray's Monograph[2] and such other literature as was accessible, have been identified as *C. radiatus* Ehr., *C. concinnus* W. Sm., *C. centralis* Rattray, and *C. fasciculatus* O'Me. The first three species have already been recorded by Bailey, and may be distinguished from one another and from *C. fasciculatus* by *C. radiatus* being the smallest, and having distinctly coarser markings and no central rosette or space; by *C. centralis* having a central rosette, but no signs of fasciculation of the markings at the periphery, near which are situated asymmetrically two apiculi; by *C. concinnus* having a central rosette, much finer markings than either of the others, these markings showing indications of fasciculation towards the periphery, and each fasciculating line terminating there in a minute apiculus; and by *C. fasciculatus* having a central space, and the markings arranged in fasciculi, each of about nine radial rows, the central one of which alone reaches the central space, the others terminating at successively greater distances from it.

Next in order of constancy to *Coscinodiscus,* though falling much behind it, was *Biddulphia,* the most frequently occurring species being *B. aurita* Lyngb., although a much larger form with small scattered chloroplasts, probably *B. mobiliensis* Grun, was also observed in several gatherings. From October, until about the end of February, *Biddulphia* was rare or absent from the collections, but throughout March and April it was of frequent occurrence, diminishing again rapidly in May. Its seasonable distribution was, therefore, similar to that of *Coscinodiscus,* except that the latter is more frequently present throughout the winter months, reaching a maximum frequency in March and April.

Examples of *Chaetoceras* occurred at rare intervals throughout the winter, becoming more numerous and more constant in April, and, it may also be noted, occurring most frequently in the surface collections, only having been observed in two occasions in those of the 6-metre level. At least four or five different species were observed, all belonging to Gran's sub-genus *Hyalochaeta.*[3]

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[1] L. W. Bailey. Some recent Diatoms, fresh-water and marine, from the vicinity of the Biological Station, St. Andrews, N.B., August 20-30, 1909. Contributions to Canadian Biology, 1906-10. Ottawa, 1912.

L. W. Bailey. The Plankton Diatoms of the Bay of Fundy. Contributions to Canadian Biology, 1911-14. Ottawa, 1915.

[2] J. Rattray. A Revision of the Genus *Coscinodiscus* and some Allied Genera. Proc. Roy. Soc. Edinburgh, xvi, 1899.

[3] H. H. Gran. Protophyta in Norwegian North-Atlantic Expedition, vii, 1897.

The most frequent form was what seemed to be *C. laciniosum* Schütt with a single chromatophore, the foramina slightly constricted at the middle, and the terminal setæ marked by a delicate spiral line most easily seen in dried samples; spores were not observed. Somewhat less frequent was a spirally coiled form which seemed to be *C. curvisetum* Cleve, with a single chromatophore adjacent to the front of each frustule. *C. decipiens* Cleve was still rarer, but readily distinguished from the others by its coarser setæ and the occurrence of four to six chromatophores, and a single example of a form with numerous scattered chromatophores, thus resembling *C. teres* Cleve, and another with two chromatophores adjacent to the ends of the frustule (*C. constrictum* Gran.?) were also observed.

An interesting seasonal distribution was shown by *Thalassiosira Nordenskjöldii* Cleve. Throughout October, November, and the winter months this species did not occur in the collections, but on March 13 it suddenly appeared in considerable quantities. It was again taken on March 25 and 26, though not in any great numbers, but on April 4 it formed by far the greater bulk of the plankton, which condition persisted until the collections ceased at the end of May.

Another genus that showed a distinct maximum of occurrence at the end of March and the beginning of April was *Rhizosolenia,* so far at least as its most frequently occurring species, *R. setigera* Brightwell, was concerned. *R. styliformis* Brightwell was also observed, but only in one collection, and another form, which seems to be very similar to *R. gracillima* Cleve was also observed. This last form was observed on four occasions, October 16 and 20, February 26 and March 2, and on all occasions except the last it was found in collections made at the 6-metre level, while it was absent, or at all events rare, in the surface collections made on the same dates and at the same stations. Whenever found it was in great numbers. The frustules were long, filiform, without any signs of markings except a slight depression close to each extremity, and were filled with small, scattered oval or circular chromatophores. The longest individuals measured as much as 2·2 mm., with a diameter of 0·0075 mm., and the great majority exceeded 1·0 mm. in length. These measurements greatly exceed those given by Cleve[1] in the description of the species, but otherwise the agreement is close. A species of *Schizonema,* and one of *Fragilaria* were also somewhat more abundant in the early spring months, and examples of other genera were occasionally observed, but no attempt was made to determine their exact identity. Of the genera so represented, mention may be made of *Navicula, Rhabdonema, Gomphonema, Bacillaria,* and *Campylodiscus.*

Of occasional occurrence also were certain filamentous algæ, the only one that was identified even as to the genus, being a species of *Cladophora,* which, like many of the diatoms, showed a maximum of occurrence, its greatest frequency and constancy being in the early part of April, and being of only a few days' duration.

## DINOFLAGELLATA.

The most frequent representative of this group was the well-known *Ceratium tripos* (O. F. M.) Nitzsch, *C. fusus* (Ehr) Dujard. also occurring, though not quite so frequently, and *C. furca* (Ehr) Dujard. was recognized in two gatherings, but only in very small numbers. Of the genus *Peridinium, P. divergens* var. *reniforme* Ehr. (*P. depressum* Bailey) was found occasionally, and was the only member of the genus recognized. *Dinophysis norvegica* C. and L. was also observed, but only on one occasion. None of the Dinoflagellates occurred in such numbers as be important quantitative constituents of the plankton, *C. tripos* only on one occasion being in sufficient quantity to be regarded as frequent.

1 P. T. Cleve. On some new and little-known diatoms. K. Svensk. Vet.-Akad. Handl, xviii, No. 5, 1881.

### SILICOFLAGELLATA.

Of this group only one form was observed, *Distephanus speculum* (Ehr) Stohr, and this only on three occasions. It was frequent in a gathering from the 6-metre level on March 6, but on the other two occasions it was rare (October 20, 6-metres) or occasional (March 2, surface).

### RHIZOPODA.

No Radiolaria were observed. These forms being essentially pelagic, it seems probable that they would only rarely, if ever, be found in waters so remote from the open sea as those in the neighbourhood of St. Andrews. Foraminifera, too, were absent, a single *Rotalia* being the only one observed, and that in a gathering which contained a good deal of sand, indicating that the net at the 6-metre level had come into contact with the bottom.

### CILIATA.

In addition to a Vorticellid that was almost invariably found attached to the Copepod *Acartia clausii*, a number of ciliates belonging to the family Tintinnodeæ were observed. The genus *Tintinnopsis* was represented by at least three species, the most frequent of which was *T. campanula* (Ehr) Daday. Examples of a form which is probably to be regarded as a variety of this were found on one occasion, their peculiarity being that they tapered aborally much more rapidly than the typical *campanula*, thus resembling closely the form figured by Brandt[1] in his fig. 8, pl. xxi. A single example was seen of *T. ventricosa* (C. and L.), characterized by its somewhat rotund "house," tapering aborally to a blunt point and with the mouth-opening greatly constricted by a circular prolongation, which, in the preserved example, was horizontal in position. A third form, of which again but a single example was seen, was considerably larger than the others and had an almost cylindrical form, enlarging only very slightly towards the mouth, and being rounded aborally; the length was about twice the breadth. In its general form it resembled closely that described by von Daday[2] as *T. beroidea*, but Brandt does not consider this identical with the form originally so named by Stein. Among the species described by Brandt the greatest similarity of form is shown by *T. sacculus*, but, unfortunately, the notes and drawing made of the St. Andrews form are insufficiently detailed to make identification with this certain.

Of occasional occurrence, and in one gathering (October 20) almost frequent, was a species of *Cyttarocylis*, whose specific identity is also uncertain. It resembles *C. Ehrenbergi* (C. and L.) Fol. very closely in its general form and in the fact that the cavity of the "house" is not continued into the aboral prolongation. This latter structure, however, is cylindrical in form, showing no traces of the three flange-like ridges which Brandt regards as characteristic of the species, although these are not noted by other writers. The surface of the "house" presents a very fine reticulation and has a minutely and irregularly corrugated appearance, most pronounced in the aboral prolongation. Near the mouth there is a narrow circular enlargement upon which follows a thin ring, sometimes single, sometimes partly divided into two portions by a fine line, as if it were composed of a spiral membrane with one and a half turns. The free edge of the ring or spiral is practically smooth, and the appearance presented is similar to that described and figured by Jorgensen[3] for his

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[1] K. Brandt. Die Tintinnodeen. Ergeb. Plankton Exped., III, L, a., 1907.

[2] E. von Daday. Monographie der Familie der Tintinnodeen. Mitth. Zool. Stat. Neapel, vii, 1887.

[3] E. Jorgensen. Ueber die Tintinnoden der Norwegischen Westküste. Bergens Mus. Aarbog., 1899.

*C. Ehrenbergi*, var. *subannulata*, except that the turns of the spiral are much fewer. The length of the "house" was 0·26 to 0·34 mm., with a diameter at the mouth of 0·7 to 0·8.

### PORIFERA AND COELENTERA.

What were taken to be sponge spicules were observed in a number of gatherings, usually associated with annelid setæ. Their occurrence is sufficiently indicated in the table. Of Coelentera, the empty cups of Campanularian hydroids were occasionnally observed associated with Crustacean exuviæ, and on October 29 and in the last collections that were made (May 29) a few examples of Anthomedusæ were observed, but unfortunately in a condition very unfavourable for certain determination.

### ECHINODERMATA.

Throughout the winter, no representatives of this group were taken, but at the end of April and beginning of May a few *Plutei* were obtained which could not be satisfactorily identified. On April 6, a considerable number of ova in various stages of segmentation up to the blastula stage were found. They were somewhat opaque, and inclosed within a thin structureless membrane. They were taken also on April 10, and with them were then associated larvæ which could be recognized as belonging to some species of Holothurian. The general appearance of the ova and younger larvæ make it exceedingly probable that they were younger stages in the development of the same form. The larvæ continued to be taken through April and May, and were a quite characteristic feature of the plankton during these months.

Two Holothurians occur at St. Andrews that may be the producers of these ova, *Cucumaria frondosa* Gunner, and *Lophothuria fabricii* (Dub and Kor). The former is the more common, but the fact that the ova and larvæ have, when alive, the same brilliant scarlet colour that makes *Lophothuria fabricii* so conspicuous, suggests that they may be the product of that species.

### ANNELIDA, NEMATODES, ROTIFERS, AND CHAETOGNATHA.

Examples of all these groups were observed, but never in such numbers that they could be regarded as important elements of the plankton.

Setæ of various forms which evidently were from Annelids were found in fair numbers in several gatherings taken after March 1, but of more importance was the occurrence of Annelid larvæ during April and May, never in any great numbers in any gathering, but sometimes reaching the grade of frequency indicated in the table by the term "occasional." It was not possible to identify the form which produced the larvæ, but from their general appearance it seems probable that they represent some Spionid form.

Small Nematodes were occasionally observed in small numbers in the spring gatherings, but no attempt was made to identify them. The same remark applies to the Rotifera, which were much rarer than might have been expected. Of the Chaetognaths the only form identified was *Sagitta elegans* which was taken January 1, the identification of some smaller forms taken October 29 remaining uncertain.

### MOLLUSCA.

A few veligers were observed, but so rarely that they have not been included in the table. The peculiar egg-capsule, probably Molluscan, having the shape of a broad-rimmed hat, which Wright described from Canso, occurred at intervals throughout the season, and sometimes in considerable numbers. Most frequently only the brown empty cases were found, though occasionally those containing developing ova were obtained.

CRUSTACEA.

The Crustacea are the most interesting group represented in the zoo-plankton, both on account of the number of species represented, and for the fact that, in the majority of gatherings, they form the greater bulk of the material. It will be convenient to consider the various forms observed under their proper orders

### *Cladocera.*

Representatives of this order were found much less frequently than was expected, occurring in any considerable numbers in only one gathering, i.e., in that taken October 16, from the 6-metre level. All the forms observed in this gathering were representatives of the species *Podon polyphemoides* Leuckart.

### *Copepoda.*

Forms belonging to this group were the most constant constituents of the plankton, being found in every gathering, with one exception, and usually in considerable numbers. It is noteworthy, however, that in the spring months when *Thalassiosira* became a prominent constituent of the plankton, the Copepoda became very much reduced in numbers. At least this was the case so far as the surface water down to the 6-metre level was concerned, the *Thalassiosira* extending to that depth, but it is quite likely that the Copepoda were present in undiminished numbers at levels beyond those occupied by the alga. The diminution of the Copepoda in the surface water coincidently with the appearance of *Thalassiosira* is clearly indicated in the table if one compares the frequency records for *Acartia clausi* and the diatom.

Of the members of the family *Calanidæ,* special interest attaches to *Calanus finmarchicus* (Gunner) Boeck, on account of its forming so important a constituent of the plankton of northern waters. It occurred at intervals throughout the winter, but never in any great quantity, although in several gatherings it was present in sufficient numbers to deserve the term "frequent." It is to be noted, however, that the plankton now under discussion was collected in the immediate vicinity of St. Andrews, and it is quite probable that *C. finmarchicus* may be much more abundant in more open water. Herdman in 1897[1] found it very abundant in the gulf of St. Lawrence and in the Atlantic off the entrance to the straits of Belle Isle, and my colleague, Dr. A. G. Huntsman, obtained it in large numbers in rather deep water off Eastport, Me., and off Grand Manan in September, 1915.

The much larger *C. hyperboreus* Kröyer was observed in only one gathering, and then only as a single individual. The fact of its occurrence is, however, of interest as it has not previously been recorded from Canadian waters.

A third Calanid, *Pseudocalanus elongatus* Boeck, easily recognized by the absence of the fifth pair of legs in the female, occurred in about the same degree of frequency as *C. finmarchicus.*

Of the family Centropagidæ, the genus Eurytemora furnished two representatives, *E. hirundoides* Nordquist and *E. herdmani,* Thompson and Scott. Neither was abundant in any gathering, but both occurred at intervals throughout the season represented by the collection, and were occasionally "frequent." *Temora longicornis* (Müll) Boeck also occurred at intervals in the autumn and winter until the end of January, after which it was not observed. On the last date on which it was found (January 27) it was the most abundant constituent of the plankton.

It is the family Pontellidæ, however, that furnishes the most characteristic feature of the plankton now being discussed, the form concerned being *Acartia*

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[1] W. A. Herdman. On the plankton collected continuously during two traverses of the North Atlantic in the summer of 1897. Trans. Liverpool Biol. Soc., xii, 1898.

*clausi* Giesbr. A glance at the table will show that this species occurred in nearly every gathering throughout the season, and that up to the early part of April it was almost always in abundance. Its reduction in numbers after that date in association with the appearance of *Thalassiosira* has already been commented upon. Another Pontellid observed was the interesting *Tortanus discaudatus* (Thompson and Scott) Giesbr. It was taken in several gatherings made during the autumn and early winter, but after December it was not again noted until the end of May. In connection with this form, it may be noted that Giesbrecht and Schmeil[1] question the correctness of Thompson and Scott's original description of the endopodite of the first pair of legs being three-jointed. There is no doubt, however, that the original description is quite correct, *discaudatus* differing from other members of the genus in this respect.

Of the Cyclopidæ, *Oithona similis* Claus was the only form observed, and that in small numbers in but three gatherings.

The Harpacticidæ have hitherto received but scant consideration in plankton lists, partly, no doubt, to difficulties inherent in their identification. The excellent monograph of the family by Sars[2] does away with some of these difficulties and, with its aid, it has been possible to determine the occurrence in the collections of a number of forms hitherto unrecorded from Canadian waters. The most frequent species was undoubtedly *Harpacticus uniremis* Kröyer, which is readily distinguishable from *H. chelifer* (Müller), among other things by the first antennæ being nine-jointed instead of eight-jointed, and by the inner expansion of the proximal joint of the fifth pair of legs bearing four marginal setæ instead of three. *H. chelifer* has been recorded by Wright[3] as occurring at Canso and also by Williams[4] from Rhode Island waters, where *H. uniremis* was also found. It is possible *H. chelifer* also occurs at St. Andrews; indeed, certain forms were identified as belonging to that species when the study of the collection was begun, but the identification was made with insufficient literature and before access was obtained to Sars' Monograph, and opportunity has not occurred for confirming the identification. It seems probable that it was erroneous in the majority of cases.

A second (or third) species of *Harpacticus* was one which closely resembled that described by Sars as *H. gracilis* Claus, differing from *H. uniremis* by the greater relative shortness of the terminal portion of the first antennæ and by the two t rmin l joints of the endopodite of the first pair of legs being confluent.

Two species of *Zaus* were observed, distinguishable by the form of the fifth pair of legs. One was evidently *Z. abbreviatus* Sars, hitherto recorded only from the coast of Norway and from the islands north of Grinnell Land; the other apparently *Z. spinatus* Goodsir, previously known from the eastern coast of the Atlantic and from the Arctic ocean. *Idya furcata* (Baird) was also occasionally found. It is a species of wide distribution, and has been recorded from Rhode Island by Williams.

A few examples of *Parathalestris Jacksoni* (Scott) Sars were also observed, a form not hitherto recorded from the Western Atlantic, a statement also true for *Halithalestris Croni* (Kroyer) a single example of which was taken, unmistakeable from its exceedingly long and divergent furcal rami.[5]

### *Cirrhipedia.*

A few Cirrhipede larvæ were observed in one of the October collections and again on February 20, February 26, and March 2. On March 6, they were present

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1 W. Giesbrecht and O. Schmeil. Copepoda I. Gymnoplea. Das Tierreich, Lief. 6, 1898.
2 G. O. Sars. An Account of the Crustacea of Norway. Vol. V. Bergen, 1911.
3 R. R. Wright. The Plankton of Eastern Nova Scotia Waters. Contr. to Canadian Biol., 1902-5. Ottawa, 1907.
4 L. W. Williams. Notes on the Marine Copepoda of Rhode Island. Amer Nat. xl, 1906.
5 In the table all the Harpacticidæ have been grouped together under a single heading, since with the exception of *H. uniremis* they were of very occasional occurrence and then only in small numbers.

in considerable numbers in the surface plankton, and on March 20 they became very abundant, and continued to be so, with some occasional diminutions, until April 21. The appearance of these *Balanus* larvæ in large numbers was, accordingly, coincident with the vernal increase of the phyto-plankton, corresponding almost exactly with the increase of *Biddulphia, Coscinodiscus* and *Fragilaria,* and preceding slightly that of *Thalassiosira.*

### *Malacostraca.*

Of the remaining groups of Crustacea, relatively few representatives were observed, and only at rare intervals. Two examples of the Schizopod *Thysanoëssa inermis* (Sars) Hansen were taken January 1, both belonging to the variety *Rhoda* of Hansen, who finds intermediate stages between the forms described as *Rhoda inermis and Thysanoëssa neglecta* and has united these into a single species with two varieties.[1]

Zoeas were also observed on various occasions, but their numbers were few, and no attempts were made to determine the species represented by them.

## PROTOCHORDATA.

Tunicate larvæ and Appendicularians were observed, the former in considerable numbers, on November 11, and in the early part of January, the latter only rarely in October. The Appendicularians were not in a satisfactory condition for exact determination, but apparently both *Fritillaria* and *Oikopleura* were represented.

## PISCES.

A few pelagic fish eggs were taken on two occasions, April 21 and May 13, but it was not possible to determine their source, since their preservation had rendered them almost opaque. A young fish, about 1 cm. in length was also taken on April 21 at the 3-fathom level. It was a young example of *Liparis liparis* Linn. and had evidently been engaged in feeding upon plankton Copepods, one of which was observed within its jaws.

This fish, with its suctorial disk, is essentially a bottom form, its suctorial disk being an adaptation to that mode of life, and its capture in a plankton-net is therefore a matter of some interest.

NOTE.—A further study of the plankton in the neighbourhood of St. Andrews during the past summer has revealed errors in the identification of two of the forms mentioned above. That which was doubtfully regarded as *Rhizosolenia gracillima* proves to be *Thalassiothrix longissima* Cleve and Grunow, while the forms identified as *Eurytemora hirundoides* were probably merely immature examples of *E. herdmani.* This latter correction is based upon observations kindly communicated by my friend, Dr. Arthur Willey.

[1] See H. J. Hansen. The *Crustacea Euphausiacea* of the United States National Museum. xlviii, 1915.

TABLE Showing the distribution of the Plankton elements during the Winter of 1914-15, at St. Andrews, N.B.

4=abundant; 3=frequent; 2=occasional; 1=rare.

| Date, 1914-15. | Locality. | Depth S=Surface | Amt. in cb. c. | Temp. Air. Fahr. | Temp. Water Fahr. | Tide. | Coscinodiscus. | Biddulphia. | Chaetoceras. | Thalassiosira. | Rhizosolenia setigera. | Thalassiothrix longissima. | Schizonema. | Fragilaria. | Pleurosigma. | Rhabdonema. | Cladophora. | Ceratium tripos. | Ceratium fusus. | Distephanus speculum. | Tintinnodae. | Holothurian ova and larvae. | Annelid larvæ. | Sagitta. | Molluscan ova. | Podon polyphemoides. | Calanus finmarchicus. | Pseudocalanus elongatus. | Eurytemora hirundoides. | Eurytemora herdmani. | Temora longicornis. | Acartia clausi. | Tortanus discaudatus. | Oithona similis. | Harpacticidæ. | Balanus larvæ. | Tunicate larvae. | Appendicularia. | Fish ova and larvæ. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct. 16 | Digdeguash Hr. | S | 11 | 57° | 52° | 1 hr. ebb | 2 | | | | | | | | | | | 1 | | | | | | | | | 1 | 2 | 2 | | | 4 | | | | 2 | | | | |
| " 6 | Digdeguash Hr. | 6 m. | 27·5 | 57° | 52° | 1 hr. ebb | | | | | | 4 | | | | | | | | | | | | | | 3 | | | | | | 3 | | | | | | 1 | | |
| " 20 | Sand Point | S | 31 | 48° | 51° | ½ ebb | 1 | | | | | | | | | | | | | | | | | | | | | | | 1 | | 4 | 3 | | | | | | | |
| " 20 | Sand Point | 6 m. | 25 | 48° | 51° | ½ ebb | 4 | 1 | 1 | | | 4 | | | 1 | | | 3 | 1 | 1 | 1 | | | | 3 | | | | | | | 4 | | | | | | 1 | | *Ceratium furca, Peridinium divergens, Dinophysis norvegica*, rare; Nauplii abundant. |
| " 22 | Joe's Point | S | 13 | 48° | 51° | 1½ hr. flood. | 2 | | | | | | | | | | | | | | | | | | | | | | | 1 | | 3 | 1 | | | | | | | Young Copepoda abundant. |
| " 22 | Joe's Point | 6 m. | 20 | 48° | 51° | 1½ hr. flood. | | | | | | | | | | | | | | | | | | | | | | | | 1 | 2 | 4 | 3 | | | | | | | |
| " 29 | Mouth of St. Croix R. | S | 12 | 44° | 48° | 1 hr. ebb | 1 | | | | | | | | | | 1 | | | | | | | 1 | 2 | | | 2 | 1 | | | 3 | | | | | | 1 | | Immature Copepoda abundant; Anthomedusa. |
| Nov. 4 | Robbinstown | 6 m. | 34 | 44° | 48° | 1 hr. ebb. | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | | | 4 | | | | | | | | |
| " 11 | Dog I. | 6 m. | 4 | 28° | 46° | ½ hr. flood. | | | | | | | | | 1 | | | | | | | | | | | | 2 | | | | | 3 | | 1 | | | 3 | | | Sponge spicules, Annelid setae; dead hydroid stems abundant. |
| " 13 | Robbinstown | S | 7·5 | 36° | 46° | ½ hr. flood. | 3 | | | | | | | | | | | | | | | | | | | | | | | | | 4 | | | | | | | | Immature Copepoda and nauplii abundant. |
| " 14 | Mill Cove | 6 m. | 40 | 40° | 42° | ½ ebb | | | | | | | | | | | | | | | | | | | | | | | | | | 4 | 1 | | | | | | | Immature Copepoda abundant. |
| " 20 | Joe's Point | S | 16·5 | 40° | 42° | ½ ebb | 1 | | | | | | | | | | | | | | | | | | | | 1 | 2 | | | 1 | 4 | | | | | | | | |
| " 20 | Joe's Point | 6 m. | 27·5 | 40° | 42° | ½ ebb | | | | | | | 1 | | | | | 1 | | | | | | | | | 1 | | | | 1 | 4 | 3 | | | | | | | |
| " 27 | Mill Cove | S | 13 | 46° | 42° | ½ ebb | | | | | | | | | | | | | | | | | | | | | | 1 | | | | 4 | 2 | | | | | | | |
| " 30 | West Light | S | 9 | 42° | 43° | ½ hr. ebb | 1 | | | | | | | | | | | 1 | | | | | | | | | | 1 | | | | 4 | | | | | | | | |
| " 30 | West Light | 6 m. | 26·5 | 42° | 43° | ½ hr. ebb. | | | | | | | | | | | | | | | | | | | | | | 3 | 1 | | | 4- | 2 | | | | | | | |
| " 30 | Navy I. | S | 9 | 42° | 43° | High | | | | | | | | | | | | 1 | | | | | | | | | | | | | | 4 | | 1 | | | | | | Immature Copepoda and Nauplii abundant. |
| " 30 | Navy I. | 6 m. | 36 | 42° | 43° | High | 1 | | | | | | | | | | | | | | | | | | | | 2 | | | | | 4 | 2 | | | | | | | |
| Dec. 12 | St. Andrew's Hr. | S | 7·7 | 26° | 39° | ½ ebb | 1 | 1 | | | | | | | | | | 1 | | | | | | | | | | | | | | 4 | | | | | | | | Much amorphous material. |
| " 12 | St. Andrew's Hr. | 6 m. | 25 | 26° | 39° | ½ ebb | 1 | | | | | | | | | | | | | | | | | | | | 2 | | | | 2 | | | | | | | | | |
| " 12 | Biol. Station | 6 m. | 35 | 28° | 38° | 1 hr. flood. | | | | | | | | | | | | | | | | | | | | | | 2 | | | | 4 | 2 | | | | | | | Immature Copepoda frequent. |
| " 28 | " | S | | 22° | 36° | 2 hrs. ebb | 1 | 1 | 1 | | 1 | | | | | | | 2 | 1 | | | | | | 1 | | | | | | | 3 | | | | | | | | Immature Copepoda and Nauplii; Sponge spicules. |
| " 28 | " | 6 m. | 8·8 | 22° | 36° | 2 hrs. ebb | | | | | | | | | | | | | | | | | | | | | 3 | 3 | | | | 4 | 1 | | | | | | | |
| " 30 | St. Andrew's Hr. | S | 10 | 38° | 37° | ½ hr. to high | 1 | | | | | | 2 | | | | 1 | 1 | 2 | | | | | | | | 1 | | | | 2 | 4 | | | | | | | | |
| " 30 | St. Andrew's Hr. | 6 m. | 16 | 38° | 37° | ½ hr. to high | 1 | | | | | | | | | | | | | | | | | | | | 3 | | | | | 4 | | | 1 | | | | | |
| Jan. 1 | Biol. Station | S | 5·5 | 10° | 36° | High | 3 | 1 | 1 | | 1 | | 1 | 2 | | | | 1 | | | | | | | | | 2 | | | | | 4 | | | | | 2 | | | |
| " 1 | Biol. Station | 6 m. | 12 | 10° | 36° | High | | | | | | | | | | | | | | | | | | 2 | | | 3 | | | | | 4 | | | | | | | | *Thysanoessa inermis.* |
| " 5 | West Light | S | 5·5 | 30° | 34° | ½ hr. to high | 3 | | | | | | 2 | 1 | | | | 2 | 2 | | | | | | | | | 2 | | | | 4 | | | | | 3 | | | |
| " 5 | West Light | 6 m. | 9 | 30° | 34° | ½ hr. to high | 1 | | | | | | | | | | | | | | | | | | | | 3 | 2 | | | | 4 | | 1 | 2 | | 2 | | | |
| " 12 | Joe's Point | S | 5·5 | 33° | 34° | High | 2 | 1 | | | | | | | | | | 2 | 1 | | | | | | | | 1 | 2 | | | | 4 | | | | | 2 | | | Immature Copepoda abundant. |
| " 12 | " | 6 m. | 5·5 | 33° | 34° | " | | | | | | | | | | | | | | | | | | | | | 2 | 3 | | | | 4 | | | | | | | | |
| " 15 | " | S | 22 | 33° | 34° | " | 1 | | | | | | | | | | | 1 | | | | | | | | | | | | | | 4 | | | | | | | | |
| " 15 | " | 6 m. | 42 | 33° | 34° | " | | | | | | | | | | | | | | | | | | | | | 1 | 1 | | 1 | | 4 | | | 1 | | | | | |
| " 18 | Biol. Station | S | 12 | 40° | 34° | ½ hr. to high | 1 | | | | 1 | | | | | | | | | | | | | | | | | | | | | 4 | | | | | | | | Immature Copepoda, Crustacean exuviae abundant. |
| " 18 | " | 6 m. | 37·5 | 40° | 34° | ½ hr. to high | | | | | | | | | | | | | | | | | | | | | 2 | | | | 1 | 4 | | | | | | | | Immature Copepoda abundant. |
| " 27 | " | S | 11 | 32° | 33·5° | ½ hr. ebb | 1 | | | | | | | | | | | | | | | | | | | | | | | 1 | 4 | 3 | | | | | | | | |
| " 27 | " | 6 m. | 33 | 32° | 33·5° | ½ hr. ebb | | 1 | | | | | | | | | | | | | | | | | | | 1 | | | 1 | 3 | 3 | | | | | | | | |
| Feb. 20 | St. Andrew's Hr | S | 16·5 | 37° | 33° | ½ hr. ebb | 2 | 1 | | | | | | | 1 | | | | | | | | | | | | | | 3 | | | 4 | | | | 1 | | | | |
| " 20 | " | 6 m. | 31 | 37° | 33° | ½ hr. ebb | 1 | | | | | | | | | | | | | | | | | | | | | | 2 | 1 | | 4 | | | 1 | | | | | |
| " 24 | " | S | 12 | 33° | 33° | 1 hr. ebb | 4 | 2 | | | | | | 1 | | | 1 | | | | | | | | | | | | | 3 | | 4 | | | 1 | | | | | |
| " 24 | " | 6 m. | 27·5 | 33° | 33° | 1 hr. ebb | 1 | | | | | | 2 | | | | | | | | | | | | | | | | | 2 | | 4 | | | 1 | | | | | |
| " 26 | Biol. Station | S | 9 | 36° | 33° | 1 hr. ebb | 2 | | | | | | | | | | 1 | | | | | | | | | | 1 | 2 | 2 | | | 4 | | | | | | | | |
| " 26 | " | 6 m. | 17·5 | 36° | 33° | 1 hr. ebb | 1 | 1 | | | | | | | | | | | | | | | | | | | 1 | | 2 | 1 | | 4 | | | 1 | 1 | | | | |
| Mar. 2 | " | S | 8 | 27·5° | 33° | 1 hr. to high | 3 | 4 | 1 | | | | 1 | | 2 | | 1 | 2 | | 2 | | | | | 3 | | | | | | | 3 | | | 1 | | | | | Sponge spicules frequent. |
| " 2 | " | 6 m. | 25 | 27·5° | 33° | 1 hr. to high | 2 | 3 | 1 | | 1 | | | 1 | 1 | | 1 | | | | | | | | | | | 2 | | | | 4 | | | | 2 | | | | Sponge (?) spicules frequent. |
| " 6 | Robbinstown | S | .... | 38° | 33° | ½ hr. to high | 3 | 2 | | | 1 | | 1 | 1 | 1 | | 1 | 1 | 1 | | | | | | 2 | | | | | | | 2 | | | | | | | | Sponge (?) spicules and Annelid setae frequent. |
| " 6 | Robbinstown | 6 m. | 14 | 38° | 33° | ½ hr. to high | 1 | 1 | | | | | | | | | | | | | | | | | 1 | | 3 | | | 1 | | 4 | | | 1 | | | | | Much miscellaneous "dirt." |
| " 13 | Joe's Point | 6 m. | 3 | 44° | 37° | High | | 3 | | 3 | | | | | 1 | | 1 | | | | | | | | 1 | | | | | | | 1 | | | 2 | 3 | | | | Sand, sponge and annelid spicules, Nematodes, Rotifers, Rotalia, Gomphonema. |
| " 16 | St. Andrew's Hr. | S | 5·5 | 30° | 33° | " | 4 | 2 | 1 | | 1 | | 2 | 1 | | 1 | 2 | | | | | | | | | | | | | | | 1 | | | | | | | | Immature Copepoda and occasional sponge and annelid setae. |
| " 16 | St. Andrew's Hr. | 6 m. | 20 | 30° | 33° | " | 1 | 1 | | | | | 3 | 2 | | | 3 | | | | | | | | 1 | | 1 | 2 | | 2 | | 4 | | | 1 | | | | | |
| " 20 | West Light | S | 4·5 | 36° | 33° | 2 hrs. to high | 2 | 2 | | | | | 1 | 1 | | | 1 | | | | | | | | | | | 1 | | 2 | | 2 | | | 1 | 4 | | | | |
| " 20 | " | 6 m. | 13 | 36° | 33° | 2 hrs. to high | 3 | 3 | | | | | 2 | 2 | 1 | | 1 | | | | | | | | | | | 2 | 2 | | | 3 | | | 1 | 4 | | | | |
| " 23 | " | S | 7·5 | 40° | 33·5° | 2 hrs. to high | 4 | 4 | | | | | | 2 | | | 1 | | | | | | | | | | 2 | | 1 | | | 4 | | | 2 | 4 | | | | |
| " 23 | " | 6 m. | 20 | 40° | 33·5° | 2 hrs. to high | 3 | 4 | | 2 | | | | 2 | | | 1 | | | | | | | | | | 3 | 1 | | 2 | | 4 | | | 2 | 4 | | | | |
| " 25 | Short Bar | S | 4·5 | 50° | 34° | 1 hr. flood. | 4 | 4 | 2 | 2 | | | 2 | 2 | | | | | | | | | | | | | | | | | | 1 | | | 3 | 4 | | | | |
| " 25 | Short Bar | 6 m. | 12 | 50° | 34° | 1 hr. flood. | 2 | 3 | | | | | | 2 | | | 1 | | | | | | | | | | 2 | 2 | | 2 | | 2 | | | 2 | 4 | | | | |
| " 29 | Biol. Station | S | 3 | 40° | 34° | ½ hr. ebb | 2 | | | | | | 1 | 2 | | | 3 | | | | | | | | | | | | | | | 2 | | | | 4 | | | | Much "dirt." |
| " 29 | " | 6 m. | 6·5 | 40° | 34° | ½ hr. ebb. | 2 | 2 | | | 1 | | 2 | 2 | 2 | | | | | | | | | | 1 | | 1 | | | | | 3 | | | | 4 | | | | Annelid and sponge spicules, Bacillaria. |
| April 3 | " | S | 7·5 | 34° | 34° | 1 hr. flood. | 4 | 4 | 3 | 4 | 1 | | | 1 | 4 | | | | | | | | 1 | | | | | | | | | | | | | 2 | | | | |
| " 3 | " | 6 m. | 13 | 34° | 34° | 1 hr. flood | | 1 | | 1 | 1 | | 1 | 1 | 2 | | 1 | | | | | | 2 | | 1 | | 1 | 1 | | | | 4 | | | 1 | 4 | | | | |
| " 6 | St. Andrew's Hr. | S | 18·5 | 45° | 35° | Low | 2 | 2 | | | 2 | | 4 | 4 | | | | | | | | 2 | | | 1 | | 2 | | | 1 | | 4 | | | 4 | 4 | | | | Crustacean exuviae abundant. |
| " 10 | Biol. Station | S | 5·5 | 40° | 36° | 1 hr. ebb | 4 | 3 | 3 | 4 | 3 | | | 2 | 2 | 1 | 3 | | | | | 2 | | | | | | | | | | | | | | 1 | | | | Crustacean exuviae frequent. |
| " 10 | Biol. Station | 6 m. | 13 | 40° | 36° | 1 hr. ebb | | 2 | | 1 | | | 2 | 2 | | 1 | 2 | | | | | 3 | | | | | | | | | | 3 | | | | 4 | | | | |
| " 13 | Joe's Point | S | 3 | 44° | 37° | High | 4 | 3 | 1 | 4 | 1 | | 1 | 2 | | | | | | | 1 | | | | | | | | | | | | | | 1 | | | | | Crustacean exuviae frequent; Rotifers rare. |
| " 17 | Biol. Station | 6 m. | 31 | 44° | 38° | ½ flood. | 3 | 4 | | 4 | | | | 3 | | | 2 | | | | | 3 | 1 | | | | | | | | | 1 | | | 1 | 3 | | | | |
| " 21 | " | S | 7·5 | 52° | 38° | ½ flood. | 3 | 3 | 3 | 4 | | | | 1 | | | | | | | | | | | | | | | | | | 2 | | | | | | | | Immature Copepoda.; Zoeas rare. |
| " 21 | " | 6 m. | 5 | 52° | 38° | ½ flood. | | 3 | | 4 | | | | | | | | | | | | 2 | | | | | 2 | | | | | 3 | | | 2 | 3 | | | 1 | |
| " 23 | Navy I. | 6 m. | 4·5 | 52° | 40° | 2½ hrs. to low | 2 | | | 4 | | | | | | | | | | | | 2 | | | | | | | | | | 2 | | | 1 | 1 | | | | Plutei rare. |
| May 13 | Joe's Point | S | | 45° | 39° | 1 hr. to high | 1 | 1 | 1 | 4 | | | 1 | | 1 | | | | | | 1 | | | | | | | | | | | 2 | | | | | | | | Copepod nauplii. |
| " 13 | Joe's Point | 6 m. | 20 | 45° | 39° | 1 hr. to high | 1 | | | 4 | | | | | | | | | | | | 1 | 1 | | 1 | | 1 | | | | | 1 | | | 1 | | | | 1 | Plutei rare. |
| " 15 | Niger Reef | S | 9 | 50° | 41° | 2 hrs. to low | | | | 4 | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | Nauplii and immature Copepoda rare; Rotifers rare. |
| " 15 | Niger Reef | 6 m. | 16·5 | 50° | 41° | 2 hrs. to low | | | | 4 | | | | | | | 1 | | | | | 2 | 2 | | 1 | | | | 2 | | | 2 | | | | | | | | Plutei rare. |
| " 25 | Navy I. | S | 31 | 56° | 44° | ½ hr. ebb | 2 | | | 4 | | | | | | | 1 | | | | | | | | | | | | | | | 1 | | | | | | | | Copepod nauplii rare. |
| " 25 | Navy I. | 6 m. | 16 | 56° | 44° | ½ hr. ebb | 2 | | 1 | 4 | | | | | | | | | | | | | 1 | | | | | | | | | 2 | | | | | | | | Rotifers rare. |
| " 29 | Biol. Station | S | .... | 48° | 41° | ½ ebb | | | 2 | 4 | 1 | | | | | | | | | | 1 | | | | | | | | | | | 1 | | | | | | | | Anthomedusæ and nauplii rare. |
| " 29 | Biol. Station | 6 m. | 16·5 | 48° | 41° | ½ ebb | | | | 4 | | | | | | | | | | | | 2 | 3 | | | | | | | | | 4 | 3 | | | | | | | Anthomedusæ rare. |

# DIATOMS AND LOBSTER REARING.

By Prof. W. T. MacClement, M.A., D.Sc., Queen's University, Kingston.

The entirely commendable desire to increase the annual crop of lobsters, and thus add to the income of the fishermen as well as to the supply of a delicious sea food, has prompted attempts at the semi-domestication of the lobster. A creature may be said to be domesticated when it will reach full size, will reproduce freely, and will live about the normal life-time of its kind, in the artificial conditions furnished by man. We are as yet far from reaching such a desirable state of affairs in our relations with the lobster. While mature female lobsters, captured in the sea, will extrude eggs freely in captivity, we have not yet, in the few experiments made, so closely approximated to the conditions required for the health and growth of young lobsters, as to see before us in the near future the prospect of large and successful lobster gardens, maintained by the amphibious farmers of the Maritime Provinces. The account of the experiments inaugurated by the Biological Board of Canada will be found elsewhere.* With only one factor of the environment of the lobsters has the present writer had intimate relations, and it is with that this article deals.

## 1. Actions of Lobster Larvæ.

For several days after they are hatched, young lobsters show a desire to occupy water that is well lighted. They crowd to the lighted side of a glass vessel, and within a few seconds will have deserted the shaded for the sunny portion of the water in which they are lying. Otherwise they show little recognition of direction in their movements, sinking quietly or jerking themselves apparently aimlessly up or down or laterally through the water, often with their backs or heads downward, and with their bristly outer leg-branches constantly vibrating. Their spasmodic movements are probably the result of various stimuli besides that of light, as is shown by the fact that they seize greedily any small object that seems likely to make them a satisfactory meal. When the minute lobsters are crowded together, this edible object is quite likely to be another lobster of the same brood. The stronger of the two immediately shows how fond he is of his relative by eating as much as possible of him or her. Cannibalism is one of the factors always to be kept in mind in connection with artificial arrangements for rearing the lobster.

Whether the lobster larvæ normally seek the lighted surface layers of the sea in which they are hatched is unknown, as few of them have been captured in open waters, and very little is known of the details of their lives when free. Surface layers may or may not be their natural haunts, but all attempts at rearing the young lobsters have been made in well-lighted and somewhat shallow enclosures. The idea is accepted by the experimenters that the young lobsters are attracted to the bright surface waters, that there they are visible to the perpetually hungry larger denizens of the ocean, such as the schools of herring and mackerel, and that consequently myriads of the lobster larvæ are devoured before they have learned even the alphabet of self-defence. After they have moulted a few times, four or five, they acquire the form and features, though minute, of the adult lobster, and show the adult habits of seeking concealment, and of using their claws as weapons of defence. Hence it is believed

* See Professor Knight's Report on Lobster Sanctuaries and Hatching Ponds. Canadian Biology, 1914-1915. Supp. 5th Ann. Rep. Dep. of Naval Service, 1916, pp. 41-54.

desirable to protect the lobster larvæ against each other, against hungry alien enemies, and against starvation, until they show at least some signs of knowing how to care for themselves.

## 2. Diatoms on Lobster Larvæ.

Well-lighted waters have many inhabitants, notably minute plants, and some of these show a tendency to attach themselves to the lobsterlings. This is especially true of certain forms of diatoms which normally grow attached to each other and to larger submerged plants. Mature lobsters confined in ponds and cars become the carriers of various animal and plant forms, which are not parasites but symbionts in the simplest degree, merely borne by the animal. The extent of the plant growth will naturally depend on the sunlight received by the lobster, copious growths of algæ reaching to many inches in length developing on the antennæ and other appendages, even on the eyes, when the animal has been confined for several months in shallow, muddy ponds. When such lobsters are removed to clean surroundings they gradually free themselves from all growths within their reach. Ordinarily the moulting process will completely remove all the effects of this symbiotic growth, but instances are known in which the rhizoids of the algæ have penetrated the covering of the lobster's eyes, and moulting left the creature clean, but blind.

The extent of the growth of diatoms on lobster larvæ is dependent on certain factors of which the three most important seem to be: (1) The amount of sunlight received, (2) the extent of time between moults, and (3) the activity or inactivity of the lobsterlings. We have direct evidence of the truth of the first two of these, and indirect evidence of the third. During the summers of 1914 and 1915 Dr. A. P. Knight, for the Biological Board of Canada, has carried on rearing experiments at Long Beach, Digby county, Nova Scotia. The complete description of these experiments will be found in Dr. Knight's reports for those years. The opportunity given the writer to study this interesting relationship between lobsters and diatoms was due to the kind invitation of Dr. Knight, who most generously placed all the resources of the station at my service.

In both summers the lobster larvæ were loaded with a growth of diatoms which became so great as to cause the larvæ to sink to the bottom of the boxes in which they were confined.

There they rolled about in the current caused by the movement of the stirring paddles, but were soon found to be dead. Their destruction was probably caused by exhaustion, and by starvation. The impeding masses of diatoms so clogged the mouth parts and the legs as to prevent the larvæ from securing food.

Similar difficulties were experienced by United States experimenters in lobster rearing at Wickford, Rhode Island, the diatom infesting the larvæ there being *Licmophora tincta* Grun. During the summer of 1914 the lobster larvæ in Dr. Knight's care at Long Beach, Nova Scotia, were destroyed by *Synedra investiens* W. Sm., which normally grows on an alga, especially on *Ectocarpus.*. This formed almost the entire growth observable during that summer, the only other forms present being *Cocconeis scutellum* Ehr. and *Lichmophora Lyngbyei* (Kutz) Grun., and these were not plentiful. In 1915, however, it was the last-named species which took possession of the larvæ and reproduced themselves so rapidly as to prove destructive. The following record will indicate the rate at which they became troublesome to the young lobsters. The figures represent only approximations, as in all probability some diatoms were in positions where they could not be seen. The lobster larvæ were carefully scrutinized under a microscope, and care taken to make the counts as accurate as possible.

| | | | | | |
|---|---|---|---|---|---|
| August 2. | Lobster larvæ | 2 | hours old | .. .. .. .. .. .. | No diatoms. |
| " 3. | " " | 24 | " | .. .. .. .. .. .. | " |
| " 4. | " " | 48 | " | .. .. .. .. .. .. | About 15 diatoms. |
| " 5. | " " | 60 | " | .. .. .. .. .. .. | " 75 " |
| " 5. | " " | 70 | " | .. .. .. .. .. .. | " 150 " |
| " 6. | " " | 96 | " | .. .. .. .. .. .. | Over 350 " |
| " 7. | " " | 120 | " | .. .. .. .. .. .. | " 500 " |
| " 8. | " " | 144 | " | .. .. .. .. .. .. | Masses of diatoms. |

## 3. Importance of Diatoms to Fish.

The complete dependence of animal life on plant life is recognized by all. Diatoms are probably the most important of those very simple plants which take up inorganic substances from water and air, and transform these by the aid of sunlight into living organic matter.

This organic matter then serves as the chief food of crustaceans and mollusks on which many fish live. The most careful study of aquatic life gives to diatoms the proud position of being a large part of the fundamental food on which the animal life of the water depends, and in this sense the expression is true that "All fish are diatoms."

## 4. Structure of Diatoms.

Diatoms are plants of the simplest kind, that is, each diatom consists of but one cell, and a cell is the simplest thing that can be recognized as alive. The greatest peculiarity of diatoms is the fact that each one has a skeleton of silica which is mostly outside the plant, and therefore might be called a shell or case. This shell is often very beautifully marked with lines of nodules or of depressions or of both, and these markings are so minute that they were long thought to be merely grooves and ridges. Diatoms may well be compared with bacteria, which are also minute plants. Diatoms differ from bacteria in being usually very much larger, in having the siliceous shell, and in having chlorophyll. This latter substance enables them to use the sunlight in making their own food, while bacteria, lacking chlorophyll, have to absorb food made by other plants. Bacteria are therefore classed with that large group of dependent plants—the fungi, while diatoms rank with the independent plants. Diatoms reproduce in much the same way as do bacteria, that is, by each mature diatom splitting into two diatoms, after the two valves of the shell have been pushed apart by the growing protoplasm within. Two new valves or half-shells are then formed, and thus each new diatom has one old valve and one new one in its shell. This splitting process, as in bacteria, may go on very rapidly if food and temperature be favourable, and it will result, at any point, in doubling the numbers of diatoms many times in a few days.

In form, diatoms are exceedingly various, such as discoidal, cylindrical, spindle-shaped, and wedge-shaped. Some are made up of segments, which are smooth or spiny, and variously fastened together; some form long ribbons by adhering closely side by side; others occurs in gelatinous tubes in which the individuals are closely packed. The majority of them are free and have some power of locomotion, but some grow attached to larger objects by gelatinous adhesions or even stalks. Of this latter sort are the kinds which have proven so prejudicial to the growth of the young lobsters.

*Synedra investiens* W. Sm., is cigar-shaped or slightly spindle-shaped when seen from the front, and narrowly rectangular in side view, and grows in clusters which are closely attached to the supporting object, and radiate from the point of attachment. It is marked by cross striations which number about nine in ten microns.

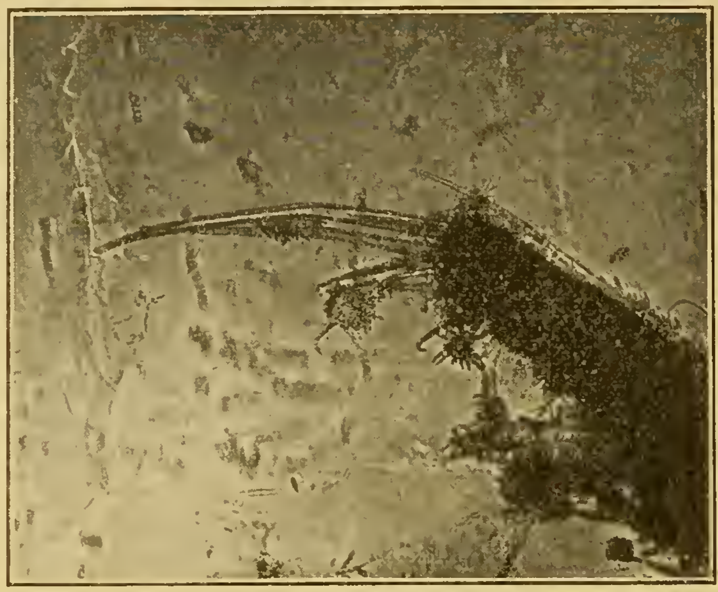

Fig. 1.
Synedra investiens W. Sm. on leg of lobster larva.

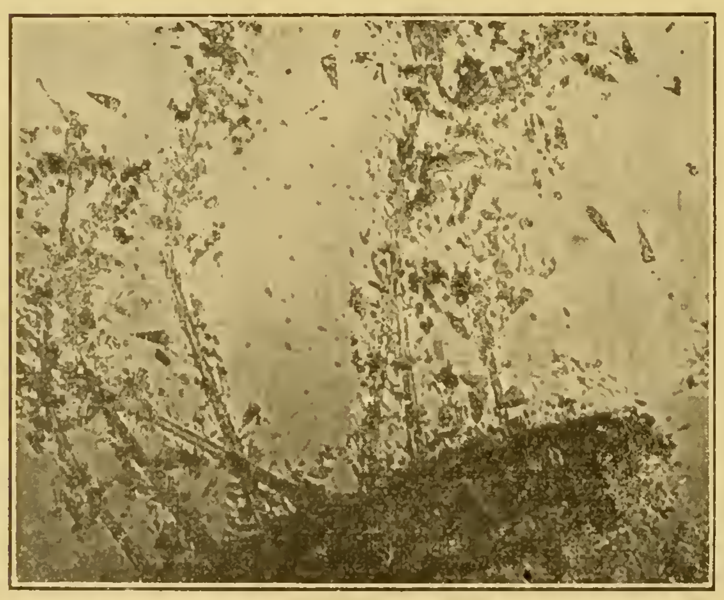

Fig. 2.
Licmophora Lyngbyei (Kutz.) Grun, on leg bristles of lobster larva.

*Licmophora Lyngbyei* (Kutz.) Grun. is wedge-shaped in the front or valve view, and club or paddle-shaped when seen in profile. The nucleus in *Licmophora* is usually visible near the centre of the cell, which is generally filled completely with yellowish granules. The markings on the shell are delicate. and appear as transverse ridges along the edges of the valves, varying from twelve per ten microns near the base, to fifteen near the upper or broad end. The stalks on which the individuals grow are slender and colourless, and may be so short as to be indistinguishable, or may reach to four or more times the length of the valves.

The usual habitat of *Licmophora* is the surface of submerged seaweeds, especially *Chorda filum,* which is common in St. Marys bay along the shore near Long Beach pond. The source of this diatom is therefore the ocean water entering the pond through a pipe at every high tide. It has also been found attached to Copepods. It is rather

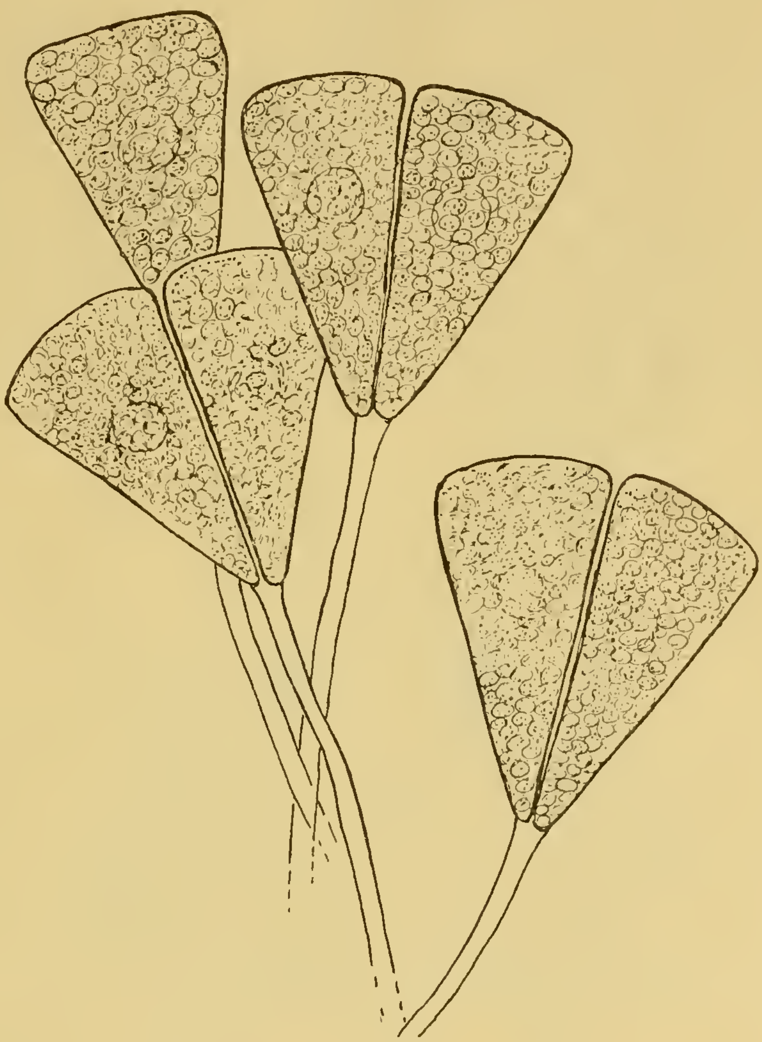

Fig. 3.

Licmophora Lyngbyei (Kutz) Grun, drawn under high magnification, showing the transparent gelatinous stalks.

remarkable that during the summer of 1914 *Licmophora* formed probably less than 1 per cent of the diatoms attached to the lobster larvæ, while in 1915 it formed almost a pure culture, entirely replacing *Synedra investiens* of the preceding year. No satisfactory reason can now be given for the difference. During the summer of 1914 the rearing boxes occupied a position about 200 yards from their location in 1915. The sea-water surrounding them there could not, as in 1915, enter freely through a pipe reaching to the sea, but filtered through a wide sea-wall of boulders. Until we know more of the factors affecting the growth of the various kinds of diatoms, we can merely state these facts without relating them to results.

### 5. Prevention of the growth of diatoms.

Two methods of discouraging or preventing the development of the diatoms on the lobster larvæ were briefly tested. One was the use of copper as an algicide, and the other was the reduction of light for the lobster larvæ. Both were very incomplete experiments, but the facts learned will be of service in future attempts at control. It has long been known that copper is an excellent fungicide, and its toxicity toward the higher plants such as dandelions and wild mustard, is of importance in agriculture. Dr. George T. Moore (U. S. A. Plant Industry Bulletin 76, issued 1905) has demonstrated the practical application of this to the purification of water supplies containing objectionable algæ. The method of using the copper is to dissolve copper sulphate in the water to the extent of one part to from five millions to twenty millions of water. This dilution served to kill such delicate forms as those producing the well known *water bloom* of August and September. For the more hardy organisms such as diatoms it was found that the amount of copper sulphate required was as high as one part or more per million parts of water. The results quoted above were accepted as correct, and the effect of such solutions of copper sulphate on lobster larvæ was examined. Vigorous larvæ, placed in fresh sea-water containing one part copper sulphate per million of water, all died within three and a half hours, although four-fifths of them lived for more than two hours. Another lot of the same copper sulphate solution was diluted to contain one part of copper sulphate in two million parts water. In this the larvæ lived more than four hours, but all were dead within six hours. In another lot of the solution diluted until there was only one part copper sulphate in three millions of water, the larvæ lived but little longer.

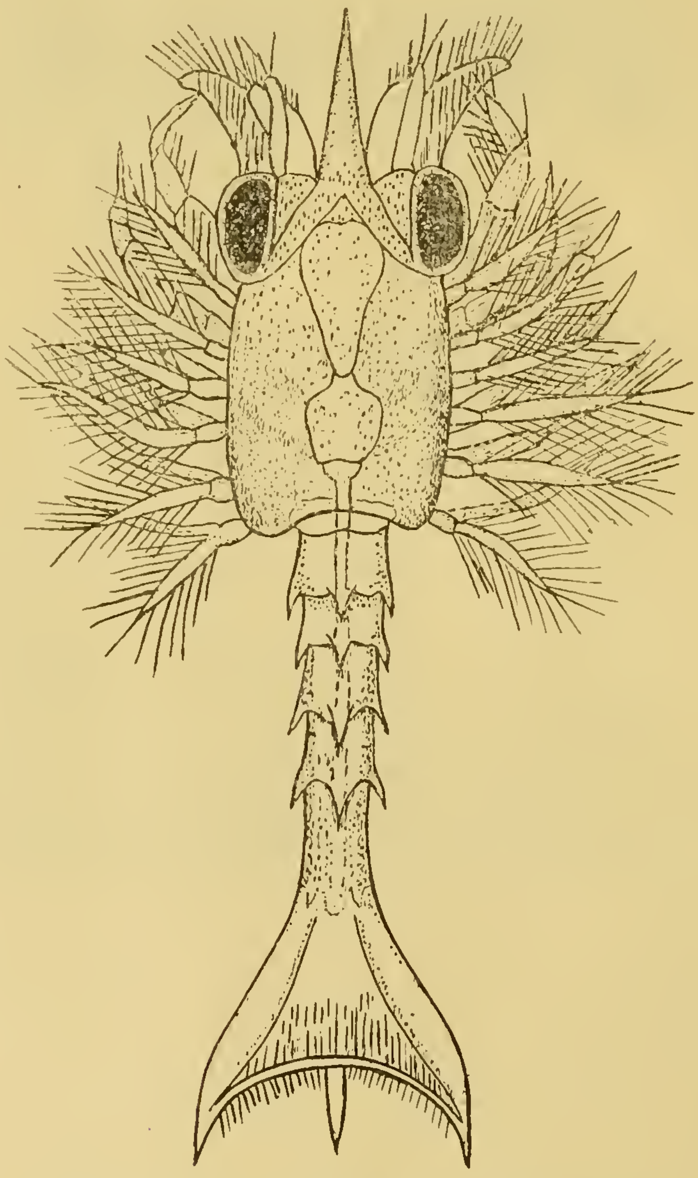

Fig. 4.
Drawing of lobster larva two hours after hatching.
No diatoms could be found attached to it.

Control experiments, exactly similar in every respect, except that the water contained no copper sulphate, were made in each case, the lobster larvæ remaining healthy and active for several days. If, as stated, diatoms require for their destruction one part of copper sulphate per million, it is clear that this algicide cannot be used in sea-water in the presence of lobster larvæ.

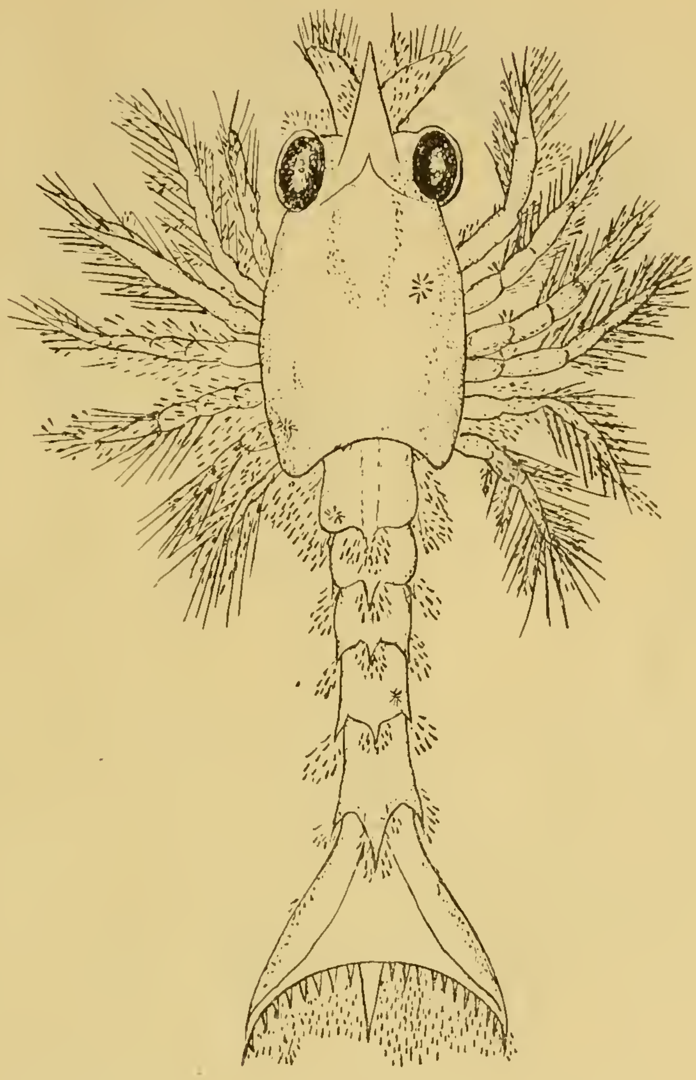

Fig. 5.
Drawing of lobster larva, twelve days old, exposed to sunlight every day. These larvae were all dead by the fourteenth day. The appendages are loaded with diatoms.

The second plan of control gave more promising results. For a plant to make its own food, sunlight is necessary. Diatoms, being independent plants, must have sunlight in order to make satisfactory growth. Ten thousand larvæ in one rearing-box were exposed to the light as usual, while a like number in a neighbouring box were kept shaded by a screen of canvas painted black, and placed horizontally over the box, within about 6 inches of the surface of the water. The larvæ were already four days old when the shade was applied, and on an average they carried between 350 and 500 diatoms each. They were examined after forty-eight hours of shading, and an improvement in their condition was apparent. Careful counts gave an average of 209 diatoms on each larva. Daily examination showed a satisfactory decrease in the number of diatoms. These shaded larvæ began moulting at the end of nine days, while those unshaded did not moult until they were thirteen days old. At the end of twelve days the shaded larvæ were active, and apparently suffering no inconvenience from the few diatoms that adhered to them. This was in striking contrast to the larvæ which had not been shaded, and which were loaded with masses of diatoms on every appendage, as indicated in the drawings.

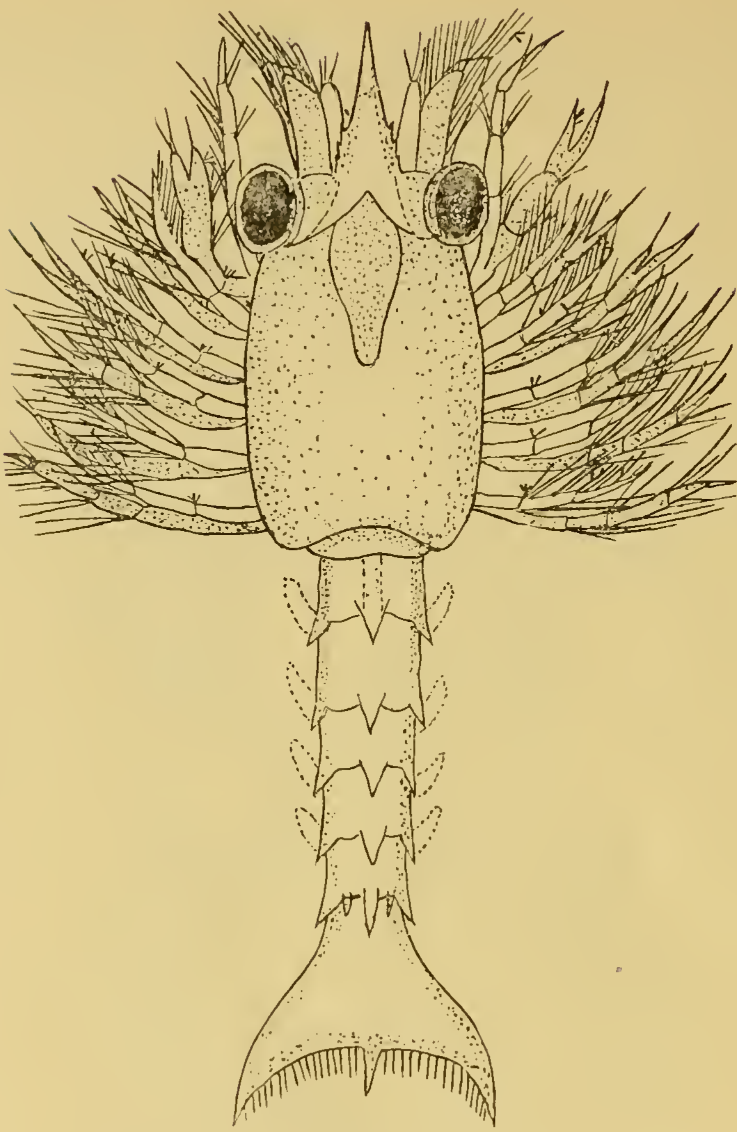

Fig. 6.
Drawing of lobster larva, twelve days old, carefully shaded from the fourth to the twelfth day. These larvae moulted on the ninth day, and show the swimmerets and the serrations on the beak which are the marks of the second phase.

## 6. Diatoms found in the Rearing Boxes.

While *Licmophora* was by far the most plentiful diatom on the lobster larvæ in 1915, other kinds were present in the rearing boxes, and occasionally on the larvæ. A few ribbons of *Fragillaria,* probably *hyalina* (Kutz) Grun., were found with the *Licmophora,* adhering to the bristly appendages of the larvæ. Others collected from the stirring paddle or from the bottom are named below, plentiful in about the order of arrangement:—

*Amphora coffaeformis* (Ag.) Kutz.
*Cocconeis scutellum* Ehr.
*Paralia sulcata* Ehr.
*Rhabdonema adriaticum* Kutz.
*Nitzschia longissima* (Breb.) Ralf. var. parva, Van H.
*Navicula* (*Stauroneis*) *spicula* Hickie.
*Melosira nummuloides* (Bory) Ag.
*Grammatophora marina* (Lyng) Kutz.

*Nitzschia closterium* W. Sm.
*Acnanthes subsessilis* Kutz.
*Fragilaria fenestrata* Grun.
*Amphora quadrata* Breb.
*Synedra affinis* Kutz.
*Coscinodiscus excentricus* Ehr.
*Grammatophora angulosa* Grun.
*Chaetoceras cinctum* Grun. (?)
*Pleurosigma affine* Grun.
*Nitzschia panduriformis* var. minor Grun.
*Actinoptychus undulatus* Ehr.

There were also many individuals of the protozoan, *Peridinium lenticulare* Ehr.

Scrapings from the carapace of a mother lobster, from which larvæ were hatched, gave a few diatoms, but the plant growth on the creature was almost entirely *Ectocarpus,* the diatoms being merely entangled in this alga.

*Licmophora Lyngbyei* (Kutz) Grun.
*Cocconeis scutellum* Ehr.
*Grammatophora marina* Grun.
*Scoliopleura tumida* Grun.

While the above were sufficiently numerous to infect the larvæ with diatoms, *Licmophora* in particular, the numbers which accumulated on the larvæ could not be accounted for by drifting or swimming forms. The almost pure growth of *Licmophora,* its firm attachment to the larvæ, and the increase in diatoms day by day, when exposed to sunlight, all point to their rapid reproduction *in situ,* as the cause of their great numbers. Another evidence was the fact that the plankton net, towed in the water about the raft which supported the rearing boxes, collected comparatively few *Licmophora,* but many individuals of other species. The species named below were found to be plentiful in about the order they are named:—

*Chaetoceras decipiens* Clave.
*Cocconeis scutellum* Ehr.
*Pleurosigma elongatum.*
*P. angulatum* W. Sm.
*Paralia sulcata* (Ehr.) Clave.
*Fragillaria hyalina* (Kutz) Grun.
*Nitzschia longissima* (Breb) Ralfs.
*Chaetoceros dichaeta.*
*Actinoptychus undulatus* Kutz.
*Licmophora Lyngbyei* (Kutz) Grun.
*Amphora quadrata* Breb.

Attached to the timbers of the rafts, and to the ropes by which the structure was anchored, was a thick growth of *Homoecladia capitata* H. L. Sm. Its brown masses showed a definite relationship to the aerated surface waters, being entirely lacking where the ropes reached down a few feet from the free atmosphere. The plankton net collected also many specimens of *Peridinium lenticulare* Ehr. and *P. reniforme,* while *Ceratium tripos* Nitsch, was not rare, and the Silico-flagellate, *Distephanus speculum* (Epr.) Haeckel, was common.

From the waters of St. Mary's bay, in front of the intake pipe of Long Beach pond, the plankton-net collected a few specimens of *Licmophora Lyngbyei* (Kuntz) Grun, but the catch was very rich in the common Bay of Fundy forms:—

*Chaetoceras decipiens* Cleve.
*C. dichaeta.*
*C. eriophyllum* Cast.
*Rhizosolenia styliformis* Bright.
*Coscinodiscus concinnus* W. Sm.
*Cocconeis scutellum* Ehr.
*Nitzschia longissima* (Breb) Ralfs.
*Paralia sulcata* (Ehr) Cleve.

Along with these were the following named infusorians and crustaceans: —

*Ceratium tripos* Nitsch.
*Amphorella subulata* (Ehr) Dad.
*Distephanus speculum* (Ehr) Haeckel.
*Ceratium fusus.*
*Tintinnopsis campanula* (Ehr) Dad.
*Calanus finmarchicus* Gunner.
*Podon intermedius* Lill.

For verification of the determinations of several species, and for the identification of others, the writer is under special obligation to Dr. Albert Mann, of the United States National Herbarium, and to Dr. A. H. MacKay, Superintendent of Education, Halifax.

# ON THE SCALES OF THE SPRING SALMON.

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A paper on "Growth of the spring salmon" was read at the San Francisco meeting of the Pacific Fisheries Society, August 9-11, 1915, and appears in the proceedings of that meeting. A more detailed analysis of the data on which it was based and of data obtained from new material, is here presented.

The spring salmon (*Oncorhynchus tschawytscha*), otherwise known as the king, tyee, chinook, or quinnat, has been the most highly favoured for investigation of all the Pacific Coast species, and much good work has been done by Rutter, Gilbert, Chamberlain, and others, largely in connection with the United States Bureau of Fisheries. By means of long-continued observations, these men and their associates have been able to put on record many facts concerning the life-history of this valuable species. In this instance, some additions, obtained by the methods recently made use of in the North Sea investigations by Hjort, Dahl, and others, are offered. McMurrich and Gilbert have included the spring salmon in the species of which the age at maturity was discussed. Incidentally, that phase of the study of scales will be considered in connection with an investigation into the rate of growth, and its bearing on the life-history of the species.

The validity of the conclusions drawn from scale study depends largely on the interpretation of the "annual rings" or "winter checks." The propriety of introducing these terms has been seriously questioned by many who have failed to see such a significance in the portions of the scale under discussion. It seemed useless to go on with scale investigation unless some definite assurance could be obtained on this point. Two species, the Pacific herring and the spring salmon, may be obtained throughout the year in the strait of Georgia, and hence these offered a basis for information. For reasons given later, the spring salmon was chosen and an investigation that began with the idea of personally settling the "winter check" question was enlarged to include other points in connection with the life-history.

## THE "WINTER CHECK."

There is no disputing the fact that in the scales of some species of fish there are areas arranged concentrically, having a different appearance to the remainder of the scale. As they are concentric they may be appropriately called "rings." Under normal conditions of growth is there one of these rings formed on each scale during each year?

Einar Lea has investigated the matter in the case of the North Sea herring, and the argument he advances is a convincing one.[1] By examining herring of the same year class, caught at short intervals over a considerable period, and from these getting measurements, he concluded that the somewhat transparent ring on the scale was formed during the period from December to March, the main growth of the scale or almost the entire growth, taking place during the other months. Though this ring is annual and is produced during the winter months, his evidence shows that the rate of growth is not primarily dependent on temperature.

[1] A study of the growth of herrings, Publ. de Circonstance, No. 61, Conseil Perm. Inter. pour l'Explor. de la Mer, 1911.

In the scale of the herring the characteristic markings, the elevated lines, run transversely across the scale; the winter check, concentrically placed, consequently crosses the regular lines at right angles laterally but runs nearly parallel with them medially. The rings are narrow and, since they are formed at the margin of the scale, it is impossible to tell when a ring begins or when it ends, with any degree of accuracy. Hence Lea had to resort to many measurements and calculations of growth. Because of this difficulty it is possible to get scales more satisfactory than the herring scales, and it is for this reason that the scales of the spring salmon have been taken in preference.

The characteristic elevated lines on the salmon scales are quite different from those on the herring scales. The arrangement is concentric around a more or less nearly circular nucleus, so that each of these lines form rings, or rather partial rings, as few of them are completed on the exposed portion of the scale. These rings are wide apart in certain areas, while in other areas at regular intervals they are quite close together. Corresponding to the transparent rings on the herring scale, therefore, there are narrow bands of closely applied rings. The term "annual rings" must have a somewhat different significance in the two cases, although the cause may be similar, but it is possible that "winter check" can be applied equally well to each. The close band is so much wider than the ring in the herring scale that it is easily possible in the majority of cases to decide when it begins or ends.

As previously stated, spring salmon are to be obtained in the strait of Georgia at all times of the year, and hence, in all probability, some of them at least remain in the strait during the whole period of their existence in salt water. The fall, winter, and spring, 1914-15, were particularly favourable for getting material. As there was so little cold or stormy weather the handline fishermen were able to go out almost every day, seldom doing so without some return for their labours. A number of men from Departure Bay fished throughout the season, and it was a simple matter to obtain data at short intervals. The majority of the fish examined were caught by Mr. E. Webber, who made special effort to have the series as complete as possible. The temperature data were obtained from daily surface readings at the station, and occasional readings at depth.

The appearance of a year's growth on a salmon scale has a much closer approximation to that of the growth in a twig of wood than that of the herring scale. The area of distant rings corresponds to the loose texture of the spring and summer growth in the twig. The rings get closer during the fall until there is a compact band corresponding to the winter ring in the wood. It was to the time that the compact band made its appearance that special attention was paid.

In the scales of fish caught in the summer time, with rare exceptions, there is always a wide area outside of any compact band, hence it was evident that this close band could not be formed at that time of the year. During the fall a certain amount of retardation was indicated since the lines near the margin were closer together. Later the beginning of the more compact band was evident in some scales, then in all, and still later the outer limit was reached and the distant lines appeared once more.

In all scales of salmon caught from January 6 to March 17 there was indication of the check in growth at the margin. On the other hand, with but few exceptions, no scales obtained after April 22 and before November 27 had indication of retardation at the margin. From March 17 to April 22 and from November 27 to January 5 some show retardation at the margin while others do not, this being true even in specimens caught on the same day. The period of check here corresponds so exactly with that reported by Lea for the herring that it can scarcely be considered a mere coincidence. As the time corresponds in general to the winter season, the term "winter check" is not inappropriate.

In order to compare the temperatures of the water during the "winter check" period with those before and after, a table of surface temperatures to cover the months from October to May, inclusive, is given, as well as a table showing temperatures at depth, taken at intervals during that period. The surface temperatures were taken at the station landing float, and the deeper temperatures about four miles out, east of Five Finger island, that being the nearest point at which water over 100 fathoms could be reached. The surface readings were taken by a Negretti and Zambra deep-sea thermometer or one standardized against it and the deep-water temperatures with a Richter deep-sea thermometer in connection with a Pettersen-Nansen water-bottle.

TABLE I.

| Day. | Oct. | Nov. | Dec. | Jan. | Feb. | March. | April. | May. |
|---|---|---|---|---|---|---|---|---|
| | ° | ° | ° | ° | ° | ° | ° | ° |
| 1 | 11·8 | 10·5 | 7·4 | 7·9 | 6·9 | 8·4 | 9·4 | 10·7 |
| 2 | 11·5 | 10·5 | 8·6 | 8·0 | 7·9 | 7·6 | 9·8 | 11·0 |
| 3 | 11·1 | 10·4 | 7·6 | 8·7 | 7·4 | 7·6 | 9·0 | 11·5 |
| 4 | 11·5 | 10·0 | 8·5 | 7·3 | 6·7 | 7·5 | 9·2 | 11·6 |
| 5 | 11·8 | 9·9 | 7·6 | 6·4 | 7·3 | 7·7 | 9·4 | 13·3 |
| 6 | 11·7 | 9·7 | 7·5 | 6·3 | 7·2 | 7·6 | 10·3 | 13·0 |
| 7 | 12·3 | 8·7 | 7·7 | 6·7 | 7·9 | 8·2 | 10·4 | 13·9 |
| 8 | 12·3 | 9·2 | 6·7 | 7·4 | 8·6 | 7·7 | 9·0 | 13·3 |
| 9 | 12·7 | 9·7 | 7·9 | 7·7 | 8·4 | 7·9 | 9·8 | 12·8 |
| 10 | 12·2 | 9·1 | 7·0 | 7·0 | 8·1 | 8·1 | 10·7 | 12·2 |
| 11 | 11·6 | 9·8 | 6·3 | 7·2 | 7·3 | 8·1 | 9·9 | 11·8 |
| 12 | 11·4 | 9·0 | 7·4 | 8·2 | 7·3 | 8·2 | 10·3 | 11·6 |
| 13 | 10·8 | 8·3 | 7·0 | 7·6 | 7·7 | 8·5 | 10·3 | 12·0 |
| 14 | 10·9 | 8·5 | 7·2 | 7·7 | 8·5 | 8·7 | 9·8 | 12·1 |
| 15 | 11·6 | 7·4 | 7·4 | 7·3 | 6·6 | 8·5 | 10·9 | 12·6 |
| 16 | 11·2 | 8·3 | 7·6 | 7·2 | 8·6 | 8·2 | 11·2 | 13·1 |
| 17 | 10·5 | 9·0 | 6·3 | 7·1 | 8·5 | 8·2 | 11·7 | 13·4 |
| 18 | 10·4 | 8·2 | 6·4 | 7·2 | 7·7 | 8·0 | 11·9 | 13·7 |
| 19 | 10·0 | 8·3 | 6·7 | 6·5 | 7·4 | 8·6 | 11·7 | 13·5 |
| 20 | 10·0 | 8·9 | 6·5 | 6·6 | 6·7 | 8·1 | 10·5 | 13·2 |
| 21 | 10·2 | 9·2 | 6·5 | 5·7 | 7·2 | 9·0 | 10·6 | 12·2 |
| 22 | 10·3 | 9·4 | 6·3 | 6·2 | 7·0 | 9·7 | 11·1 | 12·6 |
| 23 | 10·8 | 8·8 | 7·1 | 6·7 | 7·4 | 9·4 | 10·8 | 12·2 |
| 24 | 10·5 | 8·9 | 7·3 | 5·6 | 7·1 | 9·7 | 11·8 | 12·1 |
| 25 | 10·3 | 8·9 | 7·0 | 6·1 | 7·1 | 9·7 | 11·3 | 12·7 |
| 26 | 10·7 | 9·1 | 7·2 | 6·2 | 7·1 | 9·2 | 11·1 | 12·1 |
| 27 | 11·0 | 8·8 | 6·9 | 6·9 | 7·6 | 10·0 | 11·0 | 12·4 |
| 28 | 10·9 | 8·8 | 7·0 | 6·6 | 8·5 | 10·1 | 10·8 | 9·9 |
| 29 | 10·8 | 8·6 | 6·5 | 6·9 | ........ | 10·3 | 10·6 | 12·4 |
| 30 | 11·0 | 7·3 | 6·6 | 6·6 | ........ | 9·7 | 10·6 | 13·5 |
| 31 | 10·9 | ........ | 7·0 | 6·9 | ........ | 9·0 | ........ | 13·8 |
| Average | 11·1 | 9·0 | 7·2 | 7·0 | 7·4 | 8·6 | 10·5 | 12·5 |
| Maximum | 12·7 | 10·5 | 8·6 | 8·7 | 8·6 | 10·3 | 11·9 | 13·9 |
| Minimum | 10·0 | 7·3 | 6·3 | 5·6 | 6·5 | 7·5 | 9·0 | 9·9 |

TABLE II.

| — | 100f. | 50f. | 20f. | 10f. | 5f. | 0f. |
|---|---|---|---|---|---|---|
| Sept. 9, 1914 | 8·7 | 8·8 | 9·9 | 10·5 | 10·6 | 14·2 |
| October 21 | 9·1 | 9·1 | 9·4 | 9·7 | 10·0 | 10·7 |
| December 8 | 9·0 | 9·2 | 8·8 | 8·6 | 8·4 | 7·6 |
| January 18, 1915 | 9·0 | 8·7 | 7·8 | 7·0 | 6·9 | 6·9 |
| February 26 | 8·5 | 8·5 | 8·4 | 8·0 | 7·9 | 8·0 |
| April 9 | 8·4 | 8·2 | 8·3 | 8·4 | 8·6 | 9·2 |
| May 17 | 8·6 | 8·4 | 8·9 | 9·2 | 10·2 | 13·6 |

The readings are all Centigrade readings.

It will be seen from the tables that during the three months, December, January and February, the average temperatures differ little, but are lower than during the other months, while the greater portion of the retardation of growth takes place during January, February, and March. November, during which there was no evidence of check except during the last few days, was colder, on the average, than March, and had a lower minimum. October was almost as warm as April, and yet retardation is evident on occasion almost to the end of April. There are only 4·1 degrees of difference between the average of October and January, and only 2 degrees between the average for November and January. There may be that much difference between the temperature at the surface and at a depth of 5 fathoms (in table II there is a difference of 3·6 degrees shown thus for September 9), and 5 fathoms would certainly not be too great depth for a salmon to reach. Doubtless there is a maximum, an optimum and a minimum temperature for growth, but it is scarcely probable that if the optimum is reached at 13 or 14 degrees, 7 degrees would be at or near the minimum, and if it were, 8·6 degrees, the average for March, should be far enough away from that minimum to show a definite increase of growth instead of showing a continuation of the minimum.

If the check is due to the lowering temperature, one would naturally expect that the change should take place in all of the fish of the same species in the same region at or near the same time, and yet some have close rings beginning on November 27, while others have little or no sign of them on January 5; some have got over the check on March 17, while others retain it on April 22. Between these dates in the two cases there is a period of time equal to almost half of the time during which all show retardation. Again, if the check is due to the lowering temperature, all in the same vicinity should have checks of nearly the same width, but instead there is a great variation from one or two rings to six or seven. The variation occurs in the individuals in one year class as much as in any of the others, and after the first year is over the individuals that migrate as fry are affected in the same way as those that migrate as yearlings.

Nothing shows better the entire lack of relation between rate of growth and temperature than the graphs for each for the entire year. In making a graph for the growth rate, the average percentage of the total growth for the year was taken for each half-month. As the new growth for the year starts about April 1, that is taken for the basis of calculation. In the graph for water temperature (surface) the average for each half-month was taken also. The graph showing the percentage of the year's growth completed during each half-month is also given.

The curves for growth rate and temperature are so unlike that they are scarcely comparable. The greatest growth rate is in May, the highest temperature in August, by which time the growth rate has become materially reduced. The growth curve has a sharp ascent from the first of April until the middle of May and a very gradual descent for the rest of the year; the temperature curve has a gradual ascent from January until August and a gradual descent for the rest of the year. Half of the total growth for the year takes place during April, May and June, before the temperature has nearly reached its greatest height. During the next two and a half months another quarter is added, leaving but a quarter for the next six and a half months, but by the middle of September the temperature has decreased very little.

It may be remarked here that there is no indication of a total cessation of growth during January, February, and March, such as Lea says occurs in the North Sea herring. The growth is very much retarded but does not cease entirely. The width of the winter bands shows this to be true.

Taking all of these points into consideration, it can scarcely be maintained that temperature has any very definite primary effect on rate of growth.

Tables somewhat similar to those given for temperature could be given for density or salinity during the same period, but as they cover ground so similar it does not appear to be necessary. Suffice it to say that there seems to be just as little direct relation between salinity (as far as the limits in the waters of the strait of Georgia are concerned) and growth rate, as there is between temperature and growth rate.

With temperature and salinity eliminated as primary factors, the main emphasis must fall on the only other known variable that could have direct bearing on the growth of fish, viz., the food supply. That fish do not differ from other animals in which growth is accelerated by regular, suitable feeding, is shown by the success that attends the feeding of fresh-water fish in ponds, lakes, and streams. On the other hand fish, like other animals, cannot maintain normal growth if food is lacking or is insufficient in quantity to keep the various processes active. Existence may be continued for some time under such conditions, but it must be at the expense of the nourishment and energy stored up in the body. While that is being drawn upon, growth must be retarded or stopped altogether, and the weight may be considerably reduced.

The scale, like any other organ of the body, must be affected as the body as a whole is affected, hence the variation in the food supply, even without any other important factors, could account for the difference in the rate of growth.

In fishes like the salmon, where a portion of the life is spent in the fresh water and the remainder in salt water, there is a great disparity of growth during the two periods. The richness of the marine fauna as food supply, as compared with the fresh-water fauna, makes a decided difference in favour of the former. A difference in salinity, however, complicates matters as far as evidence goes in this case. A better illustration is afforded by the difference in the rate of growth of a trout, e.g., the cut-throat, in a small pond where food is scarce and in a lake where food is abundant or where there is a wider area over which to search for it.

The variation in the food supply would seem to account appropriately for the variation in rate of growth but, unfortunately, in the case of the spring salmon, the application is not self-evident. In the spring and summer, minute crustacea and a great variety of larvæ are abundant, hence such fish as the herring that feed on this should thrive better at that time of the year. The spring salmon takes this food also, but evidently eats many fish as well. Here comes the difficulty. To judge from the stomach contents, one might say that the salmon, by preference, feeds on the herring and the herring is abundant in the strait throughout the year. They are much more in evidence during the winter months, as the schools can readily be located near shore. During February and March they remain for long periods in the same locality, in the spawning season. Some of the salmon follow the herring into shallow water since a few individuals are caught in the herring nets, and I have seen them swimming around in a school of herring not far from shore. It may be that these are stragglers while the larger numbers remain in the deeper water where the herring congregate in the summer time.

An entirely different explanation is possible. The spring salmon may prefer crustaceans, as the sockeye and the coho seem to do, taking fish only when the crustacean supply runs short. Their presence with the herring schools may be due to the fact that they, like the herring, are feeding on copepods. There is some basis for such conclusion, for spring salmon caught in the neighbourhood of herring schools have been found to contain decapods, schizopods, amphipods, and copepods. At such time I have even found annelids of the *Nereis* type in their stomachs, the only evidence that I have seen that they are ever bottom-feeders after they leave the fresh water. Fishermen with spoon bait often catch many salmon right in the herring schools, while herring bait at such a time is useless. If crustaceans make up the main part of the food supply, then they would fare better in spring and early summer when the pelagic crustacea are so numerous. In the winter time they take to the herring in the extremity of hunger, as being the chief food available, enough to keep them alive but not enough for ample nourishment for growth equivalent to the summer growth.

If retardation of growth in the scale is due to the lack of suitable food, an explanation is readily available for the extra checks that appear between the regular winter checks, or at the margin in fish caught during the summer. Local conditions may become such, even in the summer, that a fish cannot get a good food supply for some time, and the growth is checked. That there are not more of these checks goes to show what an abundant and well-distributed fauna there must be in the sea. Fish must be subject to periods of ill health, as all animals are, and during such times growth may be seriously retarded. This would account for the small amount of growth sometimes found between two successive winter checks.

Regenerated scales show that fish are subject to injury. As on the regenerated scales, only those rings corresponding to those formed afterwards on the normal scales appear, leaving the central portion of the scale blank. The time of the injury is thus indicated. If the injury is a serious one the normal scales on the fish may show a check on account of the retardation of growth due to the drain on the system in recovering from the injury. These checks may or may not decrease the total amount of growth for the year. In some cases it does noticeably, but in others the later growth seems to have been accelerated so as to fully make up for the lost time.

At first such extra checks may cause considerable confusion in scale reading, but after the normal scale becomes familiar, such checks, with rare exceptions, may readily be distinguished from the regular winter checks.

## RATE OF GROWTH.

Since data as to length and weight of the fish from which the scales for this investigation had been recorded, these scales became available for a study of rate of growth. Since that time other material has been added. Some of this additional material was obtained from the Departure Bay fishermen, and hence is comparable to the previous material; some was obtained from the cannery at Nanaimo, some from a cannery at New Westminster (these were caught in the Fraser river), some from the Vancouver fish companies (from the Skeena and Campbell rivers), some from the cannery at Uchucklesit, Barkley sound, and a small but interesting collection from Mr. R. B. Heacock, Seabright, California. To those in charge in all these cases my thanks are due.

The lot is rather a composite one and, for some purposes, a large number from one locality taken at nearly the same time would give better results, but for other purposes, as this material contains data from specimens of all ages taken at all times of the year, from widely different localities, it is especially suitable.

In studying the rate of growth of the spring salmon it must be recognized, in the first place, that there are two types to be considered. Most observers have realized that some salmon migrate from the fresh water to the sea as fry, when they are four or five months hatched, while others remain in the fresh water throughout the first year and go down early in the second year as yearlings or fingerlings. The whole scale theory must fail if there are not two types of scales to correspond, but it does not. The most casual observer could not fail to notice that the central portion of the scale may differ materially from the corresponding portion of the scale of another individual. There is no doubt that Gilbert's interpretation of this central portion of the scale in the two types of this species is correct.

The individual that migrates as fry has no scales when it reaches the salt water, and consequently there can be no record on the scale of life in fresh water. The scale starts to develop soon after migration, the growth is rapid, and although the late start is a big handicap, the growth in the remainder of the year is slightly greater, on the average, than that of the whole second year. There is this difference, however, the fish in its first year does not seem to be able to stand adverse conditions as well as the older fish. They may not be able to partake of as great variety of food. In consequence, the distance between the rings on the scale at times start to narrow earlier so that the summer growth gradually passes into the winter growth without giving the appearance of a distinct winter check. The change from the winter check to the next summer's growth is as abrupt as in older fish. The fry are about 1·5 inch long when they migrate, and the average length at the end of the year is about 10 inches. (Here as elsewhere in this paper the caudal fin rays are not included when the length is measured.) Some measurements, given in inches, will give some indication of the rate of growth: August 18, 5.0 (2), 5.2, 5.5 (2), 6.0, 6.5, 7.5; November 6, 10.0; December 4, 8.7; December 26, 9.7; January 28, 10.0; February 11, 10.2; March 3, 10.7; March 6, 10.2; March 11, 8.8; Aprl 3, 8.8; April 6, 11.4, 8.7; April 8, 11.6; April 13, 10.4; April 14, 10.2. After this date the rapid growth had started in all the specimens examined. At this time the fish is about a year old, or slightly more, and weighs about half a pound. In the measurements given later the first year is taken to be the period to the end of the first winter check.

Concerning the later growth it is not necessary to say very much. Broad summer bands are followed in succession by narrow winter bands. In normal individuals the limit of variation is not so very great, but naturally it increases with the age of the fish. At the end of the second year the average length of the fish examined was 20·5 inches, and the weight somewhat over 4 pounds. At the end of the third year the length was 28·5 inches, and the weight 14 pounds. At the end of the fourth year the length was about 33 inches, and the weight 22 pounds. No specimens obtained had completed the fifth year.

The fry that remains in fresh water during the first year starts to develop the scale about the same time as the one that goes to sea, but as the fish in fresh water grows very slowly, the scale grows slowly also, and the rings, even in the summer time, are quite close together. In the winter they come almost together and are often incomplete or broken. The winter check can be distinguished more readily in the majority of specimens, by the narrow area of broken lines than by judging the distance between the lines. The fish is still under 4 inches in length, and hence does not compare at all favourably with the one that spent its first year in the sea. Usually the migration to the sea is made early in the spring, so that the growth in salt water is indicated immediately following the winter check. In some instances, though, there is indication of a small amount of fresh-water growth outside of the winter check before the growth in salt water commences, but it never reaches an extent similar to that sometimes found in the coho. About one-third of the specimens examined showed evidence of this growth. It would seem then that a large majority —two-thirds of the whole number in this group—migrate early in the spring, in March or early in April, and the remainder follow not so very long after, so that by the middle of May, or even earlier, the last stragglers must have disappeared from the fresh water.

After the seaward migration the growth in this type is entirely comparable to that in the other. At the end of the second year the average length is nearly 14 inches, and the weight slightly over a pound; at the end of the third year the length is over 23 inches and the weight 6 pounds; at the end of the fourth year the length is 30 inches and the weight 16 pounds. Sixth year specimens were lacking in this type also.

In making a more detailed analysis and comparison, the following data were obtained. Of 306 fish over one year old examined, 199 or 65 per cent of the whole number had migrated as fry. Of these, 83 were in the second year, 43 in the third, 59 in the fourth, and 14 in the fifth year. Of the 107 that stayed in the fresh water a year, 10 were in the second year, 18 in the third year, 44 in the fourth, and 35 in the fifth. The growth of each fish in each year has been calculated and the average for each year taken. The following table was made out for the purpose of comparison.

## TABLE OF GROWTH.

"Sea Type."

| Year Class. | No. | Growth During 1st Year. | 2nd Year. | 3rd Year. | 4th Year. |
|---|---|---|---|---|---|
| | | In. | In. | In. | In. |
| 2nd | 83 | 9·9 | ........ | ........ | |
| 3rd | 43 | 10·0 | 9·8 | ........ | |
| 4th | 59 | 11·1 | 10·1 | 7·6 | |
| 5th | 14 | 10·3 | 9·7 | 7·6 | 5·6 |
| Average | ........ | 10·3 | 9·9 | 7·6 | 5·6 |

| Year Class. | No. | Length at End of 1st Year. | 2nd Year. | 3rd Year. | 4th Year. |
|---|---|---|---|---|---|
| | | In. | In. | In. | In. |
| 2nd | 83 | 9·9 | ........ | ........ | |
| 3rd | 43 | 10·0 | 19·8 | ........ | |
| 4th | 59 | 11·1 | 21·2 | 28·7 | |
| 5th | 14 | 10·3 | 20·0 | 27·6 | 33·1 |
| Average | ........ | 10·3 | 20·5 | 28·5 | 33·1 |

"Stream Type."

| Year Class. | No. | Growth During 1st Year. | 2nd Year. | 3rd Year. | 4th Year. |
|---|---|---|---|---|---|
| | | In. | In. | In. | In. |
| 2nd | 10 | 3·6 | ........ | ........ | |
| 3rd | 18 | 3·8 | 10·4 | ........ | |
| 4th | 44 | 3·7 | 10·5 | 9·5 | |
| 5th | 35 | 3·7 | 9·6 | 9·4 | 7·2 |
| Average | ........ | 3·7 | 10·2 | 9·5 | 7·2 |

"Stream Type"—*Concluded.*

| Year Class. | No. | Length at the End of | | | |
|---|---|---|---|---|---|
| | | 1st Year. | 2nd Year. | 3rd Year. | 4th Year. |
| | | In. | In. | In. | In. |
| 2nd | 10 | 3·6 | ......... | ......... | |
| 3rd | 18 | 3·8 | 14·1 | ......... | |
| 4th | 44 | 3·7 | 14·2 | 23·7 | |
| 5th | 35 | 3·7 | 13·4 | 22·8 | 30·0 |
| Average | ........ | 3·7 | 13·9 | 23·3 | 30·0 |

Of the mature grilse only four were obtained, all of the "sea type," in their third year. The average for them was: Growth, first year, 11·1; second year, 10·7; length at end of first year, 11·1; at end of the second year, 21·8; when caught in June, 26·0.

In the previous paper on "Growth of spring salmon," 2 inches was taken as the average length when the scale starts to develop. It has been found that this was too high for the average, 1.5 inch being much nearer the length. In these calculations, therefore, 1·5 inch has been taken from the total length of the fish in each case and the remainder divided in the same proportion as a line drawn from the margin of the nucleus to the margin of the scale, would be by the outside limits of the various winter checks. To the first year value thus obtained, 1.5 inch is added to get the length of the fish at the end of the first year. In making the calculation in this way there is no "phenomenon of apparent change in growth-rate" such as is shown in the various herring investigation tables of Hjort, Dahl, and others, making the strained explanations by Rosa Lee (Publications de Circonstance, No. 63, Conseil Perm. Int. pour l'Expl. de la Mer, 1912) and of Einar Lea (*Ibid.,* No. 66, 1913) appear necessary.

When the number examined was divided up between the two types and among the different classes, the number in any one group was not large enough to make it worth while making graphs, but some points concerning each might be mentioned.

Taking the "sea type" first, the growth for the first year varies from 7·1 to 12·7 inches, but very few are less than 8·7. The number 9·3 has the greatest number of individuals, but several others have nearly as great. In the second-year growth there are some cases abnormally small, 6.2, 6.4, 6.7, 7.2. The majority fall between 8.6 and 12·2, with 10·0 and 11·1 the most numerous. The length at the end of the second year shows much the same variety as the second-year's growth. There are low ones, 14·7, 15·8, 16·4, and 16·7, and high ones, 24·1, 24·2, and 24·5, but nearly all come between 17·5 and 23·5. The growth in the third year shows much variation between the extremes of 3·8 and 4·5 on the one hand, and 11·5 on the other, but the greater number come between 7·0 and 8·5. This makes a great variation in length at the end of the third year, all the way from 24·2 to 31·8, the majority falling between 27·5 and 29·5. In the fourth-year growth there is less variation, 4·2 and 6·7 being the extremes, but at the end of the year the length varies from 29·9 to 37·9, with one abnormally low at 28·3. Those taken in the fifth year were taken at different times and a fair comparison can scarcely be made, but with the exception of the abnormal one just mentioned, which became only 30·5, there was a variation from 33·0 to 40·0, with an average of 35·8.

In the fish of the "stream type," since the growth in the first year, after the alevin stage is passed, is small, there is little variation as given in inches, for the length at the end of the first year. The extremes are 3·2 and 4·1, with the greatest number at 3·6 and the next at 3·9. In the second-year growth there is a range from 7·7 to 12·8, but nearly all are between 8·4 and 12·0. The length at the end of the second year varies from 11·4 to 16·5, but nearly all are between 12·1 and 15·9. In the third-year growth there are three exceptionally low, 5·1, 5·8, and 6·4, and apart from this there is a variation from 6·9 to 12·5, the majority being between 8·3 and 11·0. At the end of the third year, with the exception of six abnormal ones, one of which is only 16·9, the length varies from 21·1 to 26·9, and is fairly well distributed between these extremes. In the fourth year the increase is small in two cases, 5·0 and 5·3 and high in two others, 8·9 and 9·8. The remainder falls between 5·7 and 8·4, with the majority between 7·0 and 8·0. The length at the end of the fourth year varies from 25·8 to 34·0, but nearly all fall between 29·5 and 31·5. Of those caught in the fifth year, all but three were obtained on June 22. The average length when caught was 32·4, with a variation from 28·5 to 36·5.

For material from such a variety of sources, the growth values for each year show very little difference in the different classes. The differences are greater in fishes of the "sea type," since, as the spring salmon do not all spawn at the same time of the year, some of the fry must be more or less than a year old at the end of the first winter check. With the fish of the "stream type" the growth of the first year is so small that all start on much the same basis at the beginning of the second spring.

There is one point quite prominent in both types, and hence worth considering. Those fish that have matured in their fourth year have higher average growths throughout than those that do not mature until the fifth year. From this it would seem that the larger fish of a year-class spawn in the fourth year and the smaller ones of the class spawn in the fifth year. If this is true, we should expect that those that mature as grilse in the third year should be the largest of the year class. Too few were examined to justify any definite statement, but it may be said that these do not show that that might not be so. One would need to get several fish of the same year-class for three years in succession before the conclusion would be sufficiently definite.

The comparison would be more complete if six-year or even seven-year fish (Gilbert records one fish in its seventh year) could have been included. Gilbert says very little about the six and seven-year fish that he has seen. The sixth-year scale that he figures is of the "stream type" it would be interesting to know if all the others were, as well as the nature of the seventh-year fish. The data from such would have a decided bearing on the question here discussed, but in this region, at any rate, they would not appear to be sufficiently numerous to be a factor in the commercial phase of the question.

As quite a complete series of fish up to 35 inches was obtained, and as the weight of these over 5 inches was recorded, it is possible to get a satisfactory graph to show the ratio of weight to length. The curve is as regular as one could expect from the degree of accuracy of weights and measurements. There were only ten fish in the collection over 35 inches, and these show much irregularity in weight. There were: four 35·5, varying from 21 to 28·5 pounds; one 36·0, weighing 28; one 36·5, 25; one 37·5, 39; one 38, 28; one 39, 35·5; and one 40·0 weighing 36·5 pounds.

The sex was not determined in the fish obtained from New Westminster and Vancouver, hence the data are not sufficient to say definitely if there was much difference in weight between the males and the females of the same length, as this lot contained a large proportion of the mature specimens. In those where the sex was determined there was no material difference.

In comparing the salmon of the "sea type" with those of the "stream type" throughout, the former shows to good advantage. At the end of the first year, it has a length 6·6 inches greater than the other, and a somewhat similar superiority is maintained throughout. At the end of the second year three is still 6·6 inches difference and a difference of over 3 pounds in weight, as the small fish weighs very little over a pound while the larger weighs over 4. At the end of the third year the difference in length is 5·2 inches and the difference in weight, 7·5 pounds. At the end of the fourth year, the difference in length is 3·1 inches and the difference in weight, 6·5 pounds. At the time they are caught in June and July, if they are in the fourth year, the average length of the "sea type" is 31·7 inches, and of the "stream type" 26·3 inches, a difference of 5·4 inches, and a corresponding difference in weight of 7·5 pounds; if they are caught in their fifth year, there is an average difference in length of 3·4 inches, and in weight of 6·5 pounds. As in this collection 65 per cent are fish of the "sea type," it would seem to be a good thing if the remainder should be encouraged to behave likewise. Hence, instead of keeping the fry of the spring salmon in retaining ponds for a year, and losing thereby many pounds of mature fish, it would be much better to give all of them every facility in getting down to the salt water and a better supply of food as soon as they can stand the change physiologically. The only offset there is comes from the fact that a larger number of fish of the "sea type" than of the "stream type" are mature in the fourth year. The latter has one year longer to grow in such cases. As it is scarcely any larger in the fifth year than the former is in the fourth, there is no special advantage even here. If five years instead of four are taken to produce a certain size of fish, there must be a loss of 25 per cent here as well.

It must be distinctly understood that these remarks apply to the spring salmon only, and to the spring salmon as I have found it. It does not necessarily apply to any other species of Pacific salmon. That quite the opposite is true for the coho is shown in another paper being published, and it remains to be seen what is the nature of the application in other species.

## SUMMARY.

The growth of the scale in the spring salmon is a good indication of the growth of the fish. Annual bands of growth appear on the scale, each consisting of a wide portion with the lines on it somewhat distant, and a narrow portion with the lines closer together. The narrow band may be called the "winter check" appropriately, because, although the retardation of growth is due to a lack of food rather than to a lowering of the temperature, it is produced in the winter months, January, February, and March, with indications of it in December and April.

There are two types of scales, since some of the salmon migrate to the sea as fry and have no fresh-water record on their scales, while others migrate as yearlings or fingerlings after having a year of comparatively slow growth on the fresh water clearly indicated on the scales.

The majority of both types mature in their fourth or fifth years; probably a greater percentage of the "sea type" than of the "stream type" mature in the fourth year, but a majority of the whole number are of the "sea type." The fish that mature in the fourth year are, as a rule, among the larger of the year-class. Possibly if enough third-year grilse were examined there would be proof that they are among the largest of the year-class.

The "sea type" fish has a decided advantage throughout life, both in length and in weight, so much so that an average fish of the "stream type", mature in the fifth year, is scarcely larger than a "sea type" fish mature in the fourth year. If they are both in the same year when mature, either the fourth or fifth, there is an average difference of 6 or 7 pounds. Unless there is some other preponderating reason for

keeping spring salmon in rearing ponds for a year, it is decidedly unwise to do so, as, taking it either in size or in time, there must be a handicap of at least 20 or 25 per cent. in favour of the "sea-type" fish.

## EXPLANATION OF PLATES.

### PLATE I.

FIG. 1. Scale of spring salmon in third year showing summer growth at the margin, caught June 6.

" 2. Scale of spring salmon near the end of the third year showing winter check at margin, caught February 16.

" 3. Scale of spring salmon in second year showing winter check starting at margin, caught November 27.

" 4. Scale of spring salmon in second year with winter check just starting at margin, caught January 5.

### PLATE II.

" 5. Scale of spring salmon at the beginning of the fourth year with summer growth starting at the margin, caught March 17.

" 6. Scale of spring salmon at the beginning of the third year with summer growth well begun at the margin, caught April 5.

" 7. Scale of spring salmon at the beginning of the third year with no summer growth showing at the margin, caught April 13.

" 8. Scale of spring salmon at the beginning of the third year with no summer growth showing at the margin, caught April 22.

" 9. Scale of spring salmon in the third year, regenerated in the fall of the second year and showing the second winter check.

### PLATE III.

" 10. Scale of spring salmon in third year with a check showing at the margin during summer growth, caught July 26.

" 11. Centre of scale of spring salmon of "stream type" in fourth year, in which migration took place immediately after winter check.

### PLATE IV.

" 12. Centre of scale of spring salmon of "stream type" in second year, showing fresh water growth after the first winter check.

" 13. Centre of scale of spring salmon of "sea type" in second year.

### GRAPHS.

" 14. A curve to show percentage for each half month of the total growth for the year. A curve to show at the end of each half month, the percentage of the whole growth of the year attained. A curve (interrupted) showing the annual variation of the temperature of the surface water.

" 15. A curve showing ratio of weight to length.

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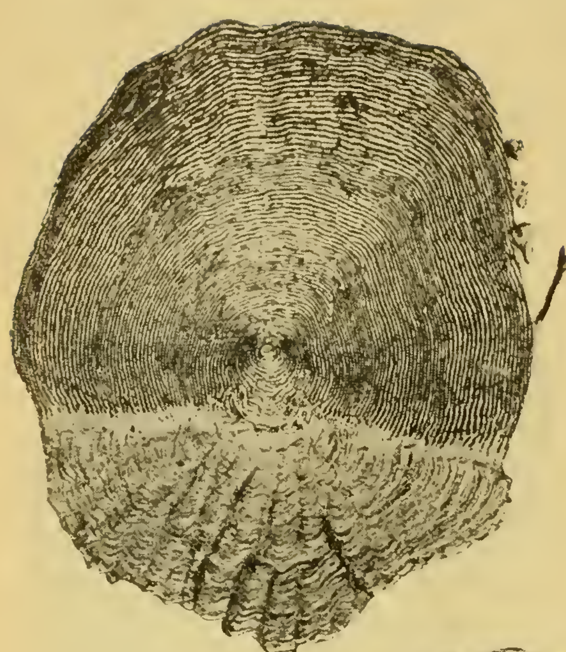
Spring Salmon.



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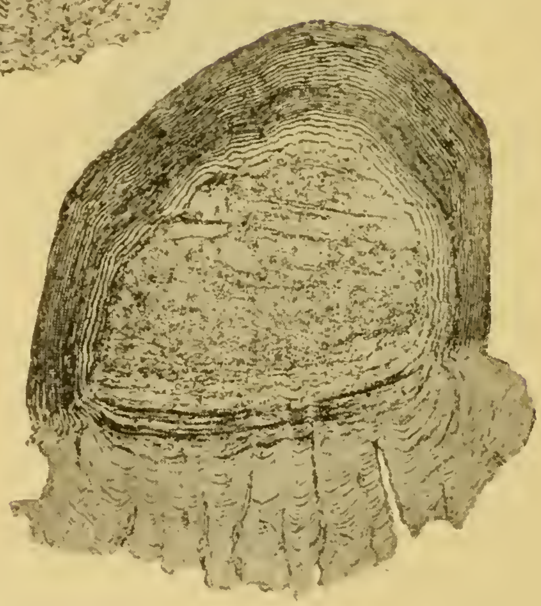


9

Spring Salmon.

10

11

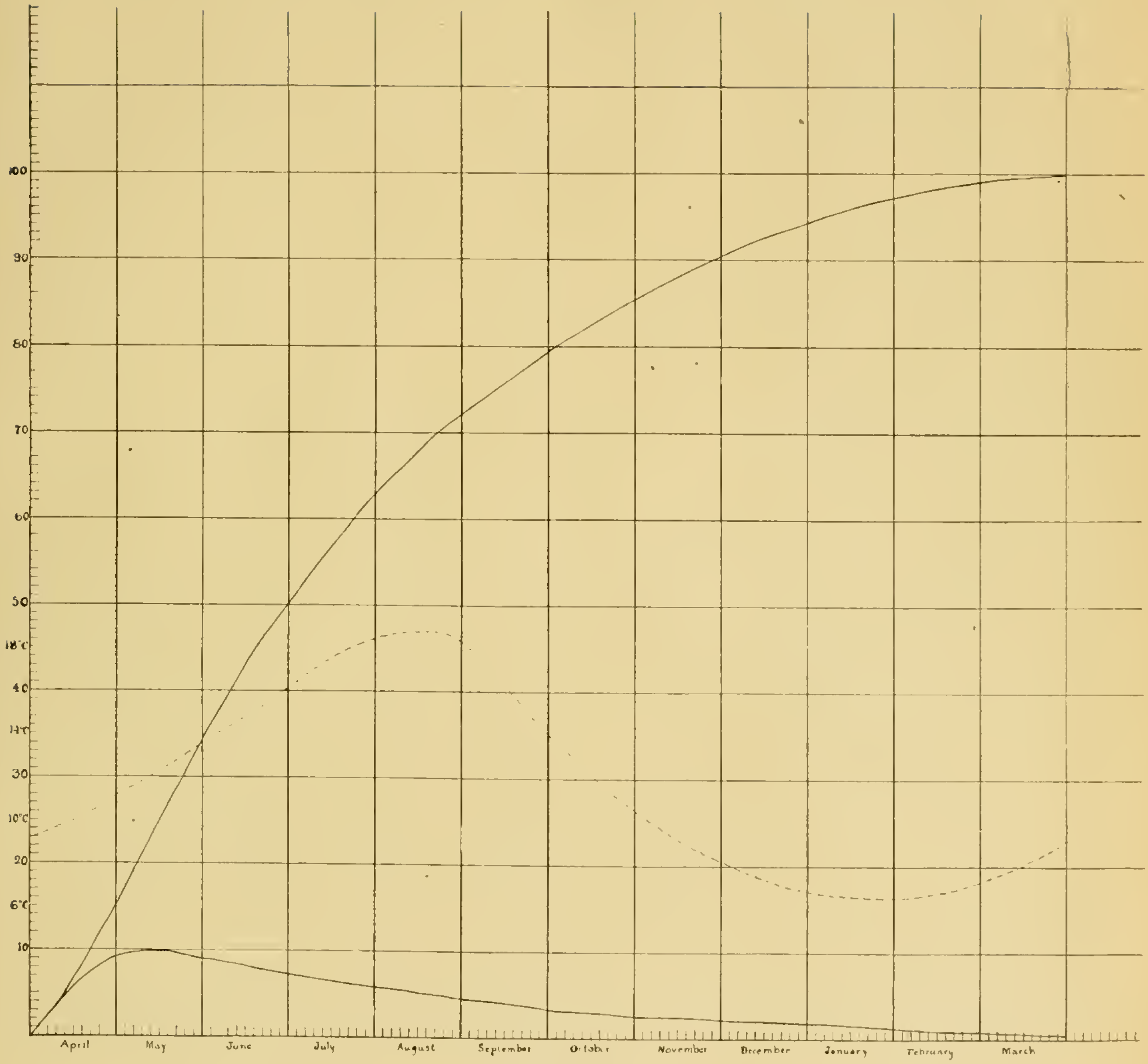
Spring Salmon.

12

13

Spring Salmon.

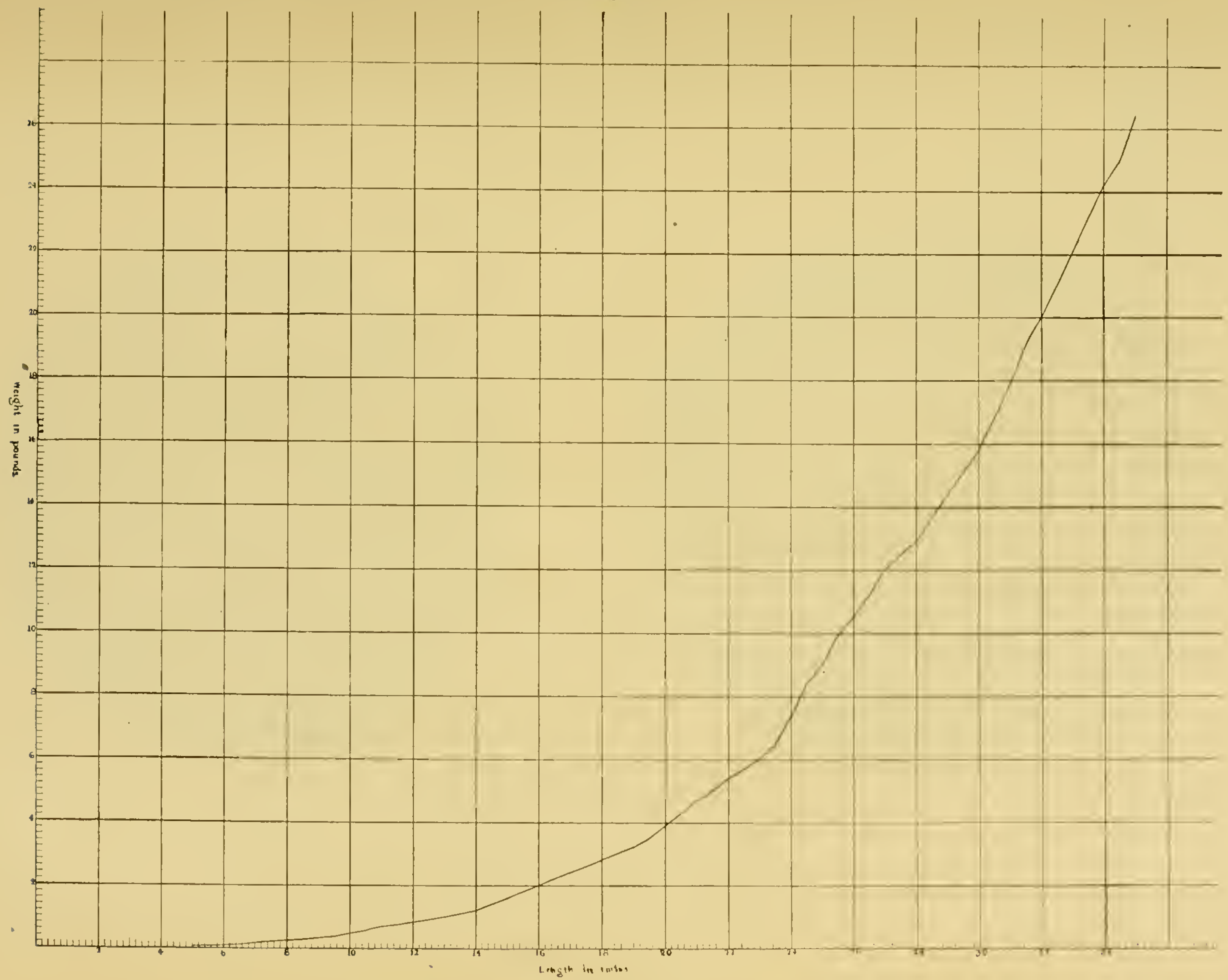
Fig. 14.




Spring Salmon.

A curve to show percentage for each half month of the total growth for the year. A curve to show at the end of each half month, the percentage of the whole growth of the year attained. A curve (interrupted) showing the annual variation of the temperature of the surface water.

Fig. 15.




Spring Salmon. A curve showing ratio of weight to length.

# ON THE LIFE-HISTORY OF THE COHO.

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(With Plates V, VI, and VII (7 figures), and figures (Graphs) 8, 9, 10, 11, 12, 13.

The sockeye and the spring salmon, among the Pacific species, have received the monopoly of attention of investigators ever since the salmon trade became an important one on the Pacific coast, and naturally so, because these two species have been so important, commercially. In more recent years, on account of the scarcity of these at times, especially in certain localities, the other species have come more into prominence. The coho or silver salmon is now quite an important factor in the output of the canneries. In the cannery statements compiled for the Pacific Fisherman Year Books it is shown that there has been a gradual though rapid increase in the coho pack in British Columbia until, for the year 1915, it amounted to 13 per cent of the whole output. It does not show as large a percentage for that year for the whole coast, but in 1912, when the sockeye pack was very low, it reached an amount over 10 per cent of the pack for the year. Besides those that are canned, an increasing number is being put in cold storage. As the importance of the coho is thus rapidly increasing it seemed worth while to take advantage of a situation somewhat favourable for learning something of the life-history of the species.

Some work has already been done on the coho. It has been considered, along with other species, in papers on the Pacific salmon, in several papers by McMurrich and one by Gilbert. These deal largely with the age at maturity of the species. Some of the points touched on in these papers will be considered in connection with others that heretofore have not received special attention.

The favourable conditions referred to are these: Coho spawn in a small creek that flows into the head of Departure bay, and in this creek, at all times of the year, the young coho may be seen. A locality for observation is thus very conveniently situated. After they have migrated, some of them must remain in the strait of Georgia throughout their lives in salt water, and possibly they all do, as they may be caught with hand lines throughout the greater part of the year. Various stages have been obtained from hand line fishermen in Departure bay. Through the kindness of Messrs. Broder, a large number of specimens of mature fish, a good representative lot for the strait, was examined at the cannery at Nanaimo. To compare with these, through the kindness of Manager Crawford, of the Neah Bay cannery, I was able to get a number from the open ocean.

In the creek at Departure bay the mature coho appear about the middle of November. As the spawning beds are but a short distance up the stream, not more than a mile, they are soon reached, and the spawning is over by the end of the month. At the Cowichan Lake hatchery, where, until this season, the greatest number of cohos in the province were hatched, the first eggs were taken about November 10, but the spawning season lasts for a considerable time, as even after the first of February there are unspawned fish in the streams of the neighbourhood.

The eggs hatch in three months, or slightly less, but the alevins remain buried in the coarse sand or fine gravel at some distance below the surface for some time. On March 7 not one could be seen in the creek, although the last year's fry were plentiful. On April 10 the alevins were plentiful, and by April 14 a few of them had the yolk all absorbed. They gradually work down stream and even into the brackish water. By May 6 many of them were near the mouth of the stream, but I have never seen any of them out in the bay, or anything to indicate that they ever get out into the bay during the first year. Relatively, those in the creek at any one time vary much in length. On April 14 a catch of alevins and fry varied from 30 to 39 mm. Of nineteen caught on June 29 there were the following lengths: 33, 36 (2), 37, 39, 41, 42 (2), 43 (3), 44 (2), 54, 58, 60 (2). On November 19 there was variation from 49 to 61; on March 7, from 52 to 67, with a single very small one only 42 mm. Some of them migrate to the sea as early as March, at which time they are a year hatched, but others linger in the fresh water much longer. I have seen none later than June 29, but on that date two were caught, 76 and 60 mm., and others were seen in the creek. None of them, however, remain throughout the whole second year. Evidence that this is true elsewhere will be referred to later, when the age question is considered more at length.

During the first months after migration the yearlings are seldom observed; they are too small to be retained in the meshes of the gill-nets, seines, or traps, and too small also to be attracted by the spoon that is used in catching larger fish. They grow very rapidly, and in October an occasional one is caught with the hook and line. They are now 10 to 12 inches long, each weighing 12 to 14 ounces. They do not appear in sufficient numbers to attract attention until the spring, when they are just over two years old. In the latter half of April, the schizopods become so plentiful near the surface of the water at certain times of the day that large areas become noticeably pink. As the cohos have a decided preference for small crustaceans, they appear in great numbers to gorge themselves on these schizopods. The crustaceans are almost at the surface, and the young coho may be seen in all directions, jumping out of the water. They take the spoon readily at this time but, apparently, not because they are hungry, as they may be taken with their stomachs much distended with the pink food made up of thousands of these individuals. Locally, at this time, they are called "bluebacks," but this term is used in so many different senses, as several common names are, that it is scarcely wise to mention the fact lest it give a wrong impression. At the same time, or somewhat later, the young herring are little larger than the schizopods, and they also provide excellent food material. Probably at no other time in the life of the coho is there such a superabundance of good food available, and in consequence the rate of growth is rather startling. Fish that weigh 1½ to 2½ pounds at the middle of April, will weigh 3 to 5 or even 5½ pounds by the middle of June, i.e., doubling the weight in two months. The length, which was from 14 to 19 inches in April, now runs from 18 to 23 inches. From this time on an occasional fish is caught in the vicinity of Nanaimo, but the real season for mature coho does not start until on in September. In other parts of the province it starts earlier than this. At several points from Alert bay to Prince Rupert a good catch was made last year before the end of August. These mature fish, now two years and seven or eight months old, vary much in length and weight. In the length, a variation from 18 to 31 inches has been observed, and in weight from 3¾ to 16½ pounds. They are now on the way to the streams to spawn, and their life-cycle is soon completed.

As to the food of the coho, from the time that the yolk is absorbed until maturity, there seems to be a decided preference for an insect and crustacean diet. When this is not available, reliance has to be placed on fish. In the nearby creek, as soon as the alevins work their way out of the gravel of the spawning bed, they move away from it down stream. By the time the yolk is all absorbed they are well distributed throughout the length of the stream, and not too much crowded in any one place. In consequence there probably is a supply of insect larvæ for all. Beside the coho, the only fish in the creek is the cut-throat trout, with an occasional small sculpin or fresh-water bullhead. The cut-throat of the same year is not hatched for some time after the coho appears, and those of the preceding year are large enough to look after themselves. The young fry, therefore, have no fish as small as themselves to attack, and hence insect larvæ, with a few fresh-water crustacea must supply the demand. It is possible that those earlier hatched may attack those later hatched and that both may attack the cut-throat fry when they come out, but by this time they must have attained greater size. It is possible, too, that the yearling coho attack the fry, and the cut-throat a year or more old may do so also, as all the Salmonidæ eat fish when other food is not available, if not at other times. In this creek the cohos and the trout seem to live in harmony, as both are commonly found in the same small group.

It is a fact that when large numbers of fry are put out in the creeks from the hatchery that the older ones may be seen devouring the younger ones, but in such cases thousands, sometimes hundreds of thousands, are put out in the one creek within comparatively narrow limits so that before they become well distributed insect food must be at a premium. As the younger fry offer the only food for the older ones, very hungry by this time, they are devoured. If there are trout in the same stream they probably assist in the operation.

The statement that coho remain in the rivers for two or three years feeding on the trout is evidently absurd. In the first place, the coho does not live to be three years old, or at least there has been no evidence adduced that it does. In the second place, there is a similar lack of evidence that any of them remain in fresh water for two years. Furthermore, as the yearling coho is seldom more than 5 inches long when it migrates, and more often is considerably short of that, the injury done to the trout by it must be very much exaggerated. In reality the coho has a much stronger case against the trout, the steelhead, the cut-throat and dolly varden or char. These fish follow the coho to the spawning beds and devour so many of the eggs as soon as they are spawned that the possible number of coho fry is at once very much reduced. No matter how often the male coho turns to chase them, they follow him back, as soon as he turns, to gorge themselves once more. After the eggs are hatched the fry are attacked, and it is there that the dolly varden does the most damage. It is the general opinion of observers all the way from the Aleutian islands to California that the dolly varden does more harm to the salmon fry than any other agency, and many will go so far as to say that it does more harm than all the other agencies put together. Therefore, instead of protecting the dolly varden by a close season, it would be very much better for the salmon fisheries if everything possible were done to reduce their numbers. The case against the other trout is not so strong, but as they remain in the fresh water for a much greater portion of their lives than the coho, the balance of destruction is probably in their favour.

The food of the coho in the sea has been indicated. Pelagic crustacea form the bulk of it. Schizopods predominate if the whole year is considered but, at certain times, larval barnacles and larval decapods form an important portion. Of the fish used, reference has been made to the small herring fry. The older fry and even the herring a year or more old are eaten later in the season. Apparently they have preference over other fish. Salmon fry, sand launces and capelin are the only other fish that have to be observed. For a short period about October the 1st the capelin are taken in large numbers as they come inshore to spawn.

The mature fish feed actively until they come to the mouth of the streams up which they go to spawn, or possibly until they enter these streams. Consequently, they must increase in weight almost until spawning time.

The general rate of growth has been considered and some remarks made about the age of the coho. A more complete analysis of the relation of growth to age, depending on the examination of scales, will now follow. The method of growth determination used is the same as that used in a prior paper on the life history of the spring salmon. In general, the winter checks show up more plainly in this species than in the spring salmon, so that there is seldom any difficulty in making out their delimitation.

The scale appears first as a small, flat, almost circular body, which becomes the nucleus of the growing scale. At that stage of the appearance of this nucleus the fry is from 31 to 34 mm. long (in all measurements in this paper the length does not include the caudal fin rays), with an average of 32·5 mm. It is this size about the end of May or early in June. The rings then begin to form. From ten to fourteen appear in the first set; these gradually get closer together, although they are not very far apart at first. The last two or three may be dim, broken, and generally indistinct. They indicate the first winter check. At the time these are formed the food supply is at its lowest ebb, so that very little growth is taking place. In March or early in April the food supply becomes more abundant and the distance between the rings increases, showing more rapid growth, somewhat similar to that near the nucleus. At migration a decided increase takes place abruptly, due to the better supply of food in the salt water. It may be that the fresh water band for the beginning of the second year is entirely absent as some of the yearlings pass down to the sea too early to show spring growth in fresh water. More commonly the band is present, varying in width with the length of time before migration takes place.

Chamberlain[1] has reported that, in Alaska, a greater number of coho pass to the sea as fry than as yearlings. The evidence available for this region indicates a condition far otherwise. Out of nearly 400 examined for the purpose of this research, only three showed indication of going to the sea as fry. These three were among those obtained at Neah bay on October 26. During the remainder of the summer the rings are formed as usual for salmon growth in the sea. The winter check follows and then the growth during the third summer, with the rings getting somewhat closer late in the fall when the fish goes up the stream to spawn.

The scales of the three that went to the salt water as fry have the first-year growth in the nature of a broad band of distant rings next to the nucleus, followed by a winter check, the whole width of the band being similar to that of the second year. Since the first year shows no fresh-water growth, the second does not either, and the third year is similar to that in other scales.

Even in the largest fish obtained there was no indication that the third year had been completed. As no one has recorded a fourth year specimen, if there are any such, they must be rare.

The analysis of the results of examining the scales of nearly 400 fish, of which 301 were in the third year, gives an admirable basis for comparing the rate of growth in the different years and in the different fish. As the fry is, on the average, 1·3 inch long when the nucleus is developed, that amount has been taken from the total length in inches in each case and the remainder divided as the scale is divided by the winter checks. Then 1·3 inch is added to the first year value to obtain the length at the end of the first year. In these scales, the growth of the fresh-water portion of the second year was calculated also.

In the whole number of fish in the third year, the least growth at the end of the first year was 2·4 inches and the greatest 4·1, with an average of 3·3. (All of the yearlings caught in the stream in early spring came between these same extremes.) The frequency curve to represent this is a fairly regular one, showing the greatest number at a length of 3·2, although nearly as many at 3·4 and 3·6. The growth for the second year varies from 7·5 to 14·4, with an average of 11·1. The greatest number came at 10·7 and 11·6. Although the base of the curve is much more spread out than in the first-year curve, the regularity is much the same. The length at the end

[1] Chamberlain, F. M. Observations on salmon and trout in Alaska. Bureau of Fisheries Document No. 627, 1907.

of the second year varies from 11·1 to 18·1, with an average of 14·3. The highest point of the curve is reached with 13·5, but there are several others nearly as high. That, in general, the yearlings that have the best start tend to keep it up, is shown by the fact that the average of the length at the end of the first year, added to the average growth in the second year, gives exactly the length at the end of the second year. For the growth in the third year, only those caught after September 15 are considered. Since there is such rapid growth during the third summer, a fair comparison could not be made of all those caught during the year. Apart from an abnormally small growth, 4·0, and an abnormally large one, 14·2, the growth for the portion of the third year varies from 6·1 to 13·5 inches, with an average of 9·7; 10·0 has the highest point on the curve, with 9·5 and 10·6 nearly approaching it. The total length at time of catching of these same third-year specimens varies from 18·0 to 31·0 inches, with an average of 24·0. The highest point on the curve is taken by 23·0, but 22·0 and 23·5 nearly equal it. As the frequency curve here is made from half-inch measurements while the others are in tenths, they are not exactly comparable. Here again the average length is equal to the sum of the average growth in the three periods, 3·3 + 11·0 + 9·7 = 24·0, and the length at the end of the three years is 3·3, 14·3, and 24·0, respectively.

The fish that went to sea as fry were not sufficiently numerous to serve as a basis for definite conclusions. The measurements were as follows:—

| | | | | | | |
|---|---|---|---|---|---|---|
| 1. | At end of 1st year, | 9·6; | 2nd year, | 16·4; | 3rd year, | 24·0 |
| 2. | " " | 11·0 | " | 19·4 | " | 25·0 |
| 3. | " " | 11·4 | " | 21·5 | " | 28·0 |
| Average | " " | 10·7 | " | 19·1 | " | 25·7 |

There is no very appreciable difference between the length of the males and the females. The averages are:—

| | | | | | | |
|---|---|---|---|---|---|---|
| Males | —At end of 1st year, | 3·3; | 2nd year, | 14·5; | 3rd year, | 24·1 |
| Females— | " " | 3·3 | " | 14·2 | " | 24·0 |

There is more difference between the average lengths of those caught at Neah bay and those caught in the strait of Georgia.

| | | | | | | |
|---|---|---|---|---|---|---|
| Strait of Georgia | —At end of 1st year, | 3·3; | 2nd year, | 14·1; | 3rd year, | 23·7 |
| Neah Bay | — " " | 3·6 | " | 15·5 | " | 25·6 |

If the difference was in the third year only, it might be accounted for partly by the fact that those from Neah bay were caught a little later in the year than the majority of those taken in the strait of Georgia, but the difference is relatively as great at the end of the second year, and is noticeable even at the end of the first year. It might be that since all of the Neah Bay specimens were from the same lot, that was an early spawned lot and they were able to keep up the initial advantage. To keep up the advantage it would be necessary to have the proper supply of food in any case and probably the food supply is better at the entrance to the strait of Fuca or somewhere in that vicinity than it is in the strait of Georgia. This is borne out in the comparison of weights, a matter which is taken up later.

The length at the time of migration varied from 2·8 to 6·6 inches, with an average of 4·5. Out of the whole number only eight were over 6·0 inches, and only twenty-two were over 5·5. The greatest number were at 4·6. Various calculations were made to see if the fish were ultimately smaller on account of the longer time spent in the fresh water at the beginning of the second year, but no constant difference could be found even in the growth for the second year. The time of hatching, and consequently the length at the end of the first year, seems to have more to do with the total growth and the second year's growth than the length of time spent in the fresh water during the second year. Possibly if a greater number were examined, some difference might be shown.

Going on the supposition that the fish that were first hatched during the season would, in general, have the greatest growth to the end of the first winter check, they were divided into three groups according to their lengths at that time. The first group included all those that were 3·0 inches or less at the end of the first winter check; the second included those that were over 3·0 inches and up to 3·5 inches; the third included those over 3·5 inches. The average growth in each case was as follows:—

| | | |
|---|---|---|
| 1st group—At end of 2nd year, | 14·0; | when caught, 23·6 |
| 2nd " " " | 14·1 | " 23·7 |
| 3rd " " " | 14·9 | " 25·0 |

The difference indicates that the fish that are the largest at the end of the first year, and hence probably those that were hatched out earliest, have an advantage that tends for greater growth throughout life.

When the weight of the fish was compared with the length, it was found that there was a very definite ratio between length and weight. The youngest fish of which the weights were taken, or which enough weights were taken to make a comparison possible, were those slightly over two years old, taken in April. From these the following table was obtained:—

| Length. | Weight. Lb. | Oz. |
|---|---|---|
| 14·75 | 1 | 8 |
| 15· | 1 | 11 |
| 15·25 | 1 | 12 |
| 15·5 | 1 | 14 |
| 15·75 | 2 | 2 |
| 16· | | |
| 16·25 | 2 | 0 |
| 16·5 | 2 | 4 |
| 16·75 | 2 | 6 |
| 17·25 | 2 | 8 |
| 18· | 3 | 0 |
| 18·5 | 3 | 4 |
| 19· | 3 | 8 |
| 19·5 | 3 | 12 |

In some cases there was but one specimen of the particular length, hence some irregularity is shown. This would probably be eliminated if there were several of that length from which to take an average.

In comparing the weights of the mature fish, the males and females were taken separately, and those from Neah bay were separated from the others.

In the table which follows there is some irregularity, as in the preceding table, due to the small number of specimens for certain lengths, more particularly towards the extremes of length, but even with these figures it is possible to see the definite relation between length and weight. There is very little difference between the weight of the male and the female for the same length. What difference there is, is in favour of the female. In comparing the Nanaimo fish with those from Neah bay, the latter have what little advantage there is. In both Nanaimo and Neah bay material, the males are at the head of the list for size, taking the whole size of the individual fish.

| Length. | Weight. | | | |
|---|---|---|---|---|
| | Nanaimo. | | Neah Bay. | |
| | Male. | Female. | Male. | Female. |
| In. | Lbs. | Lbs. | Lbs. | Lbs. |
| 18·5 | ........ | 3·75 | 3·75 | |
| 19· | 3·75 | .......... | .......... | |
| 19·5 | 4· | .......... | .......... | |
| 20· | .......... | 4·25 | .......... | |
| 20·5 | 4·75 | .......... | .......... | |
| 21· | 4·625 | 4·75 | 5·5 | |
| 21·5 | 4·875 | 5· | .......... | |
| 22· | 5·25 | 5·25 | .......... | |
| 22·5 | 5·5 | 5·75 | 6·5 | 5·75 |
| 23· | 5·875 | 6· | .......... | 7·5 |
| 23·5 | 6·375 | 6·375 | .......... | 7·5 |
| 24· | 6·5 | 6·75 | 7·25 | 8·5 |
| 24·5 | 6·625 | 7· | 7·5 | 8· |
| 25· | 7· | 7·25 | 8· | 8·25 |
| 25·5 | 8· | 8· | .......... | 10·25 |
| 26· | 8·25 | 8·375 | 9· | 9·25 |
| 26·5 | 9· | 9·25 | 9·5 | 10· |
| 27· | .......... | 9·5 | .......... | 11·25 |
| 27·5 | .......... | 10· | 11·5 | 11·5 |
| 28· | 9·75 | 11·5 | 11·5 | 11·75 |
| 28·5 | .......... | 12· | 12· | |
| 29· | .......... | 12·75 | 15· | |
| 29·5 | .......... | 13· | 13· | |
| 30· | 13·75 | .......... | .......... | |
| 30·5 | 16·5 | .......... | .......... | |
| 31· | 13· | .......... | .......... | |

SUMMARY.

The coho, which is mature in its third year, spends the entire first year, with but very few exceptions, in the Vancouver Island region, in the fresh water. Some of them migrate about the time the first year is completed, but others remain later, even until well on in the summer. There is no indication that any remain in fresh water to complete the second year. The scale shows a distinct winter check in the fresh water growth and another in the sea growth.

The average length is 3·3 inches at the end of the first year, 14·3 inches at the end of the second year, and 24·0 inches when caught in the fall of the third year.

There is an indication that the fish that are largest at the end of the first year become the largest mature fish. Although some of the yearlings stay in the fresh water longer than others, it was not apparent that this made any special difference in the ultimate size of the fish.

There is a definite ratio between length and weight. In the mature fish, the females weigh slightly more than the males of the same length.

In connection with artificial propagation, as large a portion as possible for the season's hatching should be procured from the early spawning fish that the fry may be larger at the end of the first year and consequently larger as mature fish.

No species of Pacific salmon should get more benefit from rearing ponds than the coho, as almost the whole of the fry remain in the fresh water for a year in any case, and very few naturally get the benefit of accelerated growth in the salt water in the first year.

From the standpoint of economy, the waste caused by early fishing can readily be appreciated when the great percentage increase in weight during the summer months of the third year is taken into account.

# EXPLANATION OF PLATES.

## Plate V.

Fig. 1. Coho scales in early stage of development.
" 2. Scale from a coho in the fall of the second year.
" 3. Scale from a coho in the spring of the third year.

## Plate VI.

Fig. 4. Scale of mature fiish in fall of third year.
" 5. Centre of scale more highly magnified to show winter check in fresh water growth.

## Plate VII.

Fig. 6. Scale of coho that migrated as fry.
" 7. Centre of previous scale more highly magnified.

## Graphs.

Fig. 8. Frequency curve for first-year growth.
" 9. " " second-year growth.
" 10. " " third-year growth.
" 11. " " length at the end of the second year.
" 12. " " length of mature fish.
" 13. " " amount of growth in fresh water.

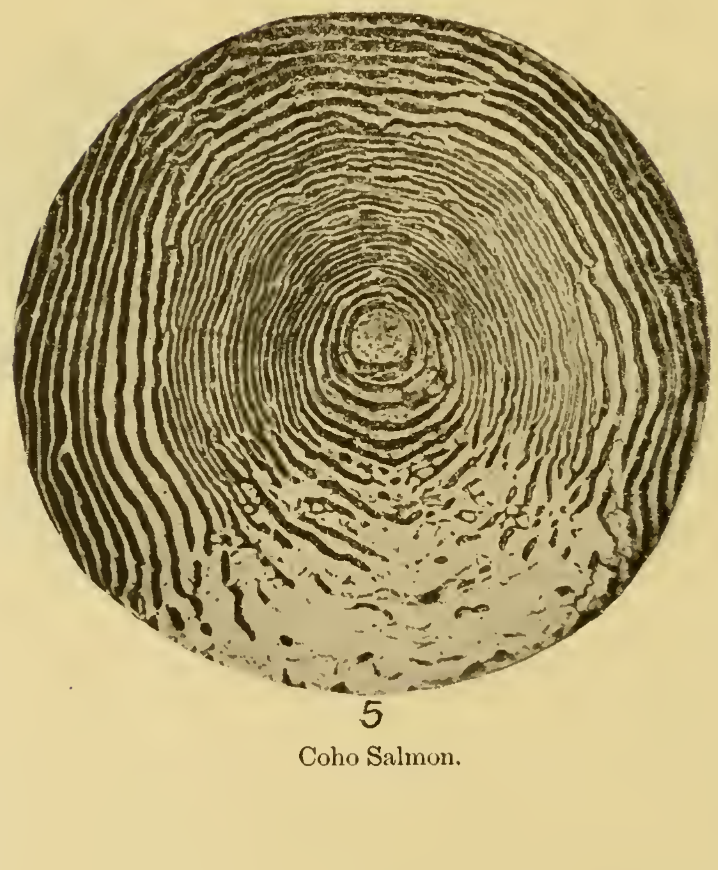
1

2

3

Coho Salmon.

4



5

Coho Salmon.

6

7

Coho Salmon.

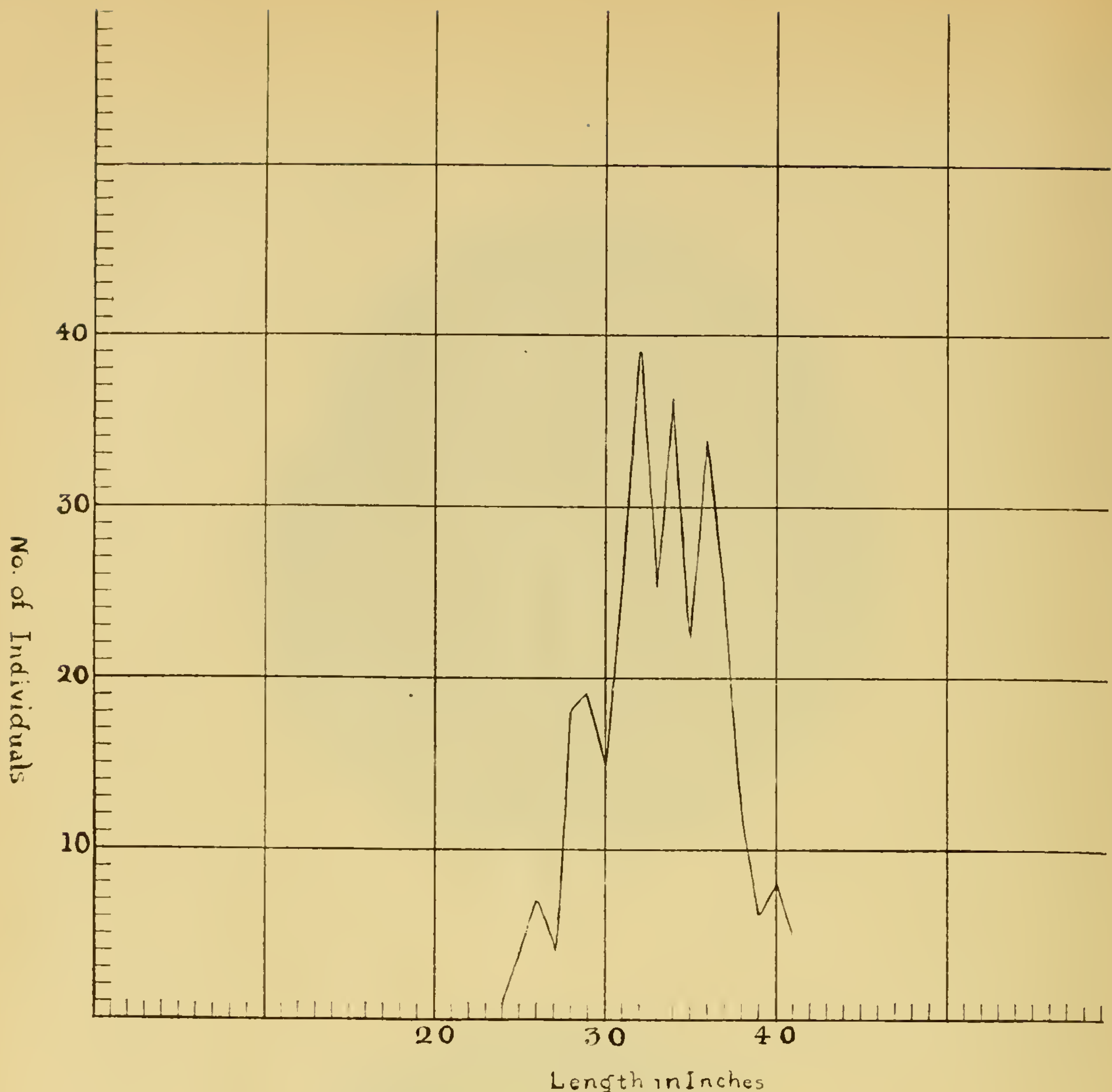



Fig. 8. Coho. Frequency curve for first-year growth.

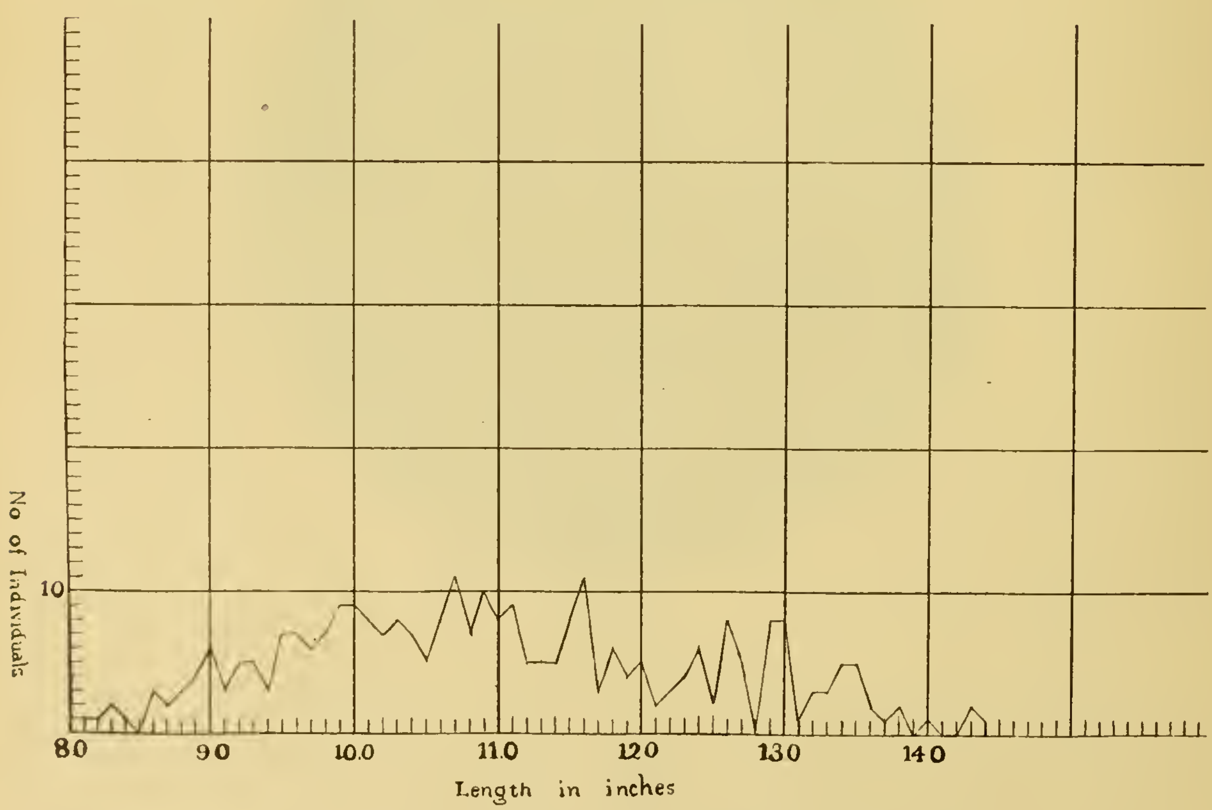



Fig. 9. Coho. Frequency curve for second-year growth.

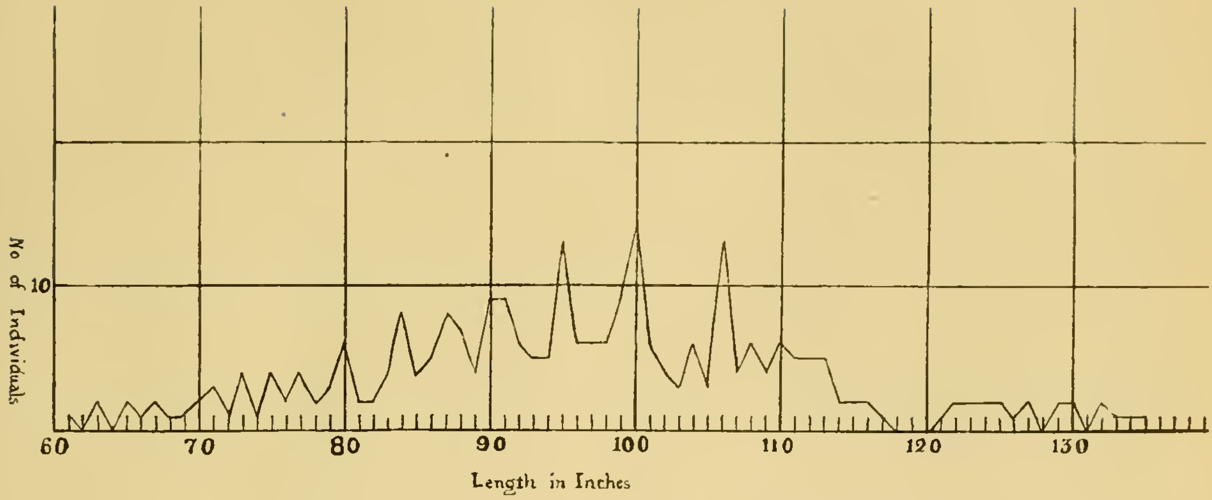



Fig. 10. Coho. Frequency curve for third-year growth.

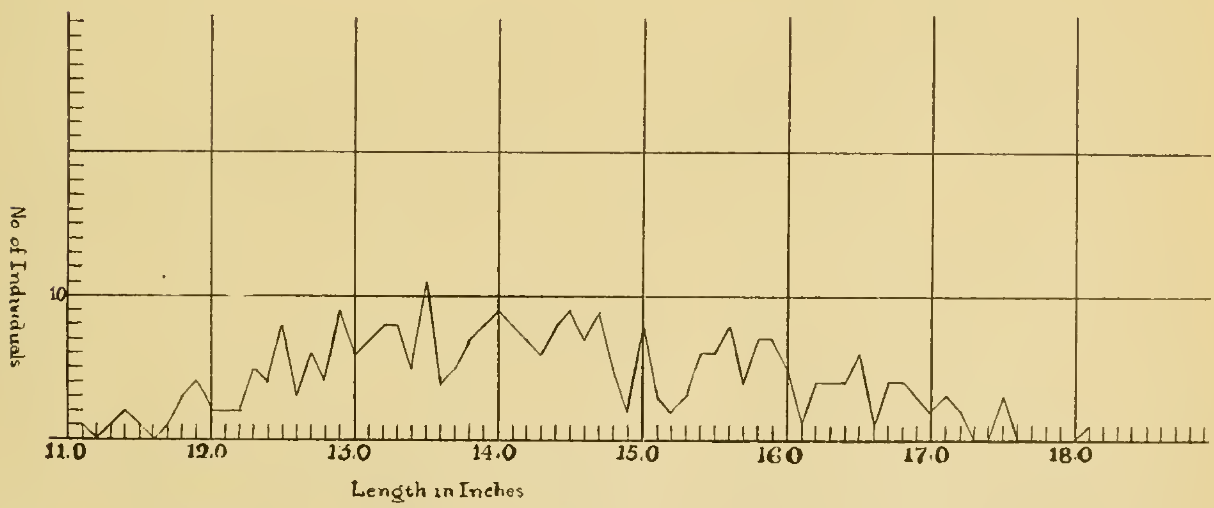



Fig. 11. Coho. Frequency curve for length at the end of the second year.

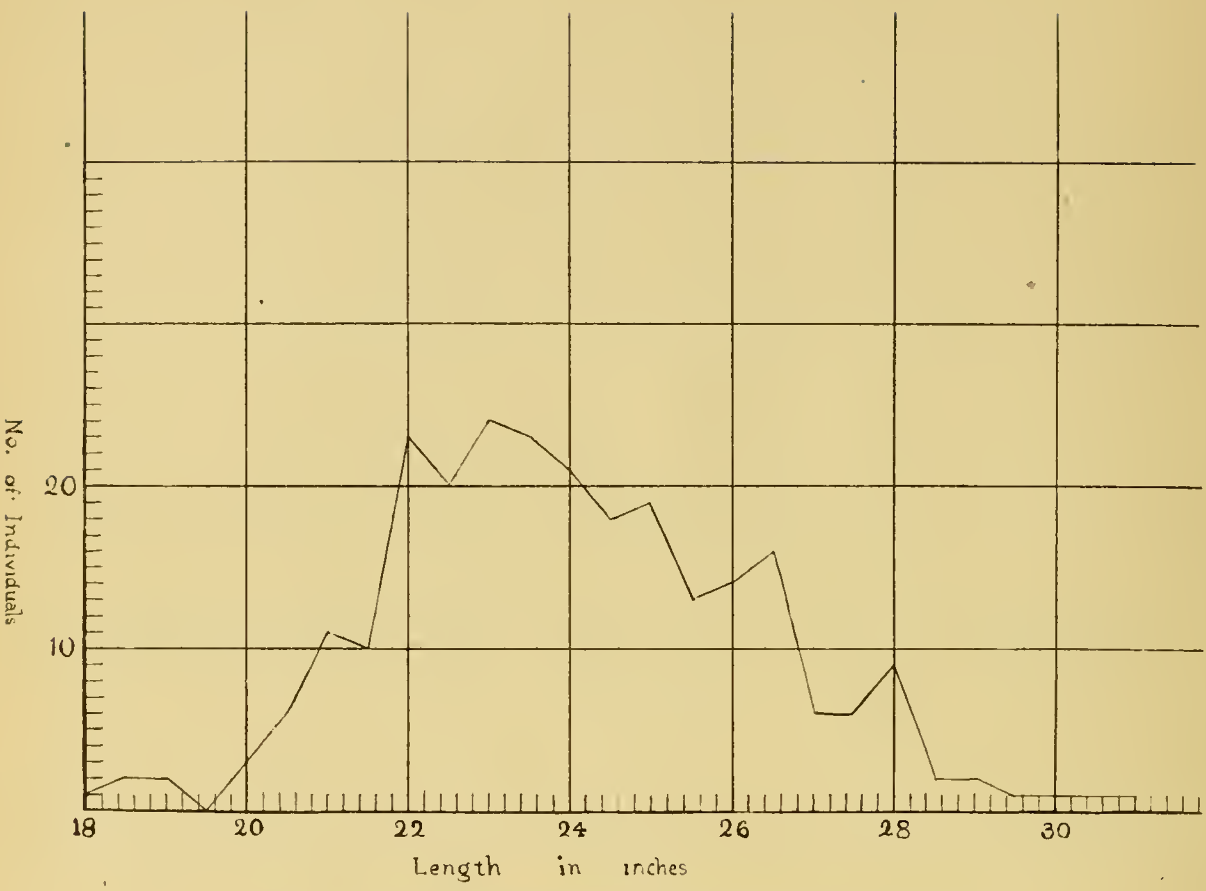



Fig. 12. Coho. Frequency curve for length of mature fish.

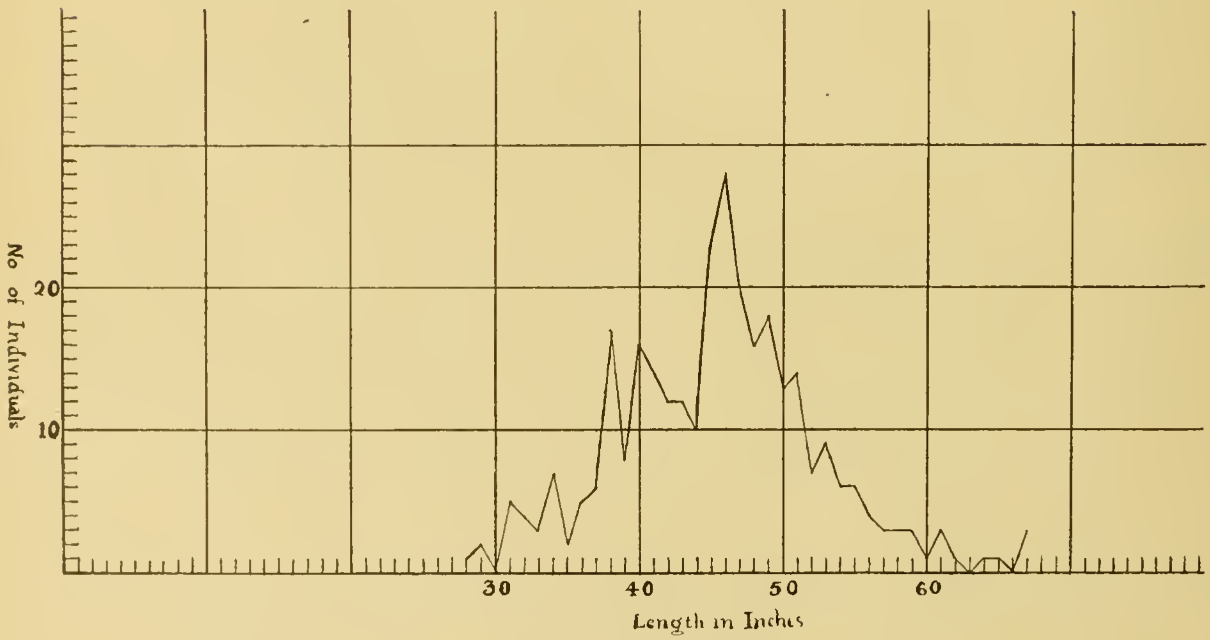



Fig. 13. Coho. Frequency curve for amount of growth in fresh water.

# AN INVESTIGATION OF OYSTER PROPAGATION IN RICHMOND BAY, P.E.I., DURING 1915.

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At the request of the Biological Board of Canada, the writer, during August, 1915, turned aside from his oyster studies in New Jersey waters to investigate the oyster situation in Richmond bay, Prince Edward Island. A study of a region so remote from a locality hitherto familiar, gave promise of furnishing data that would help in distinguishing between local and "essential" influences in oyster propagation.

The ultimate object of these studies is the promotion of the oyster industry, both as a fishery and as oyster culture. It is an effort to conserve and to increase food resources, creditable alike in those who investigate, those who direct, and all who in any way encourage such researches.

## PART I.—GENERAL PRINCIPLES OF OYSTER CONSERVATION AS APPLICABLE TO CANADA.

The oyster-bearing waters of Eastern Canada are practically confined to those bays of the gulf of St. Lawrence that indent the coast of Prince Edward Island, and the adjacent shores to the south and west, viz., Cape Breton and the province of New Brunswick. Farther south, the coast is now practically barren of living oyster beds for a thousand miles, i.e., along southwestern Nova Scotia, the bay of Fundy, and the gulf of Maine practically in its entire extent to Cape Cod. That this coast was once prolific in oysters, though more sporadically than further south, is shown by the existence of oyster reefs recently fossilized, of ancient shell-heaps and by the traditions of colonial and more recent history. It is of both practical and theoretical interest to ask, "What caused the extinction of these oyster beds?" On the true answer to this question hangs our conclusion as to the fate of the Canadian oyster industry.

One of the older[1] answers to this question assigned the cause of extinction of oyster beds along these northern coasts, to the gradual rising (geologically) of the shores, thus finally bringing the oysters so near to the surface that they were killed by wintry frosts and ice. It may be surmised that, if this process continued, the utter extinction of the Canadian oyster beds might be the ultimate outcome. It appears, however, that the coast is actually sinking; but the oyster reefs have been growing upward somewhat faster having attained a thickness of over 20 feet and have reached as near to the surface as possible. If proximity to the surface limits the growth of an oyster bed, the sinking of the coast has tended to prolong the life of the bed. It is difficult to see how either of these conditions can extinguish the life on an oyster bed, since a limit of height is ultimately attained, where there is a balance between recuperative and destructive forces. Everywhere, the tendency of oyster beds is to grow as high as possible. In the south, the oyster reefs are exposed at low tide; the oysters cannot feed while uncovered, yet the oysters are not starved out. But if the coast should rise, the living surface of such reefs would be killed, while the oysters at the edges would gradually spread into deeper water. On the other hand, the sinking of the bottom would be highly favourable to oyster growth, provided that temperature and salinity conditions

1 Ingersoll's Report on the Oyster Industry, 1882, Tenth Census of U. S., p. 35.

were not utterly transformed so as to pass beyond favourable limits. If the northern coast has been sinking, it is possible that this has permitted cold arctic currents to enter some of the bays, or to influence the adjacent water that enters on the tides, so that the temperature necessary for summer propagation (68° F.) is not attained. The extensive shallow flats of Richmond bay and other noted oyster-producing bays of the gulf of St. Lawrence offer the conditions favourable to the warming of the water to the point needed for propagation.

As regards salinity, we know that oysters flourish best when situated where there is a tidal increase and decrease in the salinity of the water: but oysters do grow in waters of very different degrees of saltness, and also in places where there is remarkable uniformity in density. While too much emphasis has been laid on this factor, yet it remains highly desirable that further study be made of the relation of salinity to oyster feeding; but temperature, oxygen, and currents are of much greater significance in oyster growth and propagation.

A study of the temperature of the waters where oysters are now extinct would discover the cause of their extinction. From the tables of temperature[1] determined by Professor Copeland for Passamaquoddy bay, it is evident that oysters can not propagate in those waters; but there is less evidence that oysters flourished there in early times than for some of the bays of Maine. Even in Prince Edward Island there are fossil oyster beds in the vicinity of living beds; thus we conclude that there must be also other causes for the extinction of oyster life.

In respect to frost, it is remarkable to what extent oysters survive exposure to freezing, when partially imbedded in mud and thawed out gradually. It is asserted that where the water is so shallow that the ice rests on the bottom, at low tide, the oysters are killed by the pressure, unless they lie on a soft bottom, where, however, they are in danger of being buried. On the other hand, a heavy fall of snow before ice forms, clogs up shallow waters and kills oysters and even clams, according to the testimony of intelligent and experienced oyster planters. The effect of melting ice, and especially snow, upon animal life has yet to be studied in a scientific manner.

We are confronted with two opposing influences. Shallow waters, especially when so free from grass as to be swept by currents, favour oyster propagation in the summer, but are most unfavourable to oyster life in winter. Just here is a situation that can be advantageously handled by the art of man, so as to greatly improve upon nature; for the young oysters produced on the flats can be moved to deeper water on the approach of winter. This is never done under the conditions of a free or public fishery. It is in the interest of conservation that oyster farming be introduced to supplement natural production. The foremost difficulty encountered in this connection is not our inexperience and our ignorance of the proper way to raise oysters, so much as the opposition of those who believe in harvesting what nature produces without contributing the labour of cultivation. It takes many years of education and the observation of the increased harvest resulting from oyster farming, as well as the annually decreasing product secured by free fishing, to teach the oyster fishermen that it is to their interest as well as that of the general public, to promote scientific oyster culture.

Man has been the oyster's greatest enemy; although, if he will use remedial measures, he can more than counteract the destruction. It is supposed that the disappearance in recent historic times of some of the natural oyster beds is due in large degree to the increased amount of sediment carried into bays by rivers, on which saw-mills have been erected, or whose drainage areas have been cleared and ploughed. Sawdust and sand are the most injurious of the forms of silt; light mud is more readily handled by the ciliary feeding apparatus of the oyster; yet when silt is present as a nearly continuous suspension in the tidal currents, it seriously

[1] Contributions to Canadian Biology 1906-10, p. 286, etc.

interferes with feeding, causing ultimate starvation. Silt that settles may be abundant enough to bury oysters; but even an exceedingly thin layer deposited on the objects used as cultch by the spat, will prevent fixation and therefore to the same degree prevent propagation. Assuming the spat to have secured fixation, it takes proportionately less silt to smother these delicate tiny oysters, than will bury the adults.

The main cause of the destruction of natural oyster beds in historic times has been improper and careless fishing. The history of the oyster industry everywhere has shown that when oyster fishing has been pursued under no other regulations than those born of the wishes of the fishermen themselves, the natural beds were rapidly depleted, and finally exterminated, unless remedial measures were undertaken. Accordingly there have arisen many laws regulating this fishery, that seem strange to those engaged in private farming. For example, oysters may not be taken from natural beds except during the "open season." The "close season," during summer, varies greatly in its limits according to locality, but usually includes May, June, July, and August. Fishing must be confined to the hours between sunrise and sunset. Oysters may be taken with tongs but not with rakes; and dredges may not be used, nor may oysters be taken through the ice. Oysters may not be sold under three inches in length, and those smaller than this must be returned to the beds, etc. These laws are enforced by police methods; and fines and penalties are imposed for a breach of their provisions.

Under private culture each farmer tries to promote his own ultimate best interests, and thus also the public welfare; but those who share in a public fishery consider only their own immediate self-interest. They sacrifice their own future, as well as the public welfare. The oyster laws are a result of an honest and fairly intelligent endeavour to conserve the natural oyster resources, and they undoubtedly partly succeed in effecting their object. It will be instructive to consider for a while the question of the depletion of natural beds and their conservation.

## AGENCIES DESTRUCTIVE TO OYSTERS.

It is a fundamental biological principle that the agencies that destroy the individuals of any living species nearly balance the natural rate of increase; that after a species has established itself in any locality the number of its population remains nearly the same from year to year, though the balance between birth-rate and death-rate will fluctuate slightly up and down as one or the other set of factors increases or decreases. For instance, if food becomes temporarily more abundant, there is an increase in population, while a decrease in food results in a reduction of individuals, through starvation. So likewise there will be fluctuation due to the prevalence of various enemies and epidemics.

Under this law there must be as many deaths as births; or, vice versa, the number of births must be sufficient to make good the loss by death. Therefore, we can judge of the extent of the destructive forces by simply noting the fecundity of a species. The oyster is one of the most prolific of all creatures. A single large "spawner" has been estimated to produce annually sixty million eggs, but we must remember that half of the oysters are males, and that there are many small oysters. Neglecting the very small "seed" oysters, we may conservatively say that an oyster bed produces from ten to fifteen million young for each adult present; so that, if all lived and there were no further propagation, an oyster bed would be ten million times larger in five years. In spite of this astounding conclusion, however, the oyster beds are being depleted simply from the annual removal of a few hundreds or thousands of barrels. This should be the most convincing proof that the natural foes of oysters are extraordinarily formidable. Then why may we not believe that the destruction caused by man is insignificant in comparison, and so need not be considered to have any practical effect? Because "it is the last straw that breaks the camel's back," and because all natural species, including oysters, exist under a balance. We have only to refer to the extinction of the American bison, which existed in such huge herds on our plains; or still better, the extinction of the wild pigeon, whose flocks in migration used to darken the skies of nearly a continent for days. It is absurd to believe that this species was hunted until the last pair was shot. The destruction by the hunter, great as it was in the case of the bison, or of the pigeon, was probably slight in comparison with all the other natural enemies, but the latter, suddenly supplemented by man, finally turned the balance, and completed the work after the hunting ceased. Let us consider some of the destructive agencies operating against oysters.

## THE MEANING OF FECUNDITY.

When the oyster ejects its millions of eggs into the water, these at first tend to sink to the bottom, which they would reach in ten minutes in calm water. In order that the eggs may develop, they must be fertilized by the male spawn or sperms. The sperms must be sufficiently abundant to enable an average of three hundred to cling to each egg during the ten minutes the egg is afloat. They must have been recently ejected from the male oyster or they will have died. The male oyster must have been ready to spawn at nearly the same time as the female, and must have lain sufficiently near, so that the water flowing over him shall reach the female by the time she emits her spawn. This is favoured by the fact that the process of spawning usually takes several hours or even days. We need to ascertain a good deal more than we know now before we can make precise statements, but we know that even where water is in such favourable agitation that the eggs are prevented from sinking to the bottom, they must be fertilized within a quarter of an hour to undergo normal development. This is the first reason for the enormous production of eggs. In spite of losses, vast numbers of developing young are started. As many as ten thousand newly hatched oyster fry or larvæ have been counted in a single bucketful of water dipped up over an oyster bed. But this signifies that there are other chances yet to be taken.

## COMPETITION WITH PLANKTON ENEMIES.

After hatching, which occurs in from five to eight hours, the young oyster swims so weakly that the feeblest current carries it hither and thither. Indeed, all it effects by swimming, is to reach the surface and then to dive again, and so keep going up and down, requiring an hour to swim a distance of a few feet. But the oyster fry find the water is crowded with minute enemies, such as Copepods (water fleas), the "veligers" if the many snails that cover the bottom, and a vast number of the larvæ of bivalves of various species, all capturing everything within reach small enough to enter their hungry maws. These enemies eat the young oysters, and the messmates consume their food. For several weeks the young oyster has to run this gauntlet and obtain sufficient food to effect an increase in volume of a hundredfold before it attains the spat stage in its development. Great as has been the ninefold decimation, yet so many survive that, if clean oyster shells be planted at the time of spatting, as many as a hundred or more spat may be caught upon a single shell almost anywhere upon or near an oyster bed.

## LOSS BY TIDES.

This great survival is the more remarkable when we reflect that twice daily a vast body of water runs over the oyster bed out to sea, carrying myriads of larvæ, and only a part of this water returns. The astonishing fecundity of the parent oysters sufficiently meets this loss also. But the struggle for life has not yet ended.

THE QUEST FOR CULTCH.

Unless man has placed clean cultch in the water, nature provides only the old shells of dead oysters, mostly buried in mud, or the outsides of the living oysters. These and other exposed shells are more or less covered with slime, silt, and mossy growths of both animal and vegetable nature. Millions of other larvæ also needing cultch, such as "deckers," "jingles," "barnacles," etc., have pre-empted the best places and are busy feeding on every living thing they can swallow. Worst of all, through the open valves of the older oysters and of mussels, clams, etc., currents of water flow, bearing all sorts of plankton, presumably also oyster fry, to be used as food. How small a chance these fry have of escaping and finding a foothold! If they cannot fixate they are doomed to destruction. But vast numbers do find a foothold and do succeed in growing, and crowding each other, and competing with all the other oysters for food. In this struggle the survivors ultimately overgrow and smother the previous generations. Great as is the loss through crowding, it is exceeded by or anticipated by an earlier destruction, sometimes including all the spat on most of the shells.

THE ENEMIES OF GROWING OYSTERS.

The numerous little Nassa snails are constantly exploring the surfaces of shells and scraping off all the newly set spat. Those that escape may reach the size of a fingernail, and then, along comes a boring snail and drills a hole through them, or a crab nips them off, or mud stirred up by storm smothers billions in a day, or the frosts of winter kill them. Later come the starfishes opening the oysters by their patient pull, or bottom fishes may crush them in their paved jaws and throats. Last of all, man comes with tongs, and rakes, and dredges, and takes the few survivors. Thus ends this eventful history. The fisherman then wonders why the Creator doesn't supply new oysters the next season to replace those taken: usually the best answer given to this question is to bow in meek submission to Providence.

CONDITIONS FOR PROPAGATION.

A little insight into oyster biology should enable any one to see that the production of oysters depends on the co-operation of four conditions, viz: (1) suitable cultch, (2) in waters stocked with a sufficient number of spawning oysters, (3) lying close enough to ensure fertilization of the eggs, (4) on a bed sufficiently extensive to fill the water, over a considerable area, with oyster plankton to such a degree as to overbalance the larval mortality.

When the large oysters, which furnish the bulk of the spawn, are yearly removed. as well as the cultch to which they are attached (including the young oysters attached either to them or to the cultch), then the bed is robbed in three-fold degree, viz., the cultch is decreased, the large spawners become fewer, and the "rising generations" are many times decimated. If the production of spawn is reduced to half, and the available cultch to half, then the production is reduced to a quarter.

When shells, hitherto buried, are uncovered by working on a bed, they become available as cultch, but this advantage is greatly reduced through the fact that much silt is scattered upon the shells by the very operation which exposed them. In oyster fishing, ultimately all the cultch utilized by spat will have been removed, and then we have remaining simply an oyster reef covered by a layer of mud, upon which not an oyster can be produced. even though a current rich in oyster plankton, derived elsewhere, should flow over it at a time when the fry are matured to the sessile stage. Clam production is much simpler, for no cultch is needed.

### STEPS IN CONSERVATION.

One of the earliest steps taken in most instances towards the conservation of natural oyster beds has been the enactment of a "cull law." This compels the fisherman to sort his catch on the bed, throwing back the unmarketable material, consisting of shells and small oysters. The main advantage secured is the conservation of a percentage of the seed oysters. The spat attached to the large oysters cannot be removed, while the shells which are returned are largely silted up when spatting time comes. In fact, these shells, unless newly dug out of the mud, require to weather for weeks, exposed to rain, snow, sun, and air before they are suitable for spat collecting.

It is evident that no fisherman would thus care for the shells, unless compelled by law; yet it seems to the writer that it would be a practically enforceable provision, were it embodied in the cull law, particularly if a market for these shells could be secured. Sometimes the State has purchased cultch and placed it on natural beds; but this practice was abandoned for two reasons: the cost of the work was greater than under private enterprise; and the Government felt it was making a gift to a special class. Where oyster farming prevails, the planters would buy this cultch, particularly in those regions, where shells are scarce because no shucking operations are carried on. Now that oyster culture is under way in Canada, the securing of cultch is a matter of great concern. It appears that the most available supply must come from a sorting of the so-called "mussel-mud" dug out of dead oyster reefs. The firmest of these shells, which are often of large size, when washed clean, are good collectors. But no cultch should be planted until spatting has just begun. Happily, scientific oyster research has in recent years enabled us to closely determine this date; but important matters are still to be cleared up.

### THE RATE OF PRODUCTION OF A BED.

The legal restrictions imposed on the fishermen have the object of conserving the natural oyster production. The cull law helps this in a measure. Another prominent legal provision is the "close season" during summer, when no oysters are permitted to be taken, because it is believed that the spawning oysters should not be disturbed, nor the cultch be littered with silt by fishing operations. This "close season" has been lengthened from time to time, at both ends, by shortening the "open season," in order to reduce the number of oysters taken, it being believed that the bed is unable to supply oysters in quantity equal to the demand. It is doubtful if this provision becomes effective unless made so drastic as to practically deprive the fisherman of his means of living.

When these enactments fail, more drastic measures are advocated, such as the closing of the oyster beds for a number of years, until nature has had time to restore them. But such legislation is founded on a failure to grasp a fundamental principle, to wit, a depleted oyster bed will be restored at a rate dependent on the percentage of available cultch multiplied into the available spat. Assuming that there are still enough oysters remaining to produce a fair abundance of spat, and that there are plantings of cultch on the bed at the proper times, then it will take five years for the bed to reach its acme. Then if this bed were henceforth left undisturbed by man, the forces of destruction and of natural production would just balance. On the other hand, suppose there was no planting of cultch, then, under nature, a depleted bed would take an indefinitely longer time to reach its original condition. In any event, after such a bed has reached the point of highest production, a survey of its extent and examination of an average square yard or rod, will enable one to calculate just how many bushels of oysters are present. Knowing then the number of bushels that can be taken in the open season, it can easily be reckoned how many years will elapse before the bed again will be reduced to a point where the fishermen can not secure their average catch. It should be evident that under artificial culture the ranks of the oysters are restored by fresh cultch, under whatever rate the adults are removed, so long as the remaining oysters furnish sufficient spat. In case a 5 year-old oyster is marketed, then, without culture, if so large a proportion as a fifth of the product on the bed be taken each year, nature would not be able to replace this completely, for reasons already explained. Yet the demand on the restored bed might be so great that half of the oysters would be removed one year, two-thirds of the remainder the next, plus any natural increase, and so on. Thus the old story of gradual depletion would be repeated. For the first two years after a bed is opened, the production would be double or treble what it was before the bed was closed, but it soon drops back to the small figures. Now, calculating that there is no harvesting for the five years during which the bed has been closed, and suppose that in five years it must be closed again, we see that in the course of ten years the average yearly product is equal to the minimum harvest. There is no gain in production, and the only advantage is the saving of the oyster bed—a bed greatly depleted and not yielding its full capacity. The fact is, that a natural bed yields the highest food production when all the oysters above a certain size are removed annually, and an equivalent of cultch is added. But such a bed gives the highest possible yield of oysters if it is used solely as a propagating bed, the seed being sold to oyster planters to mature for market on ground that could not be used for propagation. This is an important matter, and we need to go into it from the point of view of scientific oyster culture.

## Efficient Use of Oyster Ground.

Suitable localities for propagation and growth may in general be occupied by (1) natural beds, (2) under artificial oyster culture a certain additional area used for propagation and growth, and (3) an additional area for growth only, and (4) in a still further area, oysters might live for a while without growth. Area No. 4 is useful for storage only; Nos. 1 and 2 are so nearly alike, biologically, that fishermen have contended, sometimes successfully, that they are alike legally, so that farmers who had made such areas productive, were robbed of the fruits of their labour. When we realize that area No. 2 would be barren but for the labour of man, we must justly conclude that from a legal point of view they are radically different from natural beds, however much they may resemble them biologically.

Assuming that a farmer owns only areas like No. 3, then he cannot produce his own oyster seed, and must secure it in various degrees of development, from either the fishermen who harvest No. 1 or from farmers who own areas No. 2. His problem becomes this: Which ventures bring the best returns, the purchase and cultivation of oyster seed requiring one, or two, or three, or four years, to mature for market? If there is a law preventing the fishermen from removing oysters under marketable size from natural beds, then the farmer of No. 3 is dependent on what he can secure from the cultivators of No. 2.

Let us next consider the culture of ground No. 2. As this is suitable for propagation, the owner can catch his own seed and is thus independent of the public beds. His ground is also suitable for growth, and so his problem is to find out which pays better, either to keep the seed on the ground where caught, until it is marketable, or to sell it at the age of one, two, or three, or four years, to owners of No. 3. In the former case, his farm will resemble a public bed, biologically speaking, but he can handle the situation to his own best interests, with his best judgment, and not under the restrictions pertaining to public fishing. He will remove each year the right number of marketable oysters, replacing them at the proper time by fresh cultch. He may do better: he may divide his ground into five plots—*a, b, c, d, e*. Let *a* represent the plot that catches the best set of spat. Each year, for four years, he will remove all the spat from *a* and plant them successively upon *b, c, d, e,* respectively, reshelling *a* at the proper times. He gets no pecuniary returns until the fifth year, when he markets the entire crop on *b*. In case there has been annual spatting on this ground, he culls off the immature oysters and places them, not on *c* but on the plots where oysters of similar ages are found. Thus *c* is cleared to receive the next crop that is raised on *a*.

From thence on, he has an annual income, harvesting one of his plots yearly and replanting from his seed-raising ground.

We have gone into this detail with a purpose. This method of farming is the highest form of specialization, and should give the highest possible returns. Now please note well: each year the farmer harvests only one-fifth of his farm, and one-fifth of his growing crops. If he kept the entire farm like a natural bed, taking off an annual crop from the whole area, it is evident he could not do so well because all the generations would be intermixed and competing on those parts where there was most propagation, and on other parts less favourably situated, the propagation would not be at the maximum rate, but at a rate that would greatly reduce the annual product of marketable oysters. At the very best, he could not harvest as much as a fifth of his crop, and he would have to use better methods than those now in use on the natural beds, to keep his oyster bed from depletion.

Oyster farming resembles truck gardening in some respects, but differs in needing several years to mature the crop. On a mixed bed, the best returns come from removing annually as many oysters as can be spared, and not by introducing a system of open and close seasons. It is evident that what is good treatment for a mixed bed under private ownership, will be best for a similar bed under public ownership. There can be but one conclusion here, viz., that if natural beds are to be conserved, they should be under the supervision of an expert, and should receive plantings of cultch at the proper times. The expert must determine just how many oysters may be annually removed.

## THE FATE OF DEPLETED BEDS.

Under a system of private oyster culture, it is necessary for planters who have little or no propagating ground to obtain their seed from natural beds. This leads to an abrogation of the prohibitions against taking immature oysters. Then the fishermen will market their catch at home, for planting in waters more or less adjacent to the public beds. The inevitable result will be to render the latter as barren as possible. When both cultch and oysters are gone, the bed is extinguished. But in this case, if cultch be placed on the bed it is as productive as ever, up to the limit of the supply of cultch. This is due to the fact that the oysters which have been removed are still growing and spawning in neighbouring waters, so that a supply of spat is brought to the old grounds. The fishermen will harvest this crop of spat, and sell to the planter, or plant it themselves on their own farms; and history shows they will as zealously guard rights to such beds as they formerly did where they were confined to harvesting mature oysters only. As no one puts cultch on such beds, it is plain that however much spat may be present in the water derived from the private grounds, the beds will last only as long as the cultch naturally present will last, and that the production will be only as much as the available percentage of cultch present. Inevitably such beds become "barren" bottoms and open to leasing. There can be only one way of escape, and that is for the fishermen to form a co-operative society to work the public beds under a mutual agreement.

But this, of course, cannot be done, because others of the public than the fishermen, are also owners. Fishermen have been offered first chance in taking out leases of what they considered to be public ground, and have refused because they know that if once this right is granted, all or nearly all of the public grounds will ultimately come into the ownership of capitalists. So here we have a special phase of the old struggle between capital and labour. It is not our purpose to more than touch on the skirts of the matter that is political rather than biological, but still is vitally involved in any scheme of oyster conservation.

### THE LEGAL SIDE.

Experience has shown but one successful way of developing oyster resources, and that is the encouragement of oyster farming. The introduction of oyster culture has always met with opposition from the public fishermen, and such opposition has had a degree of justification. Usually it has been so mingled with prejudice and short-sightedness, that the sympathy of the general public has been estranged. Theoretically, the best interests of the whole public require that the oyster industry should be conducted wholly by methods that have proved successful in private farming—letting private judgment manage business operations, rather than a code of regulations. Practically, however, the best course to follow is to recognize the existence of public beds, and public fishing rights. Such rights and beds should be carefully defined, and the boundaries of public beds marked in a clear and simple manner, even though some barren bottoms should be included. Only by extreme or radical measures can natural oyster beds be preserved. But where oyster culture is successful there is less necessity for conserving such beds. The public oystermen have endured a surprising amount of restrictive legislation, supposed to be as much for their interest as that of the public. Under our larger view of the oyster question, the fishermen might be given more freedom and influence in shaping the regulations for the use of the public beds. Restrictions should primarily have in view the protection and encouragement of oyster culture, in which the real public interests inheres. Efforts should be made to secure impartial justice for all. A mutual obligation rests on both fishermen and farmers, to respect each others' rights. Those who wish to frame the wisest laws, seeking for harmonious co-operation between these conflicting interests, are advised to study the history of oyster legislation in as many states and countries as possible. There will be found a variety in details, resting on local conditions, and a similarity in general principles, resting on biological grounds.

### THE DECLINE IN THE CANADIAN OYSTER PRODUCTION.

That oyster production in Canada, and particularly in Prince Edward Island, has steadily been decreasing is evident from statistics. See "Table showing the aggregate quantities of oysters caught in the Dominion since 1876, compiled from annual reports of the Department of Fisheries," given on page 47 in the report of the Dominion Shellfish Fishery Commission, 1912-13. In this table we note a curious back-and-forth fluctuation from year to year; but if the entire series of years be divided into five-year periods, and the annual product be averaged for each five-year period, or semidecade, the annual catch in barrels is as follows:—

| Periods. | Years. | New Brunswick. | Nova Scotia. | Prince Edward Island. | Proportion for P.E.I. Per cent of whole. |
|---|---|---|---|---|---|
| (1)................................ | 1876–1880 | 9,724 | 1,172 | 17,020 | 60 |
| (2)................................ | 1881–1885 | 12,765 | 1,652 | 34,644 | 70 |
| (3)................................ | 1886–1890 | 20,426 | 2,049 | 36,379 | 60 |
| (4)................................ | 1891–1895 | 17,434 | 3,327 | 30,622 | 60 |
| (5)................................ | 1896–1900 | 18,740 | 2,150 | 22,735 | 50 |
| (6)................................ | 1901–1905 | 12,854 | 1,517 | 19,860 | 60 |
| (7)................................ | 1906–1910 | 16,564 | 1,597 | 10,583* | 30 |
| ................................ | 1911–1912 | 15,436 | 2,090 | 8,835 | 35 |

* For 1907-8, the quantity credited to Prince Edward Island was only 1,672 barrels. Leaving that year out, the average for the remaining four years becomes 12,811 barrels, which is 40 per cent of the average total credited to the Dominion for the same period.

The third period shows a maximum of oyster production in the Dominion, and also in the two main oyster-producing provinces. The decline began in the middle of the fourth period, mainly in Prince Edward Island, which led in production up to 1906, when it sank to the level of New Brunswck. Thenceforth it fell behind until its production reached only half of the province of New Brunswick. The decline in the latter province from the maximum has been little more than 20 per cent with 80 per cent decline in the island province. This difference in the rate of depletion has been explained as due to two main influences: the greater demand for the island product and the discovery of new beds in New Brunswick, when several of the older beds were fished out.

It is interesting to read the summary of the reports of various inspectors and experts from 1868 onward, given in Ernest Kemp's "The Oyster Fisheries of Canada," 1899. These reports sound a uniform warning that the Canadian oyster industry was in danger of complete destruction unless proper measures were taken to conserve it. The decline in the industry has not been so keenly realized by the fishermen, because the price of oysters has increased proportionately. This fact augurs seriously for this industry. Oysters, even when cheap, are considered somewhat of a luxury, and a rise in price must tend to exclude them more and more from the menus of the middle classes; while at the same time the importation of foreign oysters must increase. The Canadian fisherman has relied for the protection of his interests on the superior quality of his oysters; but this superiority is threatened in two ways: first, it has become necessary to market oysters from beds that do not produce them of the highest quality; and second, by the attempt of planters to grow imported seed in Canadian waters, in the hope that they will attain the citizenship at least, or, if possible, attain the quality of the home product. This "American" seed is sometimes of inferior quality and, although it certainly improves under cultivation in more southern waters, it lies dormant for a long time, without growth, when transplanted to the northern beds. According to the claims of the fishermen, with whose product these oysters compete, when sold, it injures their market by giving the oysters from their locality a bad reputation.

The cultivation of foreign oysters in Canadian waters is of considerable scientific as well as practical interest. From the slight evidence at hand, we conclude it will take more than a year to acclimate Connecticut seed in Canada, before growth begins. It will take a correspondingly longer time to impress the Canadian quality upon these oysters after growth begins. It will, therefore, be wise to import this seed as young as possible to secure the best results. It is still somewhat doubtful whether the Canadian oyster may not be a distinct variety, breeding true to its kind. The Canadian oyster spat, at the time of fixation to cultch, is a fourth larger than the spat in the corresponding stage of development in New Jersey waters. Whether this difference is due to environment or is inherent, remains to be settled by experimental observations. Oysters usually show improved quality in colder waters, due largely to the shortness of the spawning season. While it is interesting to note the outcome of attempts to cultivate "American" oysters in Canada, it will be wisest for the Canadian planter to do all he can to promote the production of the native seed.

## PART II.—OYSTER PROPAGATION SURVEY OF RICHMOND BAY, P.E.I.

In presenting the following synopsis of observations made in Richmond bay we wish to call attention to the fact that there are many points in the life and habits of oysters and their young that are yet unknown and which should be known in order to make the proper applications to economic problems. Aiming to make our investigations throw light upon these other matters, at the same time that we attempt to be as practical as possible, the work of surveying so extensive an area as that of Richmond bay by the methods developed by our previous experience, introduces much complexity. There were so many things that should receive simultaneous attention that much was crowded out or missed, which demands a more specialized investigation. Lacking previous familiarity with this considerable expanse of water, it seemed best to get as broad a view as possible of the conditions, from which departure could be made in any special direction, as the findings might suggest.

## DESCRIPTION OF METHODS.

The most important procedure is the determination of the oyster "plankton," i.e., the young "fry" in the water, which furnishes the "setting" of "spat." This study was prosecuted by the use of a net made from the finest bolting silk. Counting out Sundays and stormy days, plankton studies were made on eighteen days, at an average rate of fifteen per day and a maximum of more than twice that figure. The net gathers a vast number of many kinds of larvæ—bivalves, univalves, water fleas, etc., and as it is necessary to sort the oyster larvæ out from each sample, under a microscope, and count and measure them, the work is nervously strenuous and time-consuming.

Our procedure consisted in straining approximately known quantities of water through the plankton net, and then to "wash" the "catches" into a series of wide-mouthed bottles containing sufficient formalin to kill the larvæ, so that they would all settle to the bottom. After a number of such samples were collected, the boat was run into the nearest quiet harbour, where the sediment in the bottles was examined in partial lots, until the entire amount in each bottle had been sorted by the methods developed in our previous researches.

The samples were collected in the following ways:—

(1) Dipping water in the net while the boat was under full headway, the average rate was two samples per mile, each of 20 quarts of water.

(2) Dragging the net back and forth by hand a definite distance and number of times while the boat was stopped. This is called "swinging" the net.

(3) Towing a definite length of time, say a minute under reduced speed.

(4) By means of a cylinder, devised with valves for this purpose, into which the net was fitted, we secured samples at definite depths, or determined the vertical distribution of the fry by lifting the net through a fixed distance, a definite number of times.

We thus endeavoured to make our determinations quantitative as well as qualitative in character. The point from which we set out each morning, and to which we returned each evening was Malpeque wharf. We were farthest from home each day at noon, and samples were taken as opportunity offered on the return route as well. We are desirous at this point of the narrative to express our thanks and hearty appreciation for the kindly courtesies extended by Prof. A. D. Robertson, the use of whose boats and other equipment we shared, doubtless at times at a sacrifice of his convenience, at least, he being engaged in studying oyster growth.

## LOCALITIES EXAMINED.

For purposes of location and orientation, the following descripton of Richmond bay is given: This bay is a considerable southward indentation from the gulf of St. Lawrence, of the north shore of Prince Edward Island. The coast at this point trends northwest, thus the western shore of the bay is one and a half times longer than its eastern. A sandbar 10 miles long separates the bay from the gulf, and limits its outlet to a channel a mile wide situated at the northern terminus (cape Aylesbury) of the eastern shore. Each shore has three considerable indentations. On the east, most northerly is Darnley basin, next comes Shipyard basin, and at the head of the bay is Chichester cove. On the west, situated correspondingly are Bideford river, Grand river, and Bentinck cove.

Confining one's attention to the channel or deeper parts of the bay, the tide entering north of cape Aylesbury sends a small branch southward into Darnley basin. The main portion flows west at the southern end of the bar between Royalty point and "Fish" island. Three miles west from Aylesbury the tide strikes Horseshoe shoals and spreads thence in three directions: (1) northwestward for 4 miles to enter the mouth of Bideford river, between Hog island and Bird island on the east and Gilles point on the west; (2) the southwestward tide flows 2 miles to "Ram" island shoals where it bends south and southeast around Ram island on a 6 mile course into "March water," and eastward into Shipyard basin, to Malpeque wharf; (3) the central portion of the tide on Horseshoe shoals continues westward for 3½ miles to North Bunbury shoals. Part of it continues on for 5 miles farther, passing north of Charles point to reach Grand river. The main portion of the tide, 3 miles wide, turns south between Charles point and Bunbury island. Four miles to the south it runs between Beech point on the east and Bentinck point on the west, and enters the head of the bay, where it ends in three divisions, viz., Bentinck cove on the west, Chichester cove on the east, and Webber cove, with Barbara Weit river on the south, 8 miles from North Bunbury shoals.

Apart from its estuaries, Richmond bay may be conveniently divided into: (1) an outer section or Lower bay, lying east of a line drawn from Ram island northward to Hog island, but this line should curve westward far enough at its middle, to include all of Horseshoe shoals; (2) an inner section or "Upper bay," lying south of a line drawn due west from Beech point to the cliffs north of Bentinck point; (3) a middle section, between the other two, that we may designate as the "Central portion." The southern half of this section is split into two by Curtain Islands shoals, which extend nearly 4 miles northwestward from Beech point. Bunbury island, situated near the northern extremity of these shoals, marks closely the geographical centre of the bay. We shall confine the term "Central bay" to the portion north of Bunbury. The part west of the shoals, from its shape may be called the "quadrangle," that to the east is "March water." The Upper bay empties mainly into the "quadrangle," but some water flows over the shoals into March water, which in turn also partly spills over Ram Island shoals into the Lower bay. The "Central bay" receives the Bideford from the north, Grand river from the west, the quadrangle from the south, and March water from the southeast, between Bunbury and Ram islands. We shall consider successively the data secured from a study of the different localities. Most attention was given Grand river and March water; the data from other localities are fragmentary.

## BIDEFORD RIVER.

This river from the head of navigation to Gilles point is 6 miles long. Trout river enters it in the south, and a strait called the narrows, lying between Lennox island and the mainland, enters from the north. The lower part of the river is bounded on the northeast by Lennox and Bird islands, and it empties into the Central bay in conjunction with the waters of a large shallow lagoon that lies east of Lennox and Bird islands and west of the sandbar. The southern end of this lagoon is bounded by Hog island, near which are oyster beds that owe their existence to the influence of the adjacent flats, in warming the ebb tides.

At the northern end of the widest part of the Narrows, on August 6, a few oyster fry were found in 20 quarts of water of 1,021 density, 70° F., the largest being 160 microns[1] in diameter.

At head of navigation in Trout river, August 17, during rain, high water was 1015 at 72° F. Vertical sampling of different parts of the river yielded oyster fry of 160 microns to 400 microns, at the rate of one per 15 to 60 feet.

[1] Twenty-five thousand microns equal one inch. Oyster fry are first seen at 60 microns and "set" as spat when they are from 320 to 400 microns in diameter.

At the head of Upper Bideford, August 6, low water was 1019·5 at 74° F. Four samplings, each of 20 quarts, along its course to Trout river, yielded seven fry of 160 microns, and a few at 100.

Between Trout river and the Narrows, August 6, in water of 1019.5 at 72° F., large fry were present at the rate of one per 30 quarts. August 17, fry were found of sizes 120, 180 to 260, 360 to 380 microns, at the rate of one per 60 feet vertical, which means that in water 30 feet deep, ten hauls from bottom to top would yield five large fry.

In the section off south end of Lennox island, August 6, water was 1020 at 70° F., and only one large fry and a few small ones appeared. On August 17, 1019 at 70° F., three samples gave twelve fry from 160 to 400 microns, most being 240 microns.

In the section along Bird island, August 6, only few fry present, and less than 120 microns in size. On August 17, water sample 1020 at 70° F., gave one fry of 200 microns.

Central bay, adjacent to Bideford river, August 6, 1021 at 70° F., fry less than 110 microns. August 17, near low point, one fry 180 microns, one 240 microns.

### GRAND RIVER.

From the bridge to the ferry is a distance of 4 miles, and from the ferry to Charles point is 3 miles. The latter section, 2 miles wide, is more a cove than a river. From the bridge to Southwest creek is nearly a mile, thence to Cross creek nearly two, and thence to the ferry is a mile and a half. About half a mile below the ferry at Black point the river empties into its cove.

Section below the bridge, August 6, flow, 1018 at 72 F.; August 14, ebb, 1018·5 at 74° F. Vertical samples gave one fry per 20 feet, sizes 120, 160, 320, 360 microns nearly equally abundant. August 20, flow, successively 1018 at 66 F. and 68 F., 1017 at 67 F., and farthest from bridge 1019 at 68 F.; very little but sand in four samples. Samples on higher water gave one per 40 feet vertical, one per 10 quarts, four per minute towing, 80 to 200 microns. August 25, strong ebb, one fry per 6 feet of towing, from 120 to 320 microns, majority 240 microns. Towing one minute with large No. 12 net, gave seventy fry, 160 to 340 microns, with maxima at 240 and 320 microns; small fry escape through this net.

Section below Southwest creek, August 14, 1019·5 at 71° F., fry one per 2 feet vertical; farther down, one per 6 feet, ranging from 200 microns to smaller, most are below 160 mu.[1] Half of oysters dredged are still filled with spawn. August 20, 1018.5 at 68 F., early flood, few fry; but when near high, 1019·5 at 68 F., fry are abundant, one per 6 feet vertical, one per 5 quarts, thirty per minute towing, ranging from 70 mu to 280 mu, mostly below 100 mu. Farther down, 1019·5 at 68 F., one fry per 6 feet vertical, one per ten quarts, twelve per minute, 90 to 360 mu. August 21, twelve samples, 1018·5 at 70 F., near high, gave one to 40 quarts, up to nearly one per quart, from 9 to 166 per minute, from one in 4 feet vertical, up to one per foot. Sizes run from 80 to 320 mu with four-fifths of them below 110 mu, and some at 200, 240, and 320 mu. August 25, half ebb, 1020 at 70 F., twenty quarts dipped, give from 9 to 33 fry, also at low 1019 at 74 F., got one fry per 2 feet vertical, and 34 per 160 feet of towing; sizes, 80 to 320 mu, majority below 120 mu, several at 180, 240, and 280 mu. August 28, 1019·5 at 68 F. flow; one fry in 8 to 15 feet vertical, eleven in 1 minute's tow; sizes, 90 to 380 mu, with groups at 100, 150, 280, 320, 360 mu.

Section above Cross creek, August 14, 1018·5 at 72 F. Oysters dredged here have all spawned, fry abundant, one per 2 feet vertical, ranging from 100 to 200 mu, and a few at 360 mu. Majority are 160 mu, perhaps ten days old. August 20, water low flow, 1018 at 68° F., few fry until near high, 1019 at 70° F. when fry are one per 40 feet vertical, one per 5 quarts and fifteen per minute towing, and of sizes 80 to 280

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[1] The name of the Greek symbol for "microns," is "mu."

mu, with groups at 100, 180, 240 mu. August 21, fry nearly fifty per minute, eight per 20 quarts, three per 10 feet vertical; sizes 80 to 320 mu, most are below 100 mu, a group at 180, a few at 240. August 25, low ebb, nine to sixty fry per minute towing, five samples, thirty to forty in 20 quarts; sizes 80 to 380 mu, the majority are below 120 mu; groups at 140, 180, 200, 240, 280, and 320. August 28, fry are one per 4.5 feet vertical, of sizes 90 to 340 mu, majority at 140.

Section below Cross creek, August 6, a few small fry present. August 14, 1020 at 70° F., largest fry 120 mu. August 20, high, 1019·5 at 67° F., fry 80 mu to 320. Half ebb, 1020 at 70° F., fry at rate of one per 4 feet vertical, one per 5 quarts, and two per minute of towing; sizes are 80 mu to 220. August 21, fry were found at rate of two to six per 20 quarts, below 200 mu in size. August 28, fry at rate of three to nine per minute and one to 25 feet vertical, sizes are below 260 mu, mostly below 160 mu.

Section near ferry, August 14, 1020 at 69° F., fry at rate of one per 12 feet vertical, under 200 mu. August 20, 1019 at 66° F., few fry: at lower tide, 1019·5 at 68° F., fry at rate of one per 4 feet vertical, and one per 7 quarts, grouped at 100 mu, 200, and 230 to 280 mu.

Grand River Cove: The roughness of water here prevented frequent observation. August 20, 1019·5 at 67° F., in middle of cove, no fry. At cape Malpeque (Charles point) 1020·5 at 67°·5 F., fry at rate of one per 10 feet vertical, mostly small, one 200 mu. August 21, 1019·5 at 70° F., three fry per 20 quarts, largest 160 mu.

### UPPER BAY.

With the upper bay, extending 7 miles southeast of Charles point, or south from Bunbury island, we shall include: (1) the "quadrangle" 4 miles north to south and 3 miles east and west, whose corners are designated, respectively, by Charles point, Bunbury island, Beech point, and Bentinck point; (2) a southern "head," 4 miles north and south, 5 miles east and west, which receives seven tributaries, that will be reviewed in circuit beginning on the northeast.

Oyster Creek: August 7, 1018·5 at 74° F. Thirty quarts inside the grass area at its mouth, yielded four large (160 mu) and many smaller fry. Outside the grass, the fry were few and small, and snail larvæ numerous. August 13, 1020 at 72° F., vertical sampling yielded a few small and one "large" (unequal umbos) fry in three hauls of 7 feet each.

Chichester Cove and Indian River: August 7, 1019 at 73° F., in cove, and 1016 at 74° F., in the mouth of river. Snails numerous, oyster fry few and small, one "large"[1] found.

Barbara Weit River and Cove: August 7, 1018·5 at 72° F. Many snails, few oyster fry. August 13, 1018·5 at 74° F., samples yielded two large and a few small fry. Nearly all adult oysters have spawned, but some not.

Webber Creek Cove, or Waites Cove: August 7, many snails, few fry. August 13, ten hauls in 9 feet of water yielded two large, four medium, several small fry. August 24, twenty hauls of 5 feet each in 12 feet of water, yielded 33 fry, from 160 to 380 mu in diameter, at ratio of one per 3 feet vertical, and quite satisfactory. Shells were put out as cultch here.

Plat River Cove: August 7, sample was poor in plankton, 1020 at 72° F., in grass near cliff west of Webber point. Oyster fry more abundant towards Bentinck cove. August 13, ten hauls vertical in 12 feet of water yielded five medium fry.

Shemody Creek and Bentinck Cove: August 7, in creek, 1015 at 74° F., few oyster fry here. In cove, 1020 at 72° F., oyster fry more abundant. August 13, in mouth of creek, 1020 at 70° F., sample shows but one large fry. In the cove, 1021 at 69°·5 F., vertical sample in 5 feet of water yielded three large and three medium. Farther out, in 10 feet of water, vertical sampling yielded a larva of 240 mu.

[1] We use the general designation of "large" for fry with unequal umbos, "medium" for those with prominent equal umbos, and "small" for those less than 100 mu in length.

"Head" of Upper Bay: August 7, sample near Bentinck point was poor in fry. In the middle of the bay the water was 1020 at 74° F. Each of two samples contained a fry nearly ready to "set." August 24, on high water, 1020 at 68° F., a long course, dipping from Beech point towards Webbers point, yielded but few fry, the largest was 240 mu.

The quadrangle west of Curtain Shoals: August 7, in its southern portion three samples showed many snails but no oyster fry. Farther north it was much the same story, only one large fry found in four samples, but many snails.

Commentary on Upper Bay: The considerable distance of this part of Richmond bay from our base at Malpeque, combined with the roughness of the "quadrangle," prevented as full a study of this part as was desirable. Once we buffeted the waves quite to Bentinck cove and were compelled to return to shelter east of Curtain shoals. This sort of work cannot be done on a boat pitching extremely. From the data secured, it is indicated that the oyster plankton of the open bay is sparse, and that it is only close to the broad flats that line the shores, where the oyster plankton was fairly abundant. There seems to be some correspondence between water temperature and oyster plankton, more being found in the warmer waters than the colder ones. Another point to be noticed is that the water on the shore flats, probably never leaves the upper bay on the ebb tide, but retires temporarily to the edge of the flats to return on high water, and so the contained oyster plankton is not lost from this cause. This is on the supposition that the fry do not themselves have habits that would oppose their transport outwards on ebb tides. While this question is still under investigation there is strong evidence to show that fry are more abundant at the surface on flow than on ebb.

Another interesting point concerns the snail larvæ. These were extraordinarily abundant in the Upper bay. The flats of the Upper bay are extensively covered with grass. We found snails more abundant near grass plots in all parts of Richmond bay. We do not know whether the snails feed on the oyster fry, but have suspicions. This matter is worth investigating. We know that snails are enemies of the young spat. It is probable that these snails should be fought in the interest of oyster culture.

### MARCH WATER.

This part of the bay is bounded on the southwest by Curtain islands and Beech point. Across the shoals between the point and the islands, there is current communication with the "quadrangle" and with the Upper bay. March water is bounded on the northeast by Prince point and "Ram" island. Across these shoals, there is water communication with the Lower bay. But the main outlet is to the northwest, between Bunbury and Ram island, into the Central bay. The eastern part of the March water section is the Shipyard basin, at whose head is Malpeque wharf. Shipyard river enters here from the south. Shipyard basin is separated from March water by a considerable grass flat. Extensive grass flats also cover the Curtain Island shoals. The oyster beds are mainly near Prince point, Ram island, north of Bunbury shoals, and the channel between Bunbury and Ram island. Owing to the fact that our home base was at Malpeque, and also that we had to traverse March water every time a visit was made to any other part of the bay, and that it was less disturbed by winds than other parts, this section received more continuous attention than the rest of the bay. It did not, however, offer so rich a plankton as did Grand river between Southwest creek and Cross creek. We shall consider our observation of it as a whole, chronologically.

August 5, at low ebb, on "old dump" in northern part of Shipyard basin, 1020 at 70° F. A dipped sample yields many snails, Peridinias and Tintinnias, a few large oyster fry, some medium, and several small ones. Similar results found after crossing the grass. On Princetown beds the snails were fewer, oysters more numerous, but still few as compared to the numbers familiar in our New Jersey studies. The mussel and clam larvæ were more numerous, and of more kinds than in Barnegat bay, N.J.

August 6: Three samples were dipped in the "basin," with results like those of yesterday. Samples taken after passing grass, between Ram and Curtain islands and at junction with the Central bay show few small or medium oysters, none large, many other bivalve larvæ and snails. Samples were again taken on return from Bideford and Grand rivers in evening, but labels were lost.

August 7: Shipyard basin, before reaching the grass, one sample shows one large and one medium fry, and few small ones. After passing the grass, sample yielded five medium fry under 120 mu. Returning in the evening from trip to Upper bay, a sample taken between Ram and Bunbury islands, was nearly all snails; a sample near the grass had many snails, and a few oyster fry. In the Shipyard basin a sample yielded many small oyster fry.

August 9: Rainy, tide high. In the channel opposite the break between Little and Big Curtain islands, compared vertical samples with dipping from the surface. The surface was 1021 at 67° F., and yielded one large and one medium, in 20 quarts, and a fair show of small fry. The bottom 1021 at 68° F., yielded three medium, and some small fry and lots of sand. Next the surface was sampled, using 20 quarts in alternation with vertical "hauling" in the three uppermost feet, nine samples. Thirty feet of vertical sampling nearly balanced 20 quarts of surface dipping. No fry larger than 120 mu were found, and never more than one or two; small fry were present in small numbers.

August 10: Compared dipping with vertical sampling from bottom to top. In 20 feet of water between Bunbury and Ram, and Prince to Beech points, hauled net, and dipped 30 quarts from surface, 14 samples. Obtained two fry of 200 and 260 mu, three to six medium, and several small ones. Found four species of three genera of Peridinidæ, viz., *Ceratium tripos, C. divergens, Dinophysis acuta,* and *Peridinia* sp? Also many *Tintinnus subulatus.*

August 11: High water, and strong northeast wind. An oyster secured by dredging in channel is filled with immature spawn. Water 1021 at 66° F. Shells obtained by dredging hold no spat except "deckers" and barnacles. Samples of 30 quarts yield each two large fry and two medium ones. Vertical sampling secured one large fry per 20 feet; also some medium.

August 12, a sample dipped near Bunbury yielded one medium, and two smaller fry. Oysters from Ram Island point are nearly through spawning. Hung out shell cultch on buoy nearest wharf, and sampled water here, finding one large and two medium fry in 20 quarts.

August 14, in channel between Ram island and Little Curtain island, water is 1019·5 at 68° F., vertical sample gives one fry per 14 feet, the largest being 200 mu, but most are 120 mu. In Shipyard basin, at the buoy farthest from wharf, water is 1019·5 at 70° F., and vertical sampling yields one fry per 12 feet; one is 360 mu, or nearly ready to set, one is 200 mu, seven are 120 mu. At buoy nearest wharf, vertical sample gives one per 30 feet, with largest larva 160 mu.

August 16, rainy. Made a survey of March Water section, at same time compared methods of taking fry. Used vertical sampler for surface towing, as well as for deep sampling. Between Ram and Bunbury, secured fry of sizes 80, 100, 160, 200, 280 mu. In line of Beech point and Ram island, vertical sampling yielded one per 30 feet of sizes 80, 120, 160 mu. In line of Beech point and Prince point, vertical sampling gave one per 20 feet of sizes 160, 240, 340 mu. Towing towards Princetown beds yielded fry up to 180 mu. On Princetown beds, vertical sampling yielded one per 15 feet, of sizes 110 to 120 mu, 160, 240, 320, and 400 mu, which last is the largest seen, and also represents the largest after "setting." A second sample towards Grog island gave similar results, both in ratios and sizes. A towing sample yielded six large fry per minute, the leading groups being at 160, 240, and 340 mu. Small fry being quite difficult to separate from small larvæ of other bivalves, were generally not counted fully.

Vertical sampling on the "dump" yielded one per 30 feet, the largest being 200 mu. Similarly, off Ramsey's, one per 25 feet gave sizes 160, 220, and 380 mu. Towing towards the buoys farthest from the wharf, gave fry 180 to 240 mu. At this buoy a string of shells was hung as cultch; vertical sample here yielded one per 50 feet, of sizes 280 and 320 mu. Another sample at the buoy nearest the wharf gave same vertical ratio, but of size 160 mu only. Towing towards wharf also gave fry of this size. Towing towards Shipyard river yielded no fry.

August 17, on way to Bideford, water on Little Curtain shoals was 1020 at 70° F. Towing at full speed between Bunbury and Ram island, yields no fry, and we suspected that all were pressed through net. A northeast storm broke at 11 a.m., and weather did not clear until afternoon of the 19th. Meanwhile, we coated oyster shells with coal tar varnish for use as cultch.

August 20; compared 20 quarts dipped with one minute of towing. On "dump" no fry in either sample. On Princetown beds, fry were found only in towing sample, of size 140 to 200 mu. Further along channel no fry were found, nor all the way to Cross creek, in Grand river, a distance of 9 miles, and with one exception none were found in Grand river until the afternoon, when the flood tide came and there were plenty. This suggests that the fry had hidden in the bottom during the storm. On return, a pair of samples taken in March water between Ram and Bunbury islands, 1020 at 68° F., yielded no oyster fry, though plenty of mussel larvæ were present.

August 21, tide ebbing all forenoon. Tarred shells were planted on Curtain Island shoals and Ram Island shoals. The afternoon was spent in Grand river.

August 23, too rough for sampling, tarred shells placed on Reilley's lot.

August 24, visited McNeill's lots off Waites point. Oysters there had finished spawning, and shells one week planted bore spat a millimeter (1000 mu) in diameter. Tarred shells were hung out on these beds. A study of the spat on shells showed that the fry set between 320 mu and 400 mu. For future studies of the spat see later the special section on "spatting."

August 26, cool and cloudy. Found water fresh and at 60° F. at head of Shipyard river; near its mouth 1018·5 at 72° F., high water. Worked in shelter of Bunbury island ("Big Curtain" island). Made study of methods and comparison of nets Nos. 12 and 20, in the channel, and secured most variable results: out of thirteen samples, two yielded no fry, the others yielded fry groups at 100, 120, 200, 240, 280, 320, and 360 mu, at a rate of seven to twenty-four per minute, and one fry per 6 to 30 feet. Many spat show on shells on planted beds. Took up shells placed August 12 and August 16. No spat on latter; one-third of former bear spat.

August 27, cold northwest wind. Water at wharf 1019·5 at 66° F. Took up tarred shells placed on Curtain and Ram Island shoals on the 21st, and also those planted August 23 on Reilley's lot. From Curtain shoals to Reilley's, water was 1020 at 68° F. Secured nine samples en route, which were studied before being killed by formalin. We noticed action of the long proboscis-like foot of the mature fry. The larvæ swims hinge down, with foot in front or dragging behind at will; used as a feeler to test surface for fixation. The fry secured, yielded sizes of 90 to 120, 160, 220 to 240, 280, 320 to 380 mu. Fewest are near the Reilley end of route.

August 28, on Ram Island shoals, 1021 at 62° F., a few fry below 160 mu secured at rate of one per 30 feet. Fifteen quarts dipped had none.

### CENTRAL BAY.

We next consider the northern or main section of the Central bay as it receives the ebb from the southern sections (viz., the quadrangle and March water), as well as that from Bideford and Grand river. We have noticed a decided falling-off in the number of fry as this portion is approached, so that we do not expect much from its survey. It has a considerable number of more or less depleted beds in its southern part, at the junction with the southern divisions, or in the neighbourhood of North Bunbury shoals, between the northern parts of the quadrangle and March Water section.

August 6, three samples taken on the way to Bideford river showed the presence of oyster fry, but none over 120 mu. South of Low point, 1021 at 70° F., and on route to Grand river the same result was secured, and also from Grand river to March water.

August 7, the story of yesterday was repeated, and again on the 8th. The catch between the "Klondike" bed and North Bunbury shoals was mostly composed of snails. On August 10, at the west end of Horseshoe shoals, and therefore on the line of junction with the Lower bay, snails were few, but mussel and other bivalve larvæ most abundant; few oyster fry were observed; but so much sand was present as to render the examination difficult. On August 17, towing north of Bunbury en route to Bideford river yielded one fry 160 mu, on high water. Farther north, 1021·3 at 70° F., a second fry of 160 mu turned up, and a few smaller fry near Low point. Fry grew more abundant near the mouth of Bideford river. August 20 enroute to Grand river, six samples were taken from North Bunbury to half-way to cape Malpeque (Charles point) with water 1020 at 68° F., and no fry were found. Next day, between Ram and Bunbury islands, at the entrance to March Water channel the same story was repeated. We may conclude, therefore, that the main stretch of Richmond bay proper is well depleted of oysters, and that the more abundant plankton of its estuaries and shores is not carried into it, to more than a slight extent.

### THE OUTER OR LOWER BAY.

This division of Richmond bay is wide in the west, embracing the extensive Horseshoe shoals; and is narrow in the east, where the deep channel of Malpeque harbour leads out between Bill Hook island and Royalty point to the inlet. Farther east, Darnley basin connects from the south, between Royalty point and cape Aylesbury. Oyster beds are located north of the Horseshoe shoals, near Hog island, south, near Ram island, east, in the "harbour," and also at Montgomery point between Royalty point and Prince point.

August 5, samples taken near the beds of Ram Island point, and at the harbour, were crowded with mussel and other bivalve larvæ, among which was a small proportion of oyster larvæ, the largest being 165 mu; water 1020 at 68° F. In Darnley basin, 1021 at 70° F., low flow, no oyster larvæ were found either near its outlet or near its head; but an enormous number of Peridinias were present. August 10, strong east wind blowing against a strong out-going tide, between Horseshoe shoals and Ram island, one fry 120 mu, appeared, and several smaller ones in 30 quarts. Vertical sampling of a total of 30 feet, showed fewer fry, but more silt. In the harbour, a comparison by dipper sampling, with vertical sampling, showed so much sand that the determination of the fry was unsatisfactory; so far as the evidence went, it showed the presence of fewer fry than farther up the bay. North of the shoals, towards Hog island, the samples doubtfully contained oyster fry, but were crowded with Peridinias; west of the shoals, a few fry less than 120 mu were found. August 28, at Montgomery point, vertical sample showed a ratio of one fry per 15 feet, mainly small, but sizes 320 and 360 mu were also present.

*Commentary*: Our samples of this, and of the Central divisions of the bay, except March water, were not so numerous as they should have been to form definite conclusions. These parts of the bay are specially difficult of study, except in calm weather, at which time conditions are also extra favourable for study of regions richer in fry. Enough has been learned to make it reasonably certain that oyster fry were abundant in proportion to the distance from the outlet, and we believe this is due to at least three causes: (1) loss by ebb tides; (2) coldness of water near the inlet; (3) fewer oysters. Even when the oyster beds nearest the central and lower divisions of the bay were in their original full vigour, we believe that they were maintained with a narrower margin of survival than those farther away. Under the circumstances, it has been easier to deplete them, and will be correspondingly more difficult to restore them.

### SUMMARY OF THE DISTRIBUTION OF OYSTER FRY.

The yield from 20 quarts dipped was one to four fry in Bideford river, one to forty fry in Grand river, one to three fry in Upper bay, two to five fry in March water. One minute's towing yielded 2 to 166 fry in Grand river, and seven to twenty-four fry in March water. Vertical sampling yielded one fry in 15 to 60 feet in Bideford river, one to 40 feet (with majority at two to 6 feet) in Grand river, one to 24 feet (average at 10 feet) in Upper bay, and six to 50 feet (average 25 feet) in March water. Grand river leads, with March water and Upper bay struggling for second place. Our highest record of two fry per quart sinks into insignificance, when compared with the several hundreds per quart with which we have been accustomed to deal in our New Jersey oyster investigations.

TABLE summarizing the sizes, in microns, of oyster larvæ, August 5-28.

| — | Aug. 5 | 6 | 10 | 13 | 14 | 16 | 17 | 20 | 21 | 24 | 25 | 26 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stages.... | * | * | * | * | * | * | * | 70 | * | * * | * | * | * | * |
| I.......... | * | * | * | * | * | 80 | * | 80 | 80 | * | 80 | * | * | — |
| Trans..... | * | * | * | * | * | * | * | 90 | * | * | * | * | 90 | 90 |
| II......... | * | * | * | * | * | 100 | — | 100 | 100 | — | * | 100 | * | 100 |
| | 110 | — | — | — | — | 110 | — | * | 110 | — | * | 110 | * | * |
| | — | — | 120 | — | 120 | 120 | 120 | * | * | — | 120 | 120 | 120 | * |
| Trans..... | — | — | — | — | — | — | — | 140 | * | — | 140 | — | — | 140 |
| III........ | 160 | — | — | — | 160 | 160 | 160 | * | 160 | 160 | 160 | — | 160 | 160 |
| | — | — | — | — | — | 180 | 180 | 180 | 180 | * | 180 | — | — | * |
| | — | — | 200 | — | 200 | 200 | 200 | 200 | 200 | * | 200 | 200 | — | * |
| Trans..... | — | — | * | — | — | 220 | * | 220 | * | * | * | — | 220 | * |
| IV........ | — | — | * | 240 | — | 240 | * | 240 | 240 | 240 | 240 | 240 | 240 | * |
| | — | — | 260 | — | — | — | 260 | * | * | * | * | — | ...... | 260 |
| | — | — | — | — | — | 280 | * | 280 | * | * | 280 | 280 | 280 | 280 |
| Trans..... | — | — | — | — | 320 | 320 | * | 320 | 320 | 320 | 320 | 320 | 320 | 320 |
| V......... | — | — | — | — | — | 340 | * | * | — | * | 340 | — | * | * |
| | — | — | — | — | 360 | — | 360 | 360 | — | * | * | 360 | * | 360 |
| | — | — | — | — | — | 380 | 380 | — | — | 380 | 380 | — | 380 | 380 |
| | — | — | — | — | — | 400 | 400 | — | — | 400 | — | — | — | — |

The preceding table of sizes must not be interpreted without a clear understanding that it represents a summary of the records, and only roughly a summary of the actual facts. The records, as compared with the facts, are incomplete, fragmentary, and approximate. They are incomplete in that a careful correlation of sizes and temperatures was not made, or where made, the data have not been worked into the table; also incomplete, because the relative proportions of fry at the different sizes, though secured in a large number of our observations, have not been incorporated. This because of the misleading conclusions that would be derived from such a collation, in the absence of temperature relations, sufficiently complete to be of scientific value. The records are fragmentary, in that it was impossible to secure full data from all the areas, and we wished to cover all the area even though it had to be done at the sacrifice of completeness. The sizes are approximate, in that we purposely used a low-power microscope and a micrometer with coarse divisions, for the sake of

*Sizes noticed but not counted. Stages are: I., straight hinge stage, or "small"; II., equal umbos, or "medium"; III. and IV., unequal umbos, or "large"; V., ready to set as spat. New Jersey oyster larvæ set in stage IV., Canadian in Stage V. "Trans" means transition from one stage to next.

expedition, judging by the eye of the fractions. No accuracy beyond 10 microns was possible, and we rarely strove for an accuracy beyond 20 microns. Thus all our measurements fall into groups separated by 20 microns, which gives the false impression that the fry were produced in corresponding broods. There is no doubt that broods do exist, but it is necessary that the entire attention be focused on this aspect of things, in order properly to establish the number and sizes of the respective broods. We had to choose between covering a small field of observation thoroughly and accurately, or the reverse; and we deliberately chose the latter alternative, as the logical thing to do, beginning with the general and specializing on such parts as the general survey showed to be worthy of additional work. Of course, a complete uncovering of oyster biology cannot be expected in one month or one season, hence the finer work remains yet to be done.

But the table does indicate some things of practical value, and that is why it is introduced. It will be noticed that fry, ready to set, were not observed in fair abundance until August 16. Indeed, the largest recorded for the 5th, 10th, 14th, and 16th, represents a regular advance in growth of 240 microns in twelve days, or 20 microns per day, which gives seventeen days as the minimum length of life of the floating larvæ. This length of life is quite to be expected under the influence of the higher range of temperature, 72 to 74 degrees, recorded. But a large proportion of the fry exist in temperature averages of less than 70 degrees; and there is independent evidence[1] showing that the period of free life of the fry in Richmond bay is over three weeks. It is not unreasonable to suppose that some of the fry may grow even slower than this rate. The rough survey marks out the boundaries of special problems that call for more accurate researches, on the rate of growth. Another feature indicated by the table, is the distribution of spawning. Spawning began late in July or early August, and was practically continuous throughout the greater part of August, with a climax at the 20th. Not only does an individual oyster use a considerable period for ejecting its spawn, but the individuals on a bed do not mature at the same time. Further, it is evident that as the oyster beds of the bay are subjected to different ranges of temperature, the different beds do not propagate simultaneously. It follows, therefore, that spatting is also a more or less drawn-out affair, although there are special favourite days for spatting as for spawning, dependent on weather, as shown by our New Jersey researches. These researches also have shown that not all the broods of fry that appear successively, reach the spatting stage successfully. This is another problem demanding research. The practical aspect of this question lies in the fact that cultch, to be most useful, must be clean, and to be clean must be placed closest to spatting periods. It follows that cultch planting should be periodic, and that the periods should be regulated by the general weather and special plankton reports of the locality proposed to be shelled. For further discussion of spawning and spatting see those sections farther on.

### TEMPERATURE SUMMARY.

Temperature is a factor of supreme importance in oyster life. The warmth of the water depends on depth, character of bottom, distance from inlet, direction of winds, temperature of the air, and on the sunshine. The highest temperature was 76° F., observed once on the flats off Tilton creek; but 74° F., was found at the head of Bideford river, in Shemody creek, in Indian river, in the head of the bay, in Oyster creek, in Barbara Weit river, part of the time at Grand River bridge, and near Southwest Creek bridge. This is only 6 degrees above the minimum for oyster propagation, and the main areas of Richmond bay fail to reach this maximum. Thus, 72 degrees was recorded in the upper Grand river, Trout river, Bideford river, off Plat river, lower part of Shemody creek, and off Barbara Weit river, Oyster creek, and the mouth of

[1] See Stafford. "The Canadian Oyster," 1913, pp. 83 and 84. This excellent memoir is a very full exposition of the biology of the oyster.

Shipyard river. Seventy degrees was recorded for Shipyard basin, Darnley basin, Narrows, Bideford river, Shemody creek, Grand river, March water, Curtain Island flats, etc. This figure was recorded more often than any other, but 68° F., stands next in frequency, being recorded not only for the deeper and lower parts of the bay, as at the inlet, March water, head of Grand River cove, etc., but also from upper Grand river and Bideford river, after the cold winds and nights of the latter half of the month. There were eight instances of 66 to 67 degrees in March water and Grand river, after cold weather. August 28 the water at Ram Island shoals was 62 degrees. At the head of Shipyard river, where the water was quite fresh, it was 60 degrees on the 25th.

At best, the length of the season when the water in Richmond bay is warm enough for oyster propagation, is short, and when the warm weather of spring is delayed, as was the case in 1915, the spawning is shoved into August, and the spatting comes so late that the spat secure only slight growth before winter temperatures begin. The late spat of 1914 thus attained only a small size during the second summer of its existence. We found spat in August from Ram island, scarcely larger than one's little fingernail, that must have set the preceding fall.

A question arises here, to what extent may the oncoming cold of autumn interfere with the spatting of the late broods of fry which were the principal ones this year? In more southern waters we frequently get a set of spat in September, and even in October, and these have some chance to grow before winter. But there is quite likely a temperature limit, to spatting itself, which it is important to determine. The shallowness of a large part of Richmond bay, favouring rapid heating of the water, is also favourable to its quick cooling. If, therefore, the largest brood of fry should be prevented from setting, there is an additional obstacle to the rapid regeneration of oyster beds in Canadian waters. This also has favoured rapid depletion.

### SUMMARY OF DENSITY OBSERVATIONS.

A great deal too much emphasis has been laid on the question of the saltness or density of the water in which oysters may be expected to flourish. Doubtless, the admixture, more or less periodically, of fresh water with the salt water, at the mouths of rivers, has a beneficial effect, but the range of salinity in which oysters will grow is so great that the careful observation of one or two points difference in reading on the scale of the salinometer, is of little practical, or possibly even scientific, value.

While salinity depends on distance from inlet, distance up rivers, the stage of tide, on wind strength and direction, and on rainfall, the variations and range of the readings of our salinometer were remarkably small. We found, in fact, almost the same readings as obtained at our New Jersey, Edge Cove, station. The highest record was 1021 found in Darnley basin, at half flood (August 6), in the Narrows at low, off Low point at half flood, in the channel of March water, both top and bottom, at high tide August 9 and 17, in Central bay, north of Bunbury, and in Ram Island shoals at high.

A reading of 1020 was most frequent, as in Shipyard basin, August 5, in Malpeque harbour at low, off Lennox island, and in the Narrows, off the mouth of Plat river, in Shemody creek (August 7 and 13), off Tilton creek, and in the Upper bay, both at low (August 7) and high (August 24), in Oyster creek at half tide, at Grand River ferry on high, on Curtain Island shoals, and the mouth of Bideford river at high, and in March water at low (August 20 and 27).

Twenty observations gave 1019 and 1019·5 most frequently in the rivers or at the mouths of creeks. In Grand river, 1017, 1018 and 1018·5 were found not far distant from the bridge. This record was also given in Barbara Weit, Oyster creek, and Shipyard river. A reading of 1015·5 was observed well up Shemody creek at low water, and 1016 in Indian river. The lowest, 1015, was recorded at the head of Trout river; the observation at the head of Shipyard river, which was the only river that was penetrated into the parts accessible only at high water, was exceptional. Here the salinometer read 1000 at 60° F.

SPAWNING.

It was easier to ascertain the progress of spawning from examination of the plankton, than by dredging for oysters and opening the same. Dredging on natural beds did not bring up many oysters, and we depended on oysters from planted beds secured under direction of those in charge. An oyster secured in March water on the 11th was filled with immature spawn, but next day samples at Ram island showed that their spawning was completed. On the 13th in Bentinck cove we found that spawning was hardly half through, as half of the oysters had not begun, and the others were only partly spawned out. Near the Barbara Weit, on McNeill's beds, however, only a few oysters contained spawn. On the 14th, in Grand river, half-way between Southwest creek and Cross creek, we again noticed that half of the oysters were still in full spawn; but near Cross creek, all that we secured were empty. Dredging for oysters near the ferry failed to secure any samples. On the 24th, on McNeill's beds, there were still traces of spawn. On the 26th, oysters in March water were through spawning. Owing to the small number of samples opened, and few observations, only general conclusions can be drawn from these observations, viz., that before the 20th there was abundant spawn still present, and that after that date the oysters were nearly but not entirely through spawning.

Turning to the plankton record, we find that fry which were probably ten days old were present August 5, but oyster plankton was not abundant until August 14; and these fry were also about ten days old. On the 17th they were advanced to 200 microns, indicating an age of about two weeks. On the 20th, and especially on the 21st, small, lately hatched fry were most abundant. Here was a climax in the spawning, which probably occurred on the 20th, a fine day following stormy weather. On the 25th, fry under 100 mu were scarce, but very abundant at that size, and not yet a week old. This day was a banner day for showing fry; they were abundant up to 320 mu. On the 26th and 27th there was an increase in the fry under 100 mu in size, but these had attained 100 mu on the 28th.

SPATTING.

The study of spatting involves the determination of the date of "setting" (fixation of the fry to cultch as spat). Also a study of the rate of growth and of survival; also the determination of the most suitable cultch and localities and other conditions favourable to this process.

The date of spatting can be fixed by two independent sets of evidence: (1) observations on the presence and abundance of the largest fry "ready to set" in connection with the plankton data; (2) the "lifting" of the cultch, such as shells, from time to time, and giving them careful examination, after drying. Such shells should be specially selected, the cleanest obtainable, and preferably have been experimentally placed at set dates.

From the table given a few pages before, we learn that fry of spatting size (320 to 400 mu) were present in relative abundance from August 14 to 17, and on the 24th and 27th. These fry were not nearly so abundant as the fry seen previously, of sizes 260 to 320 mu. There was a reduction of at least 60 per cent. Part of this reduction may be explained as due to the probable presence of a certain number on the bottom seeking suitable cultch, so that the net necessarily failed to catch them. Part of the reduction was probably due to destruction.

When fry of 260 to 320 mu are compared with earlier stages, we find also a reduction nearly as great, and while it is possible that the fry will remain on the bottom more frequently as their shell grows larger, yet we are inclined to place the responsibility for the reduction upon destructive agencies. It must not be forgotten, however, that the number of fry secured from the water is not a true index of the number present, because a large proportion of every brood of fry will be found near the surface on fine days, and deeper down, or at the bottom in bad weather. Hence, the number is, to a good extent, an index of weather variations.

Although the water may show fry of spatting age, it does not always follow that a "set" will occur; if it did, the task of foretelling the date for placing cultch would be relatively a simple matter; this act seems to require fine weather. Much work needs to be done in this connection before we shall learn all we ought to know, in order to be of the best practical use, although what is already known can now be applied to advantage. From the table of fry sizes, it is evident that spatting was prophesied to occur from mid-August onward to the close of September, whenever conditions were favourable. It remains to study the cultch to fix those dates. We are not, however, in a position to state the exact date of "setting" from a measurement of the spat until we know their rate of growth. This in turn cannot be learned except from a knowledge of dates of setting, determined independently. As much, if not most, of the spatting occurred after we departed, our data will not be complete; but shell samples sent us later throw some light on this question.

We have seen from the table that fry, ready to set, were not abundant until mid-August. Examination of cultch on the 11th and on the 13th, as well as other dates previous to mid-August, failed to reveal the presence of spat. Experimental cultch was suspended from a buoy near Malpeque wharf on the 12th, and on a buoy farthest from the wharf on the 16th, on Reilley's lots on the 23rd and on Curtain and Ram island shoals on the 21st. Part of the cultch consisted of plain, selected, hard shells, and partly of shells of a crumbly nature taken from weathered heaps of "mussel mud." Each of the latter shells was coated for two-thirds of its area from the broad end, with coaltar varnish. The object of the experiment, was to compare the relative efficiency of such a surface with the plain part of the cultch. Coaltar varnish was chosen because this is used to cover the bottoms of boats, and a boat was shown on which a fine catch of spat had fastened the previous season, thus suggesting that this paint was attractive to spat. It is easily understood why this boat carried such a set of spat. A bacterial slime will not form on the tar because of its antiseptic qualities; and other vegetable growths will likewise be prevented. Many of the spat of other animals, such as barnacles, might reasonably be supposed to avoid that surface, the coating being applied to boat bottoms to keep clear of such things.

There is, however, another factor to be considered as present in the case of the boat, which was not imitated with the tarred cultch. The bottom of the boat in the water is an "under" surface and not connected with the bottom. Being an under surface, no silt or sediment can settle upon it; and being unconnected to the bottom, the various crawling animals, snails, etc., would not be able to reach it and browse on its collection of spat. We note another fact of importance, viz., the paint was applied in the spring, several months before the spat set. Thus the tar had become thoroughly seasoned and hard, its soluble parts, creosotes, etc., that might be offensive to spat, had largely soaked out, when spatting began. In the case of our experimental cultch, only a few days' exposure to the water was admissible before the test occurred, and the tar was still soft where thickly applied.

The earliest spat observed were on shells taken on the 24th on McNeill's grounds, near Waites cove. Some of this cultch had been planted a week before, and some had lain a year on the beds. Several oysters were taken, and the outside of their shells was fairly well set with spat. The average spat was 1000 mu in diameter (which equals a millimeter or one twenty-fifth of an inch). These, like all young spat, showed the larval shell of the size it was when setting occurred, and also the later added spat-shell. The larval shell ranged from 320 to 400 mu, and the spat shell made a rim of 75 mu around its edge. As most of the larvæ are 400 mu high, from tip of left umbo to edge of right valve, it follows that spat growth can best be indicated by omitting this "constant" from the total measurement, which will henceforth be done.

August 26, the experimental shells which were placed on the 12th and the 16th, were taken for examination. No spat were found on the shells placed August 16, but a third of the shells placed August 12, carry spat up to a diameter of one millimeter. As no spat were found on the shells placed on the 16th, the inference would be that the spatting occurred before the 16th, which, taken in conjunction with the fact that these spat were of nearly the same size as those seen August 24, on shells planted for a week, leads us to the conclusion that in both cases we have to do with the setting of spat that showed as "ready to set" in the plankton of August 14. It might, however, not be true that the shells placed August 16 failed to catch spat, because all had set that were ready. Possibly none were in the water at that point, and this supposition becomes probable when we study the shells taken from the McNutt bed, next to be considered.

Assuming the 14th as the probable date of first spatting, we get the tentative result of about 100 mu growth of spat shell per day.

On the 26th we "lifted" several oysters and shells from the McNutt beds, and these showed spat very much like those in the McNeill samples. The most spat were found on the inside of oysters that had died and decomposed recently, leaving clean inside surfaces, well protected from entrance of both silt and the larger enemies, such as snails, because the valves of the oyster shell naturally separate only narrowly. A study of the distribution of these spat is instructive. The number of spat on the outside was equal for both valves, but totalled only one-eighth of the number found inside. There were twice as many inside spat on the right valve as on the left or lowermost valve, even in the instance where both valves were absolutely clean. The number was in all cases proportional to the cleanness of the surfaces, ranging for the inside upper valve from 1 to 150 spat per shell. The highest number was on a small shell, and the spat were most beautiful, showing what nature can do even with limited resources, if given a fair chance. We should also note that the spat prefer to set on the under side of an object, even when the surface is no cleaner or otherwise better than in other positions. The European oyster farmer takes advantage of the fact in his method of tile culture. In short, the spat like a "roof over foot." This is the result of natural selection, as those fry that possess the instinct to set under a surface, are not so apt to be smothered by silt, and also they find less silt to scrape away to get a hold.

The spat shells were measured in nearly fifty instances on the best set cultch sample and we found all stages present, from spat newly set, up to those having 1200 mu of spat-shell. Sizes 150, 400, and 600 mu had the most numerous representation. Allowing 100 mu growth per day, we get twelve days as the age of the oldest, which brings the date of beginning of spatting to be the 14th, quite in harmony with the plankton evidence. The main spatting period was from August 20 to the 22nd. This is in harmony with the figures in the plankton table for this period, showing few fry in stage V, because they were exploring the bottom at the time. As the climax of the spatting occurred on the 20th, and no spat were found on the shells placed on the 16th (taken on the 26th), it is evident that no fry ready to set were present at that locality. Still farther from the wharf were the Reilley experimental shells; they were placed on the 23rd and taken up on the 27th, and no spat were present on them. So here, too, was an area which was poor in spat, at those dates at least. Just how far fry may wander from their birthplace, during the weeks of their plankton life, is not known, but it is a possibility that they do not wander far. This is a subject of great importance, and deserves careful research. While they are in the plankton condition they are a part of the water, and they use their swimming powers to rise or to sink. By rising into the tide early in flow, and settling to the bottom before ebb begins, it is evident they can wander as far from home as the distance travelled by a tide in six or seven hours. This would not distribute them laterally, to the current, except when strong winds blow crosswise and they are at the surface, which is not usually true in rough weather. Everything depends on the adjustment they make in reference to the tides. We have found most fry on the flood tide. This would prove that the tendency is to work away from the inlet, and up towards headwaters.

On August 27, samples of tarred shells, placed on the 21st on Curtain island and Ram Island shoals were taken. Spat were found only on the Curtain island shells, on about six out of two dozen shells, and only from one to three spat per shell. The spat shell added, ranged in width from 160 mu to 600 mu during the six days' sojourn, thus corroborating our previous calculations. It is of course possible that the largest did not "set" at the earliest hour after planting, and so the growth might be greater than 100 mu per day. This would not be surprising, since the conditions for growth are very good on these current-washed shoals. If the rings of growth seen correspond to diurnal additions, then one spat grew at the rate of 180 mu per day. But it has yet to be proved, that the growth of the dissoconch or any other shell growth, is adjusted to diurnal rather than tidal variations, or something else.

On September 3, Robert McKenzie took samples of shells from the McNutt beds, which were forwarded to me. Three of the seven shells sent carried spat; two "rights" held twenty and fifteen spat, respectively, and one "left" held six spat. This distribution suggests that they came from intact shells, for if the valves had lain on the ground separately, the left valves would have carried the most spat. The appearance of the shells showed that they came from "cluckers" (i.e., oysters which, when tapped, sound empty). Two-thirds of the spat on these shells were newly set, and the oldest had a spat shell of 900 mu, which brings the date of their first setting not earlier than August 25. In harmony with this, our plankton table shows a considerable number of fry ready to set on the 24th, with subsequent relative absence of this size. On this latter date also there was a great increase in younger stages, which probably furnished the spat that set September 2 to 5.

On September 18, Hubert P. McNeill took up and forwarded a string of tarred shells which we had placed on his beds on August 24, and also a large shell, which he wrote was planted August 30. These samples proved highly interesting. Considering first the August 30 shell, this was a large left valve and remarkably clean after having been in the water for "eighteen days." It carried a small shell on its back with its smooth or inside surface facing in the same direction as the outside of the main shell, and occupying a seventh of its surface. The smooth inside of the large shell carried thirty-four spat, the outside eighty-nine spat, and the small shell thirty-eight. Had the small shell been absent, there should have been a hundred spat, or three times as many as on the inside; but if the entire surface had been as good as that of the little shell, there would have been 266 spat, or nearly eight times as many as on the inside. To account for this, we believe the shell hung with the curved side down. Had it rested on the ground, the spat would have been excluded from the center part of the convex surface. The sizes of the spat shells, viz., 40 to 560 mu, show that spatting had occurred within five or six days, so that there is a question as to its having been exposed for a longer period than a week. Turning now to consider the sizes of the spat shell-growth on the shells placed August 24, we have ranges of 0 to 2600 mu. As these shells were exposed twenty-five days, we have another fine coincidence on the basis of 100 mu growth per day, assuming that setting began at once, which is probable, as the water at the place where the shells were hung had the finest show of fry, ready to set, seen in the entire bay. Granting this assumption, then there was spatting at this point on August 24, 28 and on Sepetmber 3, 5, 7, 8, 11, 16, and 18, with climaxes on the 5th and 15th. The latter climax fits the facts of the large shell lifted September 18, but leaves a mystery about the absence of fry on September 3 to 5, if it was placed August 30, for the tarred shells corroborate the evidence of the McNutt shells. It must be carefully noted, that in all this calculation the assumption is that the spat grow equally and similarly and uniformly, certainly rather unlikely. We need to have some careful research made on this problem.

Next let us consider the value of tar as a coating for oyster shells; does it improve shells to varnish them with coal tar? Striving to not crowd these pages with detailed tables, we shall give only the results of counting the spat. The figures show that per unit area, the tarred surface captured only two-fifths as many spat as did the unvarnished shell; that the smooth side and rough side of the plain right valve were equal; that tarring reduced the number of outside spat to half, and those setting inside to a quarter as many as would have otherwise set. For the left valve, there was no difference between the plain and tarred surfaces outside, but a reduction to a fifth for the inside. The left valves caught more than twice as many spat as did the right valves. This was true respectively both for the plain and the tarred surfaces. We had long ago established similar ratios for these valves; yet we showed above that in "cluckers" lying in the normal position, it is the right valve that gathers most spat. The reason the left, free, valve and outside surface is superior to the right, is due to the fact that the silt fails to bury its edges as quickly as in the case of the flatter valve, when both are free.

The outcome of these researches is to suggest further studies with cultch coated with the composition (equal parts of lime, sand, cement) used for tiles in Europe. This is useful in view of the scarcity of cultch in Prince Edward Island.

October 4, Mr. McKenzie gathered samples from Ram island, placed there August 21. These shells held only "deckers" (Crepidulas). October 5, Mr. McKenzie gathered samples of Curtain island shells left there August 21, and therefore exposed for forty-five days. Two of them were tarred shells, carrying Crepidulas both on the tarred and the plain areas. The plain shells have but one spat on one surface (rarely on both). They range from 4 to 10 millimeters in diameter. Fragments of a Mya shell carry four spat of 16 to 20 millimeters in diameter. On the supposition that the largest had "set" as early as mid-August, they would be not more than fifty days old, and in the case of the largest spat, a growth of 400 mu per day must have been attained on an average. Of course the growth is absolutely more rapid the older the spat, though it may relatively be less so. It is desirable to have careful studies made on growth, and we await with interest the results of Professor Robertson's researches on this subject.

## CONCLUSION.

We have found that oyster propagation in Richmond bay shows the effects of the very considerable depletion indicated by statistics; but there are still areas, where careful planting of cultch will capture a fair set of spat. We wish to emphasize the necessity of pushing the practice of raising oysters from the seed, by artificial culture, insistently, persistently, consistently, and intelligently and scientifically, as the only way to restore the bay to its original productiveness, or even to keep its beds from ultimate destruction. But if the practice of scientific oyster culture be encouraged and developed, there is no reason for doubting that the maximum production formerly exhibited by this bay, under nature, and by fishing methods, can be increased very much. We do not think that every one of the 32,000 acres in this domain, can be made productive, but there is a good possibility that a quarter of this acreage may be made productive, and when that time arrives the annual product should be nearly a million bushels. It is worth while to strive for that figure, even if it may take a long while to reach it; by thus striving, it is certain that the present production will be increased many fold, to say nothing of conserving the very life of the oyster industry. If we go not forward we shall surely drift backward.

# THE MARINE ALGÆ OF THE PASSAMAQUODDY REGION, NEW BRUNSWICK.

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(Plate VIII.)

The work which forms the basis of this report was done at the Marine Biological Station, St. Andrews, N.B., in April, May and June, 1912, and May, June, August and September, 1913.

The region covered is from St. Stephen, at the head of navigation on the St. Croix river, to Grand Manan.

The Algal flora of this region is distinctly boreal in character, as is shown by the luxuriant growth of *Fuci* and *Laminariae,* and by the occurrence in comparatively shallow water of *Dictyosiphon hippuroides, Halosaccion ramentaceum, Saccorhiza dermatodea, Agarum turneri* and *Monostroma fuscum blyttii.*

There is a considerable difference in the Algal flora of what we may term "inside" and "outside" points. By "inside" we mean on the mainland side of Passamaquoddy bay, by "outside" the shores of the islands (Deer, Pendleton's and MacMaster's) which form the outer boundary of the bay, and all points beyond these islands. These differences in the Algal flora may be pretty definitely traced to differences in the salinity of the water "outside" and "inside." Inside the water has a specific gravity at the surface of from 1·0226 to 1·0235, and a percentage of total salts of from 2·99 to 3·202, while outside waters have a specific gravity of from 1·0235 to 1·0242, and a total salt content of from 3·201 to 3·280 per cent. For these figures I am indebted to the work of Mr. G. G. Copeland in 1909, published in the report of the Biological Stations of Canada "Contributions to Canadian Biology, 1906–1910."

The only paper dealing with the algæ of this region of which I have any knowledge is Prof. D. C. Eaton's "List of Marine Algæ collected near Eastport, Maine, in August and September, 1873, in connection with the work of the United States Fish Commission," and, where his records are for Canadian stations and for species which I have not collected, I quote them here.

In many countries the marine algæ are of great economic importance, as food, as the source of food products such as isinglass, in the production of a "size" for textile fabrics, in the clarifying of beer and wines, as the source of iodine and potassium, in the manufacture of a very strong adhesive known as seaweed glue, in the production of a demulcent for use in relieving coughs, and as a fertilizer. Except that some are put to the last-mentioned use along the coast, and small quantities of dulse (*Rhodymenia palmata*) are gathered and dried for eating, the marine algæ are made no use of in Canada, and therefore represent one of our undeveloped resources.

## 1.—Cyanophyceæ.

*Gomphospheria aponina,* Kuetzing.—In brackish pool off Kitty's cove, St. Andrews, September 6, 1913.

*Pleurocapsa fuliginosa,* Hauck.—Common on sandstone conglomerate cliffs at high-tide mark in places moistened by dripping fresh water near the Biological Station. This species forms thin black coatings. This is the first Canadian record.

*Dermocarpa prasina,* Bornet and Thuret.—On *Petrocelis cruenta* at Head harbour, Campobello island, June 12, 1912. Not previously recorded from Canada.

*Hyella caespitosa,* Bornet and Flahault.—Common in dead shells of *Mya arenaria* in the vicinity of St. Andrews. It imparts a yellowish-green colour to the shells. This is one of the perforating algæ, and in studying it the calcareous matter of the shell must be dissolved out with Perenyi's fluid, which is made up as follows: 10 per cent nitric acid—40 cc., ethyl alcohol—30 cc., and ½ per cent aqueous solution of chromic acid—30 cc.

*Oscillatoria laetevirens,* Crouan.—On old wharf near St. Stephen, at about ¾ flood-tide mark, May 13, 1913.

*Oscillatoria nigro-viridis,* Thwaites.—In a brackish pool flooded only by the very highest tides, at Welchpool, Campobello island, June 17, 1912. This is the first record for this species in Canada.

*Spirulina subsalsa,* Oersted.—In brackish pool flooded only by highest tides at Welchpool, Campobello. On rocks near low tide mark, Leonardville, Deer island. On wharf at the Biological Station. These are the first Canadian records.

*Lyngbya aestuarii,* Liebman.—In a brackish pool at Welchpool.

*Nodularia harveyana,* Thuret.—In lagoon in salt marsh, St. Andrews, June 6, 1912. This is the first Canadian record.

*Anabaena variabilis,* Kuetzing.—In brackish pool flooded only by highest tides, Welchpool, June 17, 1912. Not previously recorded from Canada.

*Calothrix confervicola,* Agardh.—Common on *Cladophora flavescens* floating in Kitty's cove, St. Andrews, August 28, 1913.

*Rivularia atra,* Roth.—Forming black gelatinous nodules on sandstone conglomerate cliffs at high-water mark in places where the cliffs are moist with dripping fresh water, near the Biological Station.

### 2.—Chlorophyceæ.

*Ulothrix flacca,* Thuret.—Common on rocks, timbers and moorings and on *Fucus vesciculosus* throughout the region.

*Ulothrix implexa,* Kuetzing.—Common on sandstone rocks at high-tide mark in places moistened by dripping fresh water, near the Biological Station. In estuary of a small stream flowing into Brandy cove.

*Enteromorpha percursa,* J. G. Agardh.—In lagoon in salt marsh near St. Andrews, May 11, 1912. On dead twigs, etc., in estuary of a small stream into Brandy cove.

*Enteromorpha crinita,* J. G. Agardh.—In lagoon in salt marsh near St. Andrews. In estuary of a small stream into Brandy cove. Rolled up in long rope-like masses at the edge of Kitty's cove. Not previously recorded from Canada.

*Enteromorpha compressa subsimplex,* J. G. Agardh.—In tide-pools at Adam island. In tide-pools on the Short Bar, St. Andrews. One of these tide-pools is shown in Fig. 1, Plate VIII.

*Enteromorpha minima,* Naegeli.—On rock in tide-pool in Chamcook harbour. On sandstone rocks at high-tide mark in places where moistened by dripping fresh water, in Brandy cove and near Joe's point.

*Enteromorpha micrococca,* Kuetzing.—Common on sandstone cliffs where moist with fresh water at high-side mark near the Biological Station.

*Enteromorpha intestinalis,* Greville.—In a tidal creek near St. Andrews. This habitat is shown in Fig. 2, Plate VIII. Extremely abundant in tidal creek at Grand Harbour, Grand Manan. An extremely small form, with the largest thalli only 3 mm. in diameter, was found in a pool in the cliffs of Swallow-tail, Grand Manan, about sixty feet above high-tide mark, and only reached by spray which flies to a great height at this point.

*Enteromorpha linza,* J. G. Agardh.—Common on muddy gravel beach at half-tide mark on Adam island. On weir stakes at low-tide mark off Navy island. On weir stakes in Brandy cove.

*Ilea fulvescens,* J. G. Agardh.—On rocks in stream in littoral zone, Brandy cove. In rock pool reached only by the very highest tides, Biological Station.

*Monostroma fuscum blyttii,* Collins.—Common in tide-pools at all outside points. In a stream of salt water flowing, at low tide, out of Kitty's cove. Some of this species was served on the table at the Biological Station, and it was found to resemble a very strongly flavoured and rather slippery spinach.

*Ulva lactuca rigida,* Le Jolis.—Common from half-tide mark down on rocky beach at Welchpool, and at Grand harbour, Grand Manan.

*Chaetomorpha melagonium rupincola,* Kjellman.—In a tide-pool near low-tide mark at Herring cove, Campobello.

*Chaetomorpha aerea linum,* Collins.—In curled masses in pool off Kitty's cove, St. Andrews.

*Rhizoclonium riparium polyrhizum,* Rosenvinge.—At base of sandstone cliffs near high-tide mark in Brandy cove. On dead twigs in estuary of a little stream into Brandy cove, exposed from one-quarter ebb tide. In pool in cliffs of Swallow-tail, Grand Manan, about sixty feet above high-tide mark.

*Rhizoclonium tortuosum,* Kuetzing.—In tide-pools at Upper Green point.

*Cladophora laetevirens,* Harvey.—In sub-littoral zone on weir stakes in old weir off Navy island, June 8, 1912. This is the first Canadian record.

*Cladophora rupestris,* Kuetzing.—Common on rocks near low-tide mark at all outside points.

*Cladophora gracilis expansa,* Farlow.—In shallow tide-pools on the Short Bar, St. Andrews.

*Cladophora flavescens,* Kuetzing.—Floating in large yellowish masses in Kitty's cove, St. Andrews.

*Spongomorpha arcta,* Kuetzing.—Common in spring in tide-pools throughout the region, occurring in rounded tufts.

*Spongomorpha spinescens,* Kuetzing.—On *Fucus evanescens* in littoral zone at Head harbour, Campobello. This species has not been previously recorded from Canada.

*Hormiscia penicilliformis,* Fries.—On *Fucus evanescens,* Little Letite.

*Gomontia polyrhiza,* Bornet and Flahault.—Common on dead shells of *Mya arenaria* in shallow tide-pools.

*Vaucheria thuretii,* Woronin.—On mud at high-tide mark, Harbour de Loutre, Campobello. On mud in salt marsh, Friar's bay, Campobello. On mud-flats at Grand harbour, Grand Manan.

### 3.—PHÆOPHYCEÆ.

*Phyllitis fascia*, Kuetzing.—Common in tide-pools throughout the region.

*Scytosiphon lomentarius*, Agardh.—Common in a small form with few constrictions in tide-pools at inside points. Common in a large form with many well-marked constrictions in tide-pools from half-tide mark down at outside points. A large form twisted into tight spirals occurs at Welchpool, Campobello. This spiral form is mentioned by Eaton as occurring at Eastport, Me.

*Desmarestia aculeata*, Lamx.—In upper sub-littoral zone at Welchpool. In tide-pools near low-tide mark at Herring cove, Campobello.

*Desmarestia viridis*, Lamx.—Common in sub-littoral zone on Tongue shoal, near St. Andrews. Off Navy island in sub-littoral zone on weir brush. In tide-pool at low-tide mark at Little Letite.

*Dictyosiphon foeniculaceus*, Grey.—Common in tide-pools throughout the region.

*Dictyosiphon hippuroides*, Aresch.—On rocky shore near low-tide mark at Welchpool, Campobello.

*Ectocarpus confervoides*, Le Jolis.—On *Ascophyllum nodosum* at the Biological Station. On weir brush in old weir off Navy island, unilocular and pleurilocular sporangia present June 8.

*Ectocarpus littoralis*, Lyngbye.—Common on weir brush off Navy island, at and below low-tide mark. On old weir stake in Warwig river.

*Leathesia difformis*, Aresch.—On *Cladophora gracilis expansa* in tide-pools on Short Bar, St. Andrews. On rocks near low-tide mark, Spruce island.

*Elachistea fucicola*, Fries.—On *Fucus evanescens* at Head harbour, Campobello. On *Ascophyllum nodosum* in Brandy cove. On *Fucus vesciculosus* on Navy island. On *Fucus furcatus* on Bliss island.

*Chordaria flagelliformis*, Agardh.—Common in tide-pools.

*Ralfsia verrucosa*, Aresch.—Common in tide-pools, forming black leathery expansions on pebbles.

*Ralfsia deusta*, J. Agardh.—On rocks in tide-pools on Short Bar, St. Andrews.

*Chorda filum*, Linn.—Attached to stones at low-tide mark at Biological Station. Common in sub-littoral zone off Head harbour, off Spruce island, and in the Narrows.

*Laminaria saccharina*, Lamx.—Common at and below low-tide mark throughout the region.

*Laminaria longicruris*, De La Pyl.—Common in sub-littoral zone off Head harbour. Common in sub-littoral zone at Welchpool, off Richardsonville, Deer island, off Herring cove, Campobello, and off Southern head, Grand Manan. This alga attains a larger size than any other in this region. The specimen shown in Fig. 3, Plate VIII, hanging on the wall of the residence at the Biological Station, had a blade five feet ten inches long and a stipe nine feet long.

*Laminaria digitata*, Lamx.—In tide-pools near low-tide mark on Spruce island. In tide-pools near low-tide mark at Head harbour.

*Saccorhiza dermatodea*, De La Pyl.—Common in upper sub-littoral zone at Welchpool.

*Agarum turneri*, Post. and Rupr.—Fairly common in the lower littoral and upper sub-littoral zone throughout the region.

*Alaria esculenta latifolia,* Post and Rupr.—Common at low-water mark at all outside points. Fig 4, Plate VIII, shows the lateral leaflets upon which the fruit is borne.

*Ascophyllum nodosum,* Le Jolis.—Abundant in the upper two-thirds of the littoral zone throughout the region. Fig 5, Plate VIII, shows the rocks near the Biological Station covered with this species and *Fucus vesciculosus.*

*Fucus vesciculosus,* Linn.—Abundant in the upper half of the littoral zone throughout the region. A form with very long vescicles and long receptacles occurs at the Biological Station, and a form with almost spherical receptacles is common on Adam island.

*Fucus evanescens, Agardh.*—Common in the lower half of the littoral zone at all outside points.

*Fucus furcatus,* Agardh.—Rare in a tide-pool near low-tide mark at Head harbour. Scarce in tide-pools at half-tide mark on Adam island. Common near low-tide mark on Bliss island.

## 4.—Rhodophyceæ.

*Porphyra umbilicalis,* J. Agardh.—Common in the littoral zone. Occurs in two forms, the umbillicate form of a brownish colour at outside points, and the expanded, laciniate form of a red or pale pinkish-green colour at inside points.

*Petrocelis cruenta,* J. Agardh.—On rocks at Head harbour and at Welchpool, in the littoral zone.

*Hildenbrantia rosea,* Kuetzing.—Common on stones in the lower part of the littoral zone throughout the region.

*Callithamnion rothii,* Lyngbye.—Reported from Grand Manan by Eaton.

*Callithamnion pylaisaei,* Mont.—Common on weir brush in the sub-littoral zone off Navy island. Cystocarps present, May 22.

*Ptilota elegans,* Bonnem.—Reported by Eaton from tide-pools on Campobello, and from Little Green island near Grand Manan.

*Ptilota serrata,* Kuetzing.—Dredged in 10 fathoms off Pendleton's island, in 27 fathoms off Harwood island, in 30 fathoms off MacMaster's island, and in 12 fathoms off Three islands, Grand Manan. One specimen found growing in a tide-pool at low-tide mark on the Black Ledges.

*Ceramium rubrum,* Agardh.—In tide-pools on Bliss island, and on Grand Manan.

*Halosaccion ramentaceum,* Agardh.—Common in lower littoral zone at Welchpool and in littoral zone at Herring cove, Campobello, and Grand harbour, Grand Manan. This species varies greatly in amount of branching.

*Halosaccion ramentaceum gladiatum,* Eaton.—Common at low-tide mark on Spruce island, mostly red and but little inflated. Frequent at low-tide mark in Little Letite, very large, brownish and much inflated. Scarce on the Black Ledges, rather small and but little inflated, red in young stages, brownish in older stage. Common on muddy gravel beach on Adam island. This variety was described by Eaton from Eastport material. Neither this form, nor the species are found at any inside point.

*Ahnfeltia plicata,* Fries.—Reported from Grand Manan by Eaton.

*Cystoclonium purpurascens*, Kuetzing.—Reported from Grand Manan and Campobello by Eaton.

*Gigartina mamillosa*, Agardh.—Common on rocks at low-tide mark throughout the region.

*Chrondrus crispus*, Stack.—Frequent in tide-pools in lower half of littoral zone at the Biological Station. Common in lower littoral zone at Welchpool and at Herring Cove.

*Rhodomenia palmata*, Greville.—Common near low-tide mark at all outside points. The only record for an inside point is one specimen found on weir brush below low-tide mark off Navy island.

*Rhodophyllis veprecula cirrhata*, Harvey.—Reported from Campobello and Grand Manan (under the name *Calliblepharis ciliata*) by Eaton.

*Polyides rotundus*, Greville.—Scarce in the sub-littoral zone at Head harbour.

*Euthora cristata*, J. Agardh.—Reported by Eaton from Campobello and Grand Manan.

*Delesseria sinuosa*, Lamx.—On *Ptilota serrata* dredged in 27 fathoms off Harwood island. Common on the Tunicate, *Caesira canadensis*, on weir brush in sub-littoral zone off Navy island. Dredged in 12 fathoms off Three islands, Grand Manan.

*Rhodomela subfusca*, Agarth.—In tide-pools on Bliss island.

*Polysiphonia urceolata formosa*, Agarth.—Common on weir brush at and below low-tide mark off Navy island. Scarce on rocks at low-tide mark at Head harbour.

*Polysiphonia fastigiata*, Greville.—Common on *Ascophyllum nodosum* throughout the region.

*Corallina officinalis*, Linn.—Common at low-tide mark on Spruce island, at Head harbour and on Grand Manan. Scarce on rocks in a tide-pool near low-tide mark on Short Bar near St. Andrews.

*Melobesia lejolisii*, Rosanoff.—Common on *Zostera marina* in Kitty's cove, St. Andrews.

*Lithothamnion polmorphum*, Aresch.—Common in the sub-littoral zone throughout the region.

*Lithothamnion fasciculatum*, Aresch.—Dredged in the Narrows off Campobello and off Grand Manan.

## EXPLANATION OF PLATE.

### Plate VIII.

Fig. 1. Tide-pool on Short Bar, St. Andrews.
" 2. Tidal creek, the habitat of *Enteromorpha intestinalis*.
" 3. Specimen of *Laminaria longicruris*, Biological Station, St. Andrews.
" 4. Specimen of *Alaria esculenta latifolia*.
" 5. Rocks, at about half-tide, St. Andrews, covered with *Fusus vesiculosus* and *Ascophyllum nodosum*.

Fig 1 TIDE POOL ON SHORT BAR – ST. ANDREWS N.B.

Fig 3 LAMINARIA LONGICRURIS

Fig 4 ALARIA ESCULENTA LATIFOLIA

Fig 2 TIDAL CREEK – the habitat of ENTEROMORPHA INTESTINALIS

Fig 5 ROCKS ABOUT HALF-TIDE, ST ANDREWS, COVERED with FUCUS VESCICULOSUS and ASCOPHYLLUM NODOSUM

# ON SERIALLY STRIPED HADDOCK IN NEW BRUNSWICK.

BY

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(With one Plate).

Interesting striped specimens of the common haddock (*Gadus aeglefinus*) have been brought at times to the Atlantic Biological Station, which are noteworthy on account of the contrast which they present to the usual type brought in by the fishermen. They exhibit a series of broad bands and blotches of dark pigment on each side of the body, from the shoulder to the tail. The specimens do not seem to be by any means rare in Passamaquoddy bay, adjacent to St. Andrews, where the Biological Station is situated, and they are of some interest in themselves, and of wider interest in connection with the coloration of fishes, and of animals generally.

The usual coloration of the haddock, to quote from Jordan and Evermann (1, page 2543) is "dark grey above, whitish below, lateral line black, a large blotch above the pectorals, dorsals and caudal dusky"; but the freshly-caught haddock exhibits other striking colour features. The dorsal surface is, indeed, usually of a metallic purplish hue, darkest in the upper portions, and becoming paler down the sides, where it merges in the pearly white colour of the throat and under-surface of the body. Immediately below the thin blackish lateral line a large sooty spot occurs, forming a prominent feature a little below the mid-portion of the high first dorsal fin (Plate IX., fig. 1). The black spot, variously called "Satan's thumb-mark," or "St. Peter's finger-mark," is about the size and shape of a large black thumb mark. In the drawings which illustrate this brief paper (Plate IX., figs. 2 and 3) it will be noticed that one specimen, fig. 2, shows no less than six "thumb marks," or dark blotches, while the other (fig. 3) shows traces, more or less distinct, of four transverse stripes. The first specimen, measuring 11 in. (279 mm.) from snout to base of tail fin, *i.e.*, the tip of the caudal trunk; or 11¾ inches to the free hind-border of the tail fin, exhibited three very prominent pigment patches, the most anterior being below the middle of the first dorsal fin, whose base measured 1⁵⁄₁₆-inch, and this patch was ⁹⁄₁₆-inch broad, and extended from the base of the fin above to the usual distance below the lateral line, terminating behind and above the pectoral fin. This patch appeared like the usual dark thumb-mark; but a paler extension continued upward to the contour line of the dorsum. It was the most deeply tinted patch in the series, and especially dense below the lateral line. The next large patch occurred below the mid-portion of the second dorsal fin, more faintly coloured, and exactly ¾ of an inch in breadth; the breadth of the fin above, along its base, being 2⅝ inches. This second band passed down from the base of the fin to a considerable distance below the lateral line, indeed, down to a point within a quarter of an inch of the ventral contour line. The third large band, of a pale greyish tint, occurred between the mid-portion of the third dorsal fin (whose base is 1⁹⁄₁₆-inch long) and extends to a little distance below the lateral line. It was ¹¹⁄₁₆-inch in breadth. Between these three major transverse stripes or bands there appeared minor patches, the first being merely a rounded pale greyish spot, ⁵⁄₁₆-inch across and occurring midway down the side of the body, a little distance below the curved lateral line, and above the position of the anus. The next minor patch, also about ⁵⁄₁₆-inch in diameter, occurred on the lateral line, partly above and partly below, and midway between the dorsum and the anterior margin of the second anal fin below. Some obscure pigment above the patch suggests that it was really an interrupted transverse band passing from the posterior eighth of the second dorsal fin and extending, as just stated, to a point below the lateral line. Lastly, a third minor patch of blackish grey extending from the anterior margin of the upper caudal fin lobe reached almost to the lateral line. It was a pale, irregular patch about ¼-inch across. The three marked major stripes, and the three more obscure minor spots, formed a series of six dark patches from the shoulder to the tail.

The second specimen (Fig. 3) was larger than the haddock just described, being 15 in. long (406 mm.), inclusive of caudal fin. Exclusive of the tail-fin it measured 14 in. (354 mm.), from tip of the snout to tip of caudal trunk. Along each side of the fish were four transverse bands or patches of dark pigment, the breadth of each being respectively, first stripe, 11/16-inch; second stripe, ⅞-inch; third stripe, ½-inch; and the fourth stripe or patch, ⅜-inch. The length of the base of each of the three dorsal fins was, respectively, 2½-inch, 2⅞-inch, and 2½-inch. The first dark patch extended from the middle of the base of the first dorsal fin to the lateral line, and spread downwards to a point midway between the lateral line and the ventral contour of the fish. The second patch, extending from the middle of the base of the second dorsal fin almost to the anterior edge, was very pale, and passed over the lateral line to a point midway between that line and the anus. Both these bands or patches were darker below the lateral line than above it, and the first band was very dark in its lower portion. The third band, extending over the anterior half of the base of the third dorsal fin, passed downward as a tongue-shaped patch to the lateral line, and just beyond it, while the fourth band appeared simply as a rounded indefinite blotch, in front of the dorsal portion of the caudal fin, and passing barely to the lateral line. In this haddock three of the four bands clearly correspond to the three major patches in the first specimen, and in position and shape each series closely resembled the other, while the last patch on the dorsal portion of the caudal trunk in each also showed close resemblance; but the two extra minor blotches in the first specimen did not seem to be represented in the second. It is interesting to recall the fact that a closely related species, the European bib or pout (*Gadus luscus*) frequently exhibits cross bands along the sides, in addition to " a black axillary spot behind the base of the pectoral fin," according to Dr. Gunther (2, p. 541). Dr. H. C. Williamson, in his masterly and thorough paper on the specific characters of *G. luscus* and other Gadoids (8, p. 137), states that the axillary mark "is a large blue-black patch covering the sides of the axilla, and extending out on the clavicle and over the base of the pectoral fin," and it is present in *G. minutus* and *G. esmarkii,* but is much more limited in area.

Professor W. C. McIntosh gave an interesting account, seven or eight years ago, of some young specimens of the European bib, *Gadus luscus,* showing bold transverse bars of pigment (3, pp. 153-154); but he pointed out that specimens captured in the nets of the shrimp-trawlers, at the mouth of the Thames, were not banded, and he referred to the view of Couch and Malm that the striped condition is an occasional occurrence only. Professor McIntosh's small barred specimen was only about 2⅘ inches (70 mm.) long, and was obtained on April 3, 1908, at St. Andrews, Scotland. The fish was of a reddish brown colour on the sides, variegated by four well-marked broad black bands (Plate IX., fig. 4). A broad stripe passed from the dorsum, between the first and second dorsal fin, down the side to the ventral border; while the second band, darker and more definite, extending from the last third of the second dorsal fin to the base of the third dorsal fin, passed diagonally down to the posterior part of the base of the first anal fin. The last stripe covered the side of the caudal trunk from a line drawn to the hind margin of the second anal, from the hind margin of the third dorsal fin. On the top of the head occurred a large dark patch, and the dorsal and ventral edges of the body showed much black pigment; and black spots occurred in the dorso-lateral region, and minute specks upon the fins. An upper opercular patch, and a patch at the base of the pectoral fin also were discernible. Similarly four dark stripes were observed in a larger specimen of *Gadus luscus* (193 mm.) 7⅝ inches long, described by Professor McIntosh. The first stripe occurred in the shoulder region, passing from the front of the first dorsal fin, and including its anterior third, and extending to the pectoral fin. The second stripe passed ventrally from a point anterior to the middle of the base of the second dorsal fin, while the third stripe, or belt, spread diagonally downward from the posterior third of the second dorsal fin to the ventral border of the turnk. Only traces were discernible of the fourth patch or stripe, on the surface of the caudal trunk near the base of the tail.

What is the meaning of this phenomenon? How can the occasional appearance of definite serial stripes or patches be accounted for, in species of fish and other animals in which normally they are absent? It would be interesting to trace out embryologically the development of a banded or barred arrangement in the external coloration of fishes, and to point out examples, discovered in recent years, of larval and post-larval arrangements of pigment in the integument; but in this paper the attempt will not be made, and a few salient points alone will be set forth. Most people familiar with our common food fishes have asked the question, "What is the explanation of the black thumb-mark on the shoulder of the haddock?" Why do not closely related fishes such as the cod, pollock, and other species, exhibit similar dark patches or spots? The English whiting (*Gadus merlangus*) does show a patch of black at the base of the pectoral fin or rather in the axil of the fin, and the post-larval stage 1⅛-inch (28 mm.) long, shows thirteen or more spots or partial stripes of black along the dorsum, as Professor McIntosh has described and figured, 4, p. 17, *vide* Plate IX., fig. 5. Dr. Gunther pointed out (2, p. 540) that in Greenland, Iceland, and Northern Scandinavia, the common cod exhibits a large irregular blotch of black pigment on the side; but the absence of striking dark patches in species closely related, as just stated, can only be explained on the ground that such stripes are of little utility, and that a barred coloration is not essential to the welfare of the fish. There are many living creatures to which a patched or banded condition appears to be of vital importance. Spots and stripes have been proved to be of value for protective purposes, especially for concealment, but such purposes cannot be served by the presence of dark bands along the body in the haddock or bib, and any key to the origin and meaning of such coloration must be sought more remotely. There can be little doubt that the significance of these serial stripes is ancestral. Beddard called attention to the fact (6, p. 19) that among segmented creatures, like worms, caterpillars, etc., we find a pattern of coloration conforming exactly to the segmentation of the body. Rings of colour correspond to the rings of the body. Now, in their earliest larval condition young fishes have a long cylindrical body, like a worm or eel, and it shows division into segments or serial body-rings, called metameres. May it not be the case that the bars or serial patches of colour primitively correspond to the muscle-segments, the myotomes or metameres?* If a segmented body be typical of the ancestral form of animals, there is strong presumption that repeated spots and stripes along the surface of the body may be ancestral also. As I ventured to point out in a paper on this subject of "Animal Coloration" (7, pp. 154-155): "In some flat fishes the bars along the sides of the body divide into spots or large patches, four rows of them, and still preserving their metameric or serial succession from the head to the tail. Thus from successive cross-stripes the spots arise, and these surface arrangements of colour continue long after the internal organs, the muscles, etc., have wholly altered their original anatomical arrangement. Further, the successive series of spots may unite later as longitudinal stripes, and such stripes we find in the post-larval ling (*Molva*)." We have thus a key to the arrangement of

*The late Professor J. A. Ryder said (Embryography of Osseous Fishes, U.S. Fish Comm. Rep. 1882, Washington, 1884, p. 502): "The pigment cells are stellate, and exhibit a slow amoeboid or migratory movement as development proceeds, becoming aggregated at a later period by this means into patches upon definite regions of the body."

colour in a vast number of animals. Professor McIntosh's description of the young cod is interesting: "The minute larval cod escapes from the egg," says that authority, "marked by a series of transverse bars, then the black pigment is re-arranged longitudinally along the dorsum as it swims high in the water. To this is added, by and by, yellow pigment, causing (with the black) a greenish hue. When it seeks the rocky margins it becomes boldly tessellated. . . . . . the larval haddock has no transverse bars, though bred side by side with the cod; but the dorsal band of black pigment is developed in the next stage (post-larval). Instead of seeking the shore the little haddock keeps to deep water, and it soon develops the characteristic bold touches of black on the sides above the pectoral region." (5, p. 237.)

But the presence of stripes or transverse bars of colour is not confined to pelagic larval fishes out in the open sea, like cod, etc., for even familiar shore fishes in their young stages often show this striking arrangement of pigment. Thus I find in the common cunner, or sea perch (*Tautogolabrus adspersus*) so abundant along our eastern shores, the young forms exhibit the transverse bars, eight or nine dark ochre bands richly spotted with black dots, extending from the head region to the base of the tail, when the fish is barely half-an-inch long (13.5 mm.). See Plate IX., fig. 8. The young salmon of the Pacific and Atlantic rivers, as is well known, show definite stripes. The young sockeye or red salmon, *Oncorhynchus nerka,* seven months old, shows eleven to twelve bars, and the Atlantic salmon parr, *Salmo salar,* shows nine or ten such bars or stripes. (Plate IX., figs. 6 and 7). The pigment spots, of which these coloured bands and patches are composed, are rounded particles of naked protoplasm, packed with coloured granules and capable of contracting and expanding in stellate form. The centre or nucleus is often more deeply coloured than the rest of the corpuscle. A group of such pigment corpuscles or cells from the skin of a young fish $\frac{1}{3}$ of an inch long (a larval *Gastrosteus aculeatus* 8·9 mm.) are shown on Plate IX., fig. 9. These coloured particles move with such facility under the influence of light or electrical, chemical and nervous stimuli, that the arrangements of colour may undergo very rapid changes. The tranformation of spots into bars, by serial aggregation, or the separation of transverse stripes into separate rounded patches, can be readily understood. But the most interesting point that arises in connection with these striped haddocks is this, that they demonstrate the resumption at times of an arrangement of colour, which must have ancestrally applied to the species as a whole; but now appears only erratically and locally. The causes of such ancestral reminiscence are obscure and little understood. Ancestral traits, long lost, even amongst human beings, occasionally reappear, and amongst such fishes as the haddock, an ancestral, long-lost arrangement of external coloration is revived at times, and may even become marked as a not infrequent local variation as in the striped Passamaquoddy haddocks.

The black stripes have disappeared altogether in the adult cod; but a remnant persists in the ordinary haddock as a black blotch in the shoulder region, the dark "thumb-mark." Such blotches or thumb-marks, when repeated serially, must be regarded therefore as atavistic, a reappearance of an ancestral trait or feature, which in most specimens has practically disappeared.

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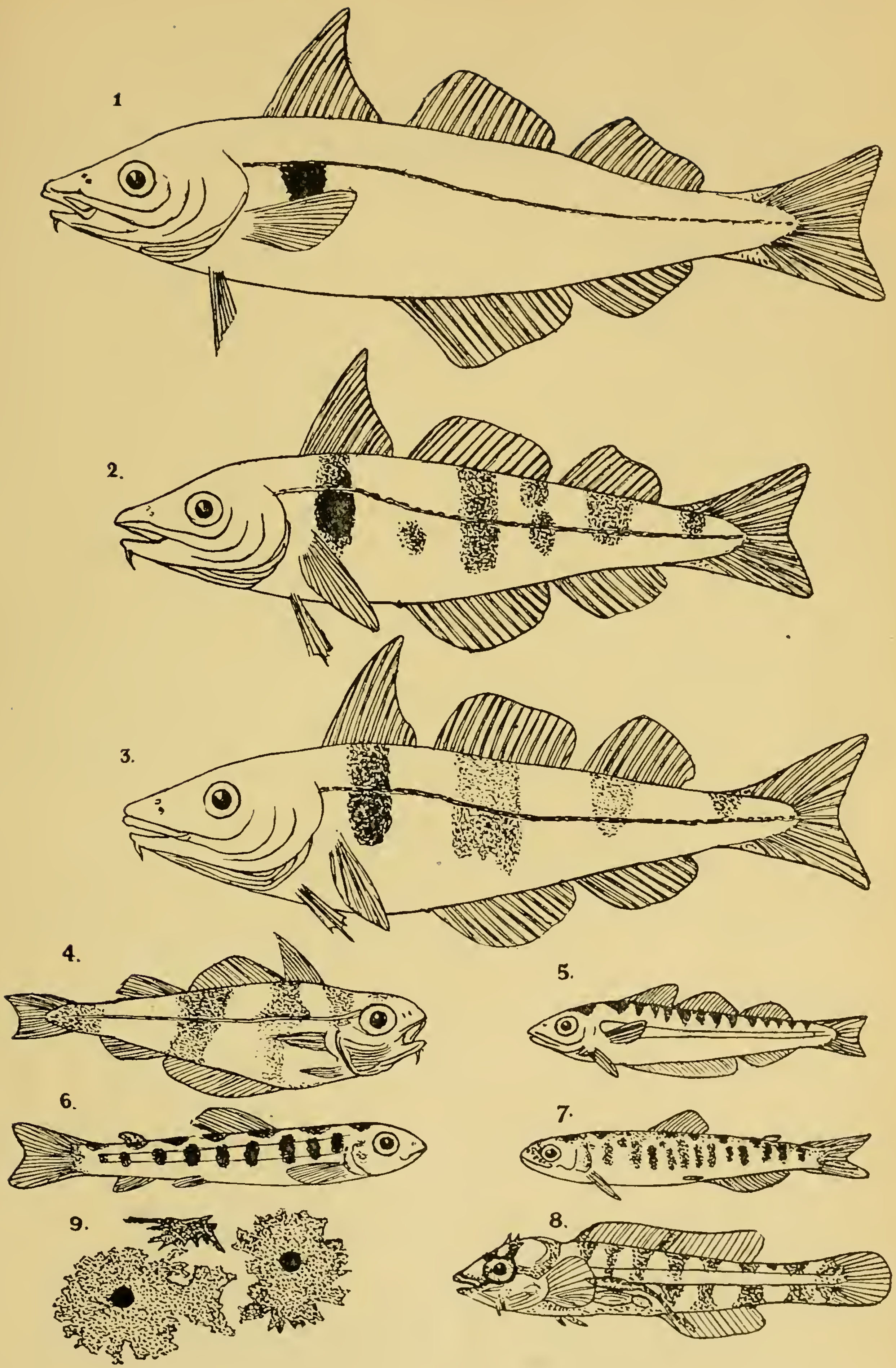
## EXPLANATION OF PLATE.

### PLATE IX.

Fig. 1. Haddock, *Gadus aeglefinus*, showing usual "thumb-mark."
" 2. Haddock, *Gadus aeglefinus* (11¾-inch long), with six transverse bars or thumb-marks.
" 3. Haddock, *Gadus aeglefinus* (15-inch long), with four transverse bars or thumb-marks.
" 4. European Bib, *Gadus luscus* (2⅘-inch long), with four transverse bars, after W. C. McIntosh.
" 5. European Whiting, *G. merlangus* (1⅛-inch long), with thirteen partial bars.
" 6. Atlantic Salmon parr, *Salmo salar*, with nine lateral patches enlarged one-third.
" 7. Pacific Sockeye salmon parr, *Oncorhynchus nerka*, eight months old, with 12 or 14 lateral patches, somewhat enlarged.
" 8. Cunner or Sea Perch, *Tautogolabrus adspersus* (½-inch long), with nine lateral bars.
" 9. Black Chromatophores or pigment spots in the skin of the Stickleback (*G. aculeatus*). × 250.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# NOTES ON THE PHYTO-PLANKTON OF THE BAY OF FUNDY AND PASSAMAQUODDY BAY.

By L. W. Bailey, M.A., Ph.D., LL.D., F.R.S.C., *Emeritus Professor of Natural History in the University of New Brunswick, Fredericton, N.B.*

In previous publications relating to the Diatoms of New Brunswick and Prince Edward Island, fairly complete lists of these, as found at a series of localities along the Atlantic coast, have been given, but no attempt has been made to distinguish between littoral or neritic and deeper water or planktonic forms, or to show the relations of either of these to differences of season and environment. Yet it is obvious that, as with other plants, such varying relationships do exist, and as their varying abundance must directly affect the food supply of the different animals, such as young fishes, oysters, etc., which feed upon them, as complete a knowledge as possible upon these points is highly desirable.

The present notes are intended mainly to apply to the Phyto-Plankton of the bay of Fundy and Passamaquoddy bay, though occasional references are made to points on the north shore of New Brunswick and to Prince Edward Island. Moreover, as the line between planktonic and non-planktonic forms is ill-defined, species ordinarily regarded as neritic are not unfrequently met with far from shore, and may even constitute a considerable part of any planktonic gathering. In the following pages, lists of such gatherings from numerous localities are given for the various months of the year, excepting December, for which latter month no data are yet available.

## I. SEASONAL AND DISTRIBUTIONAL VARIATIONS IN THE PHYTO-PLANKTON.

(*a*) *January.*

The following records were made during this month:—

Biological Station, January 1.

*Chætoceras decipiens*, Cleve. Abundant.
*Biddulphia aurita*, Breb.
*Coscinodiscus eccentricus*, Ehr.
A fine Radiolarian (*Actinophrys*?).

Chance Harbour, January 12.

Diatoms few, mainly—
*Coscinodiscus eccentricus*, Ehr.
*Actinoptychus undulatus*, Kutz.
*Chætoceras decipiens* (few).
*Biddulphia Mobilensis*, Bailey.

Bald Head, January 15.

*Biddulphia Mobilensis*, Bail.=*B. Baileyi*, Sm.
*Coscinodiscus eccentricus*, Ehr.
*Chætoceras decipiens*, Cleve. = *Ch. sociale*, Land.
*Skeletonema costatum*, Grev.
*Fragillaria.*

Wilson's Beach, January 16.

*Biddulphia Mobilensis*, Bail.
*Coscinodiscus eccentricus*, Ehr. Common.
*Rhizosolenia setigera*, Br.

Friar's Bay, Campobello, January 26.

Diatoms few.
*Chætoceras decipiens*, Cleve.

Head Harbour, Campobello, January 27.

*Biddulphia Mobilensis*, Bail.
*Coscinodiscus eccentricus*, Ehr.
" *concinnus*, W. Sm.
*Chætoceras decipiens*, Cleve.
" *boreale*, Bail. Rare.
*Rhizosolenia setigera*, Br.

St. John Harbour, January 27.

Diatoms few.
*Biddulphia Mobilensis*, Bail.
*Actinoptychus undulatus*, Kutz.
*Coscinodiscus eccentricus*, Ehr.
*Paralia sulcata*.
*Rhizosolenia setigera*, Br.

Seely's Cove, January 31.

*Biddulphia Mobilensis*, Bail.
*Coscinodiscus asteromphalus*, Ehr.
" *concinnus*, W.S.
*Chætoceras decipiens*. Rare.
*Rhizosolenia setigera*, Br.

Friar's Bay, Campobello, January 30.

*Cocconeis scutellum*, Ehr. In clusters on algæ. Abundant.

Letite.

*Thalassiosira sociale*. One specimen only.

Lepreau, January 29. Water temperature, 33° F.

*Biddulphia Mobilensis*, Bail.
*Pleurosigma formosum*, W.S.

(*b*) February.

The Plankton during this month is much richer, both in number and variety, than that of the preceding month. The following observations have been made:—

St. Andrews Harbour, February 19.

*Chætoceras decipiens*, Cleve.
" *sociale*.
*Coscinodiscus eccentricus*, Ehr.
" *radiatus*, Grun.
" *asteromphalus*, Ehr.
" *concinnus*, W.S.
*Biddulphia aurita*, Breb.
" *pulchella*, Gr.

*Melosira subflexilis,* Kutz.
*Pleurosigma decorum,* Sm.
" *formosum,* W.S.
" *strigosum* (?) W.S.
*Rhizosolenia setigera,* Br.
*Paralia sulcata.*
*Skeletonema costatum,* Grev.
*Thalassiosira Nordenskioldii,* Cleve.

Biological Station, St. Andrews, February 27.



*Biddulphia aurita,* Breb.
*Actinoptychus undulatus,* Ehr.
*Chætoceras sociale,* Land.
" *decipiens,* Cl.
*Coscinodiscus eccentricus,* Ehr.
*Grammatophora marina,* Kutz.
*Pleurosigma fasciola,* Sm.
" *decorum.*
*Thalassiosira Nordenskioldii,* Cleve.
*Thalassiothrix.*
*Rhizosolenia setigera,* Br.

Manawagonish, St. John County, N.B., February 5.

*Coscinodiscus eccentricus,* Ehr.
*Ditylum Brightwellii,* Grun.
*Rhizosolenia setigera,* Br.
*Skeletonema costatum,* Grev.
*Thalassiosira nitschioides.*

St. John, Reversing Falls, February 14. Temperature, 32° F.

*Actinoptychus undulatus,* Ehr.
*Biddulphia Mobilensis,* Bail.
*Coscinodiscus asteromphalus,* Ehr.
" *eccentricus,* Ehr.
" *radiatus,* Ehr.
*Melosira subflexilis,* Kutz.
*Pleurosigma formosum.*
" *fasciola,* W.S.

(*c*) *March.*

St. Andrews, N.B., West Light, March 17.

*Chætoceras decipiens,* Cleve.
" *sociale.*
*Coscinodiscus concinnus,* W.S., with chromatophores.
*Biddulphia aurita,* Breb.
*Pleurosigma.*
*Thalassiosira Nordenskioldii,* Cleve.

Joe's Point.

*Biddulphia aurita,* Breb.
" *pulchella.*
*Chætoceras decipiens,* Cleve.

*Coscinodiscus asteromphalus,* Ehr.
" *concinnus,* W.S.
" *radiatus,* Grun.
*Melosira subflexilis,* Kutz.
*Rhizosolenia setigera,* Br.

Doucett's (Dochet) Island, March 27.

*Chætoceras decipiens,* Cl.
" *sociale.*
*Coscinodiscus eccentricus,* Ehr.
*Biddulphia pulchella.*
" *aurita,* Breb.
*Pleurosigma.*
*Thalassiosira Nordenskioldii,* Cl.

St. Croix River, at mouth, March 28.

Diatoms abundant.
*Biddulphia aurita,* Breb. Common.
" *pulchella,* Gray. Common.
*Chætoceras decipiens,* Cl.
*Coscinodiscus concinnus,* W.S. Common.
" *asteromphalus,* Ehr. Common.
" *radiatus,* Grun. Rare.
*Fragillaria capucina,* Desm.
*Melosira varians,* Ag.
*Rhizosolenia setigera,* Br.
*Thalassiosira Nordenskioldii,* Cl.

Doucett's (Dochet) Island, March 27.

*Chætoceras decipiens,* Cl.
" *sociale.*
*Coscinodiscus eccentricus,* Ehr.
*Biddulphia pulchella,* Gray.
" *aurita,* Breb.
*Pleurosigma.*
*Thalassiosira Nordenskioldii,* Cleve.

St. Andrews Harbour, March 4.

*Biddulphia aurita,* Breb.
*Chætoceras decipiens,* Cl.
" *sociale,* Land.
*Coscinodiscus asteromphalus,* Ehr.
*Melosira Jerghensii,* Ag.
*Pleurosigma.*

Letite, March 28.

*Biddulphia aurita,* Breb. Common.
" *pulchella,* Gray. Abundant.
*Coscinodiscus asteromphalus,* Ehr. Common.
" *concinnus,* W.S. Common.
*Chætoceras decipiens,* Cl. Common.
" *boreale,* Bail. Rare.

(*d*) *April.*

St. Andrews, April 19.

*Biddulphia aurita*, Breb.
" *pulchella*, Gray.
*Coscinodiscus eccentricus*, Ehr.
" *concinnus*, W.S.
*Chætoceras decipiens*, Cl.
" *sociale*, Land.
*Fragillaria capucina.*
*Thalassiosira Nordenskioldii*, Cl.

St. Andrews, April 9.

*Actinoptychus undulatus*, Ehr.
*Chætoceras decipiens*, Cl. Few.
*Biddulphia aurita*, Breb.
*Coscinodiscus eccentricus*, Ehr.
*Ditylum Brightwellii*, Grun.
*Nitschia sigmoidea*, W.S.
" *closterium.*
*Melosira Jerghensii*, Ag.
*Pleurosigma fasciola*, W.S.
" *intermedium*, and others.

St. Andrews Harbour, April 17.

*Biddulphia aurita*, Breb. Abundant.
*Chætoceras decipiens*, Cleve.
*Coscinodiscus asteromphalus*, Ehr., with Chromatophores.
*Thalassiosira Nordenskioldii.* Two varieties. Very abundant.

Similar forms are met with at Navy island, Little Douchet islands, Mill Cove, Eastport, Campobello, and other points.

(*e*) *May.*

Robbinston, Me., in the waters opposite the Biological Station, St. Andrews, N.B., May 23 and 25.

*Biddulphia pulchella*, Gray.
*Chætoceras decipiens*, Cl.
*Coscinodiscus concinnus*, Sm.
*Fragillaria capucina*, Desm.
*Pleurosigma decorum.* Rare.
" (indt.).
*Rhizosolenia setigera*, Br.
*Thalassiosira Nordenskioldii*, Cl. Common.

(*f*) *June.*

West Quoddy, June 17.

*Actinoptychus undulatus*, Kutz.
*Coscinodiscus.* Rare.
*Cocconeis scutellum*, Ehr.
*Gomphonema marinum.*
*Grammatophora serpentina*, Ehr.
" *marina*, Kutz. Common in chains.
*Navicula.*
*Pleurosigma fasciola*, W.S.
*Rhabdonema arcuatum*, Kutz.

Biological Station, June 28.

*Actinoptychus undulatus,* Kutz.
*Biddulphia aurita,* Breb.
*Coscinodiscus eccentricus,* Ehr.
*Melosira Jerghensii,* Ag.
*Navicula distans.*
" *viridis,* Kutz.
*Pleurosigma Balticum,* W.S.
" *fasciola,* W.S.
*Tabellaria.*
*Stephanopyxis.*
*Nitschia closterium,* W.S.
" *vermicularis,* Grun.
*Rhabdonema arcuatum,* Kutz.

(*g*) *July.*

St. Andrews, N.B., near Indian Point, July 7.

*Biddulphia aurita,* Breb.
*Chætoceras.*
*Coscinodiscus.*
*Navicula.*
*Pleurosigma strigosum* (?).
*Nitschia sigma,* Sm.
*Rhabdonema arcuatum,* Kutz.
*Synedra.*

Some *Protozoans* were found and determined in this July collection, viz.:—

*Tintinnopsis.* Common.
*Amphorella subulata.*
*Rotalia.*
*Discorbina.*
*Spirillina* (?).
*Distephanus speculum.*

Eastport, Me., July 29.

*Skeletonema costatum,* Grev.
*Actinoptychus undulatus,* Ehr.
*Amphiprora alata,* Kutz.
*Thalassiosira Nordenskioldii,* Cleve.
*Chætoceras decipiens,* Cl.
" *sociale,* Land.
*Coscinodisus asteromphalus,* Ehr.
" *concinnus,* S.M.
" *eccentricus,* Ehr.

(*h*) *August.*

Friar's Bay, Campobello, August 1.

*Fragillaria capucina,* Desm.
*Chætoceras decipiens,* Cl.
" *crinitum,* Schutt.
*Nitschia seriata,* Cl.
*Rhoicosphrenia curvata,* Grun.
*Rhizosolenia setigera,* Br.
*Skeletonema costatum,* Grev. Rare.

Eastport, August.

*Coscinodiscus asteromphalus,* Ehr.
" *concinnus,* W.S.
*Isthmia nervosa.* Rare.
*Grammatophora serpentina,* Ehr.

West Quoddy.

*Actinoptychus undulatus,* Ehr.
*Fragillaria.*
*Cyclotella.*
*Grammatophora marina,* Kutz.
" *serpentina,* Ehr.

Chamcook Harbour.

*Coscinodiscus asteromphalus,* Ehr. Common.
" *concinnus,* W.S. Common.

White Horse.

*Coscinodiscus eccentricus,* Ehr. Common.
" *asteromphalus,* Ehr. Common.

St. Martins, August, 1910.

*Amphora.*
*Amphiprora alata,* Kutz.
*Amphipleura sigmoidea,* W.S.
*Actinoptychus undulatus,* Kutz.
*Coscinodiscus eccentricus,* Ehr.
*Grammatophora marina,* Kutz.
*Melosira nummuloides,* Ag.
" *Jerghensii,* Ag.
*Navicula Smithi,* Breb.
" *didyma,* Kutz.
" *rhyncocephala,* Kutz.
" *distans.*
*Nitschia sigma,* W.S.
" *sigmoidea,* W.S.
" *dubia.*
" *vermicularis,* Hautz.
*Pleurosigma obscurum,* W.S.
*Plagiotropis vitrea,* Grun.
*Rhabdonema arcuatum.* K.
*Stauroneis salina,* W.S.
*Surirella striata.*
" *ovalis,* Breb.
" *constricta.*
" *Molleriana* (?) Grun.
*Synedra gracilis.*
" *radians,* W.S.
*Triceratium alternans,* Bail.
*Tryblionella.*

L'Etang Harbour, August 10.

*Coscinodiscus asteromphalus,* Ehr. Very abundant.
*Biddulphia Mobilensis,* Bailey.
*Chætoceras.*

*Cocconeis scutellum*, Ehr. Rare.
" *placentula*, Ehr.
*Grammatophora serpentina*, Ehr.
*Paralia (Melosira) sulcata.*
*Nitschia sigma*, W.S.
*Rhizosolenia setigera*, Br.
*Pleurosigma fasciola*, Sm.
" *formosum*, W.S.
*Skeletonema costatum*, Grev.
*Thalassiosira Nordenskioldii*, Cleve.

Deadman's Harbour, August 10.

*Chætoceras.* Common.
*Ditylum Brightwellii*, Grun. Common.
*Asterionella.* Very rare.
*Rhizosolenia setigera*, Br.
*Skeletonema costata.* Common.
*Thalassiosira Nordenskioldii*, Cl.

Tynemouth Creek, St. John County, N.B., August.

*Chætoceras.*
*Biddulphia Mobilensis* (= *B. Baileyi*), in great numbers, making up the larger part of the plankton.
*Coscinodiscus asteromphalus*, Ehr.
" *radiatus*, Ehr.
*Doryphora amphiceros*, Kutz. (= *Raphoneis*).
*Pleurosigma Balticum*, Sm.
*Actinoptychus undulatus.*
*Rhizosolenia setigera.*
*Navicula didyma.*

Narrows of St. John River, New Brunswick, August 10.

*Actinoptychus undulatus*, Ehr.
*Asterionella.*
*Amphiprora ornata*, Bail.
*Bacillaria paradoxa*, Gmel.
*Coscinodiscus minor*, Ehr.
*Doryphora Boeckii*, W.S.
*Gomphonema.*
*Campylodiscus cribrosus*, W.S.
*Cocconeis scutellum*, Ehr.
*Melosira nummuloides.*
" *subflexilis.*
*Navicula elliptica*, K.
" *viridis*, Kg.
" *ovalis*, W.S.
*Pleurosigma.*
*Synedra salina*, W.S.
*Surirella striatula*, Turp.
*Tabellaria fenestrata*, Kutz.
*Tryblionella.*
*Rhoicosphenia curvata*, Grun.
*Homœcladia sigmoidea*, W.S.
*Zygoceros (Biddulphia) Mobilensis*, Bail.
*Isthmia enervis*, Ehr.

St. John Harbour and Docks, August.

*Actinoptychus undulatus.*
*Amphiprora alata.*
*Acnanthes longipes.*
" *subsessilis.*
*Bacillaria paradoxa.*
*Biddulphia aurita.* Common.
*Cocconeis scutellum.*
" *pediculus.*
*Coscinodiscus radiatus.*
" *minor.*
" *eccentricus.*
*Cocconema cistula.*
*Cyclotella striata.*
*Gomphonema geminatum.*
*Melosira nummuloides.*
" *Jerghensii.*
" *varians.*
*Navicula didyma.*
" *maculata.*
" *ovalis.*
" *distans.*
*Nitschia closterium.*
" *sigmoidea.*
" *vermicularis,* Hantz.
*Orthosira marina.*
*Pleurosigma fasciola.*
*Rhabdonema arcuatum.*
" *minutum.*
*Surirella gemma.*
*Tryblionella gracilis.*
*Triceratium alternans.*
*Raphoneis (Doryphora) Boeckii.*
" *amphiceros.*

(*i*) *September.*

"PRINCE" COLLECTION.

September 8. Station 17, Yarmouth Harbour; 7 fathoms.
Diatoms almost wanting in the plankton.

September 18. Station 5, Bay of Fundy, between Head Harbour and the Wolves; 51 fathoms.
*Skeletonema.* Abundant.
*Nitschia seriata.* Rare.
*Coscinodiscus,* with bright green chromatophores.

September 19. Station 20, Bay of Fundy, off St. John Harbour.
Diatoms few. Copepods abundant.

September 20. Station 21, Kennebecasis Bay, at east end of Long Island.
Copepods only.

September 21. Station 22, St. John River, near mouth of Kennebecasis River.
*Melosira subflexilis.*
*Thalassionema.*

September 21. Station 23, Bay of Fundy, between St. John and Digby, N.S.
*Melosira subflexilis*, in numerous chains and the only Diatom present excepting *Biddulphia Mobilensis*, rare. Copepods abundant.

September 22. Station 26, Annapolis Basin, above Annapolis.
A few *Coscinodisci* occurred.

September 23. Station 24, Bay of Fundy, between St. John and Digby.
No diatoms. Copepods only.

September 23. Station 25, Bay of Fundy, off Digby Gut.
No diatoms.

September 25. Station 26, Basin in river inside Annapolis Royal.
*Rhizosolenia setigera* abundant in fine groups. Copepods abundant.

September 26. Station 27, Annapolis River, near Goat Island.
*Rhizosolenia setigera* abundant, but no other diatoms present.

September 27. Station 28, lower end of Annapolis Basin.
*Coscinodiscus.*
*Rhizosolenia setigera*, with spear-like terminal spine.

(*j*) *October.*

October 3. Station 4, Passamaquoddy Bay.
Great quantities of *Synedra*-like cylinders dotted on margins. Supposed to be a variety of *Thalassionema*. Other forms wanting.

October 9. Station 6, St Croix River between the Biological Station and Robbinston, Me.
Same as Station 4.

October 16. Station 10, Eastern Entrance to St. Andrews Harbour.
*Ditylum.* Abundant, with chromatophores.
*Chætoceras decipiens.*
*Coscinodiscus eccentricus.* Rare.
*Rhizosolenia setigera.*

October 2. Station 6, St. Croix River.
*Coscinodiscus asteromphalus.*
" *radiatus.*
*Ditylum.* Rare.
*Thalassionema* (?).

October 19. Station 19, St. John Harbour.
*Biddulphia Mobilensis*, in chains.
*Coscinodiscus.* Rare.
*Rhizosolenia setigera.*

October 3. Station 9, Off Grand Manan.

*Coscinodiscus eccentricus.*
*Chætoceras decipiens.* Rare.
*Ditylum.* Common.
*Rhizosolenia setigera.* Common.
*Thalassionema* (?). Very abundant.
Copepods few.

October 9. Station 10, St. Andrews Harbour.

Principally *Thalassionema.* Abundant.
*Chætoceras decipiens.*
*Ditylum.* With fringed extremities. Rare.
*Rhizosolenia setigera.*
Copepods few.

October 27. Station 25, Bay of Fundy, off Digby Gut.

*Chætoceras decipiens.*
*Thalassionema.* Abundant.
Copepods, etc. Abundant.

## II. NOTES ON THE MORE CHARACTERISTIC GENERA.

*Acnanthes.*—Though the species of this genus are usually attached by a stipe, and therefore not strictly planktonic, they are still not unfrequently found as isolated frustules or small chains in planktonic gatherings. The most common species is *A. subsessilis,* found along with *A. longipes* in St. John harbour in August, and near Grand Manan, also in Passamaquoddy bay and the St. Croix river. The genus is more common on the north shore of New Brunswick.

*Actinoptychus.*—Like most genera of circular form, this genus is free-floating, and though nowhere very abundant, is widely distributed. The only species is *A. undulatus.* It was found in Chance harbour, in January; at the Biological Station, February 19, in the reversing Falls, St. John, February 14, near St. Andrews, April 9, West Quoddy, June 17, Biological Station, June 28, West Quoddy, August 1. St. Martin's bay, August, Narrows of St. John river, August 10, but was not observed in any of the samples of the "Prince" collection in September and October. No marked differences except as regards these latter months as to relative numbers have been observed, either as regards distribution or season.

*Amphiprora.*—The members of this beautiful genus occur but sparingly in the plankton; but owing to their delicacy and transparency, the result of imperfect silicification, are apt to be overlooked.. *Amphiprora alata,* the most common form, was found at Eastport, July 29, St. John harbour and St. Martins in August; but was rare at both. The very beautiful but rare *Amp. ornata* was obtained, but one specimen only, in the Narrows of the St. John river, August 10.

*Asterionella.*—This is a typically planktonic genus, common in the plankton of Europe, as well as America, but is very rare in that of New Brunswick. A species, doubtfully referred to *As. Berkeleyi,* has been found in considerable numbers at some stations in the Bay of Fundy.

*Biddulphia.*—This is a very characteristic plankton genus, the attachment of the frustule to form chains of considerable length adapting its members readily to flotation.

Of its species the most common is *B. aurita,* found on almost all gatherings, and at almost every season. It occurs in January at the Biological Station; at St. Andrews, again in February; in March and April at various stations on the St. Croix river and Passamaquoddy bay, as also in June and July. It is common in the waters of St. John harbour in August, and probably occurs, though not yet recorded, in the later months. No examples were noted in the "Prince" series. The much larger species *B. Mobilensis* (=B. Baileyi) was found at Chance harbour, Bald Head, Campo Bello, St. John harbour, Seely's Cove, and Lepreau, at different dates in January (the water temperature being 33° F.), and on February 14 at the Reversing Falls, St. John. It was not observed during the summer months about Passamaquoddy bay, but at Tynemouth creek, in St. John county, in August, it was so abundant as to make up the bulk of the plankton, and on September 27, it was found but rarely in the Bay of Fundy between St. John and Digby Gut. It would appear to be more common in deep water, and is one of the species quoted as being characteristic of the European plankton. *B. pulchella* was found in St. Andrews harbour, February 19, and again March 17, and April 19, but it is very rare.

*Chaetoceras.*—This is the most typical, as it is also the most common and widespread of all the genera which distinguish the Phyto-plankton. Of the several species represented, by far the most common, both as to numbers, time, and place, is *C. decipiens* usually easily recognized by the narrow slit-like form of the inter-cellular spaces. It was abundant on January 1, at the Biological Station, and throughout the month at other points about Passamaquoddy bay, accompanied, though much less abundantly, by the *C. sociale.* Both of these species, but with the same difference in relative numbers, were found through February in St. Andrews harbour, and again in March, extending up the St. Croix river to and above Doucett's island. Both species were similarly found all through April and May but became less common in June, and still less, in the latter months, though both were found at Eastport July 29, and Campobelle August 1. No specimens were found in the August plankton of St. Martin's or St. John, though found during this month in collections from L'Etang and Deadman's harbour. In the "Prince" series the only records of this genus are *Chaetoceras decipiens* at the eastern entrance of St. Andrew's harbour October 16, and the same species at Grand Manan, but rarely, on October 3 and 27.

*Coscinodiscus.*—This genus is almost invariably present in the marine plankton, and sometimes to the exclusion of almost everything else. The most common species is *C. asteromphalus,* Ehr., easily distinguished by the conspicuous central rosette of cells; and *C. concinnus,* remarkable for its large size, fine radial sculpture, and short marginal striæ. Both species were found at Campo Bello and Seely's Cove in January; but not commonly. Both again were obtained in St. Andrews harbour, February 19 and March 18, and were abundant at La Tete, March 28. They were common in April in St. Andrews, as also in succeeding months at many different stations both in Passamaquoddy bay and the bay of Fundy. In almost all instances they were accompanied by the much smaller species *C. eccentricus* and less frequently by *C. radiatus.*

*Ditylum.*—This genus, though frequently, and sometimes abundantly represented in the plankton of the bay of Fundy and Passamaquoddy bay, is one as to whose relationships much doubt still exists. First named and described by the late Professor J. W. Bailey of West Point, N.Y., it was subsequently referred, by West and others, to *Triceratium,* while this latter genus was itself later referred to *Biddulphia.* Except, however, in the outline of the valves, varying, as in *Triceratium* from triangular to quadrangular and pentagonal, it bears, as remarked by Mann in his report on the Diatoms of the Albatross Expedition, not the remotest resemblance to the genus last named.

As found in New Brunswick waters the genus *Ditylum* (*dis,* two, and *tyle,* a swelling) is usually in the form of a lengthened quadrate cylinder, due to the great length of its zone or girdle, the terminal valves being somewhat puckered or constricted, with slight but conspicuous bristles at the angles bordering a circle or fringe of very delicate and short bristles, from the centre of which springs a single long and stout spine. The sculpture of the valve is radio-punctate, the rays being delicate and grouped around the base of the central spine. The areolation, so marked in *Triceratium,* is entirely wanting. Though usually triangular, specimens have been observed in which triangular, quadrate, and pentagonal valves have been found, enclosed in the same connecting membrane, which is very imperfectly silicified. In the writer's opinion the forms are much more nearly related to *Rhizosolenia* and *Corethron,* than to either *Triceratium* or *Biddulphia.* They are often found in groups, of which the individuals may be attached either laterally or by the ends, on the sagittal plane. As to distributional and seasonal variations, the representatives of the genus *Ditylum* have been found in the bay of Fundy, near St. John, in February, and at St. Andrews in April, but only rarely. They were abundant in Deadman's harbour, August 10, and especially abundant in St. Andrews harbour, and off Grand Manan, in October. They were also observed during this latter month at the mouth of the St. Croix river, but rarely.

*Fragillaria.*—This genus, though usually to be found in plankton collections elsewhere, is not common in the region under review. This species represented appears to be mainly *Fr. capucina* and *Fr. pacifica* (?).

*Grammataphora.*—The species *Gr. marina* and *Gr. serpentina* are both found in the bay of Fundy and Passamaquoddy bay, but not very generally. They were both found rather abundantly and forming long chains in the waters about West Quoddy Head on the 28th of June; at Eastport, August 1 and St. Martins, also at L'Etang harbour, August 10. None were observed in the "Prince" collections, made in September and October.

*Hyalodiscus.*—This genus, as represented by the species *H. subtilis,* is occasionally met with in the plankton, but not in sufficient numbers to be made the basis of comparative statements. It is found but rarely in Passamaquoddy bay.

*Isthmia.*—Only a few specimens of this genius, including both *I. nervosa* and *I. enervis,* have been observed in the summer plankton about Campo Bello; but not in Passamaquoddy bay.

*Melosira.*—No genus is more widely or more abundantly met with than this, its rabit of forming long chains, some times including thirty or more frustules, making it quite conspicuous. The most common species is *M. nummuloides,* though *M. varians* and *M. Borerii* and *M. Jerghensii* are by no means rare. They have been found at various stations in the bay of Fundy and also about Passamaquoddy bay. *M. subflexilis* was found at St. John and St. Andrews, in February and March, the others almost everywhere during the summer months. In the "Prince" collection *M. subflexilis* was obtained between St. John and Digby on the 21st of September, and quite abundantly.

*Navicula.*—Specimens of this genus, which includes a very large number of species, are found in nearly all collections, but the majority of the latter are littoral rather than pelagic or planktonic. Of those occurring in the plankton one of the most common and widely distributed is *N. didymo,* which has been found during the summer months at many points along the coast between Grand Manan and St. Martins. *N. distans* and *N. Smithii* (including *N.elliptica*) are also of common occurrence; but none have yet been recorded from winter collections. They are common in Passamaquoddy bay, in July and August.

*Nitschia.*—Though represented generally, and by a large number of species, few of these are found in the plankton. The most common are *N. sigmoidea* and *N. closterium,* found near St. Andrews, April 19. *N. Sigma* was observed at the same station July 7th, and *N. seriata* in August. Besides the above *N. dubia* and *N. vermicularis* were found at St. Martins in August; *N. closterium, N. sigmoidea* and *N. vermicularis* in St. John harbour during the same month. *N. seriata* was obtained from the "Prince" collection, at Station 3 (between Head harbour and the Wolves) September 18; but not from other points. None were observed in October gatherings.

*Pleurosigma.*—Though a littoral and brackish water genus, some of its species are also pelagic and planktonic. *P. decorum* and *P. formosum* were found in St. Andrews harbour February 19; *P. fasciola* and *P. decorum* at the Biological Station February 27; the same at the Reversing Falls, St. John, February 14; at Doucette's island in March; *P. intermedium* and others in St. Andrews harbour, April 17; *P. fasciola* at West Quoddy June 17; *P. Balticum* and *P. fasciola* at the Biological Station June 28; and *P. obscurum* at St. Martins in August. *P. fasciola* and *P. formosum* were found in L'Etang harbour August 10, and *P. Balticum* at Tynemouth creek August. No representatives of the genus were found in the "Prince" collections of September or October.

*Rhabdonema.*—Isolated frustules, and more rarely short chains of *R. arcuatum* are occasionally met with in the plankton, but are not common.

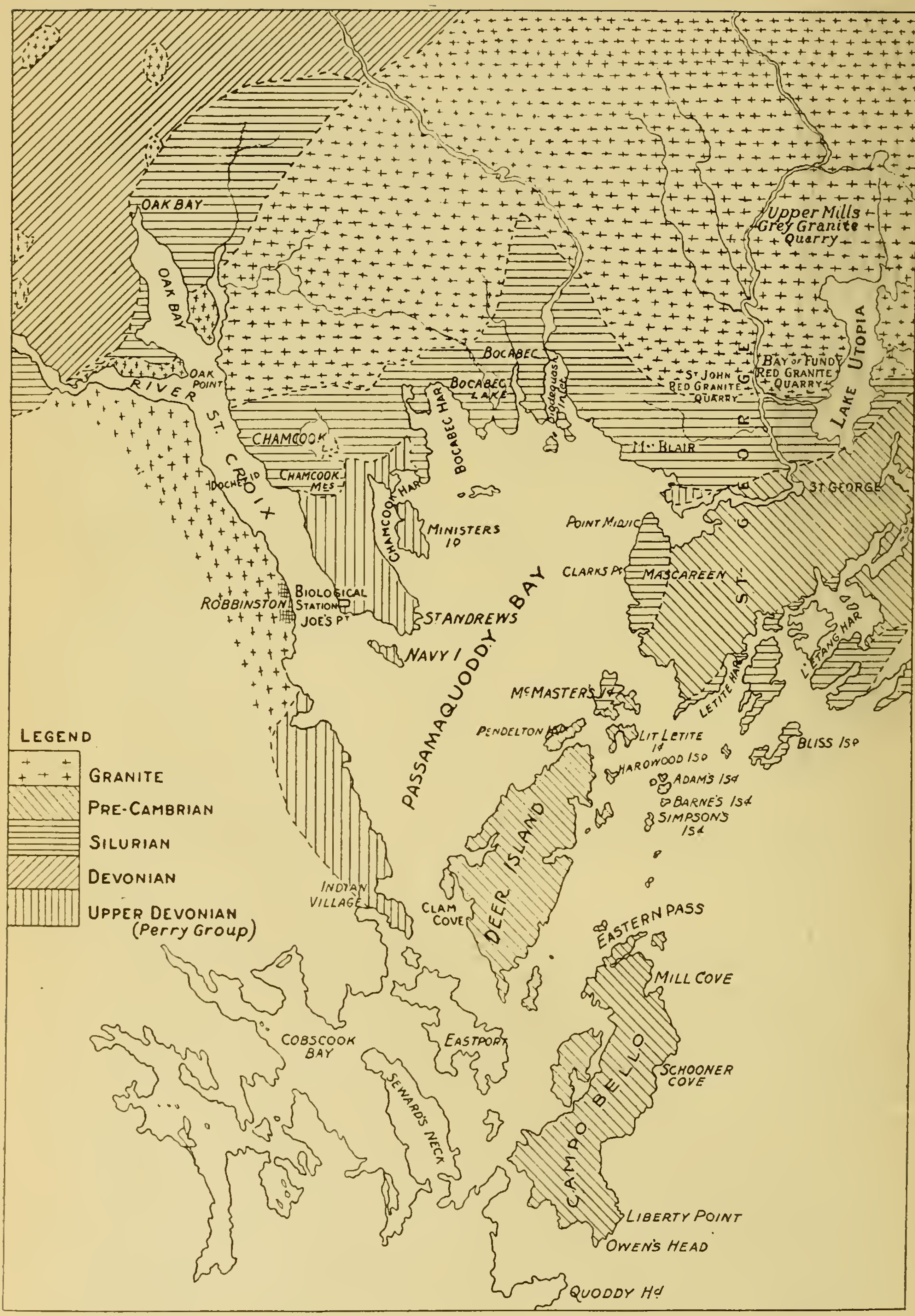
*Rhizosolenia.*—This is one of the typically planktonic genera, and as represented by *R. setigera,* is often very abundant. It was obtained as early as January 16 at Wilson's beach, Campbello, and at Seeley's cove January 31; in St. Andrews harbour February 19, and the Biological Station February 27; at Joe's Point, St. Andrews, and the St. Croix river March 28; and at Robbinstown May 23; but appears to be absent in June and July. It was found at Campbello August 1, and L'Etang harbour August 10, also at Tynemouth creek the same month. In the "Prince" series it was September 27 at the lower end of Annapolis Basin (with spear-like enlargements of the terminal spines, not yet observed in the bay of Fundy), and on the Annapolis river, near Goat island. In the same series it occurs as found in St. Andrews harbour October 10, St. John harbour October 19 and Grand Manan (abundantly).

*Skeletonema.*—This is another of the distinctly planktonic genera, its adaptation to a floating life being effected by the association of the frustules in long chains, sometimes embracing forty or fifty individuals. It is, however, characterized by much diversity as regards size, distribution and seasonal variations. It was found at Bald Head January 15, St. Andrews harbour February 19 and Manawagonish, St. John county Febraury 5; but no occurrences have been recorded at any station for March, April, May, or June. It was found at Eastport July 29, Campbello August 1 (rare). L'Etang harbour and Deadman's harbour August 10. From the "Prince" collections, in September and October, it appears to be wholly absent.

*Thalassiosira.*—Another characteristic plankton genus, easily recognized by the interposition between the widely separated frustules of long filamentous threads (Slime threads of the Germans). Of its two species *Th. Nordenskioldii* is the more common. but exhibits great seasonal differences. It was found in January and February at the Biological Station, again very abundantly about Joe's point, St. Andrews, on May 27, as also at La Tete, Campbello and Eastport; and at the latter station again on July 29; Biological Station March 17, St. Croix river and La Tete March 28; Doucette's island March 27; Joe's point April 30, St. Andrews harbour April 18, very abundantly;

Robbinstown May 23; Biological Station May 21, very abundantly. It was found at Eastport in July, and in L'Etang harbour August 10; but was wanting in collections later than August both in Passamaquoddy bay and the Bay of Fundy. It would seem to attain its maximum in April and May.

*Thalassionema*.—Forms believed to be referable to this genius have been found in several gatherings made by the "Prince" in Passamaquoddy bay. Some of these, collected in October, being composed of little else. The frustules bear considerable resemblance to those of *Synedra*, and again to some varieties of *Rhizosolenia*, but differ greatly from both. The most remarkable feature, the specimens referred to is their enormous length, running from 300 to 800 mu, with a zonal breadth from 3½ to 8 mu. The sculpture along the edge is a very minute row of points, perhaps running about 20 in 10 mu. The cells show variations in diameter, and are often curved or flexuose, but do not taper at the ends or bear bristles, as in *Rhizosolenia*.. Perugallo following Van Heurck places the genus *Thalassionema* between *Synedra* and *Thalassiothrix*. Dr. McKay is disposed to regard the form here described as new. It may be a variety of *Thalassiothrix nitschioides*.




Geolo ical Map of Passamaquoddy Bay and Surroundings, by L. W. Bailey.

# THE GEOLOGICAL FEATURES OF THE ST. CROIX RIVER AND PASSAMAQUODDY BAY.

By L. W. Bailey, LL.D., Ph.D., F.R.S.C., etc., *Emeritus Professor of Natural History and Geology, University of New Brunswick.*

(With map.)

Of those who visit the Biological Station at St. Andrews, whether as tourists or as members of the staff and participants in its work, there are many who, attracted by the unusual beauty of its surroundings, would like to know something of the causes to which that beauty is due. I have therefore been asked by members of the Biological Board to prepare a short sketch of the geological features of the region. These, of course, are fully detailed in the reports of the Canadian Geological Survey, but are contained in many different volumes, and are not always easily accessible and are so associated with the geology of wider areas as to make it somewhat difficult to obtain the desired facts. In this sketch only those are given which seem to be of general interest.

## I.

The region under review is naturally divided into three sections. Of these, the first is the St. Croix river proper, a wholly fresh water stream having its sources in connection with considerable lakes north and west of Vanceboro, and thence flowing in a southerly direction to meet the second section at the falls in St. Stephen. The volume of water, though sufficient for lumbering and milling purposes, does not produce any appreciable effect on the salinity or density of the water in this second section.

The latter may be called the St. Croix estuary, and extends from the head of tide-water at the falls in St. Stephen to the vicinity of St. Andrews, where it gradually widens out into Passamaquoddy bay. Through this and the preceding section, it constitutes a part of the international boundary. The third section is that of Passamaquoddy bay itself, an area about eleven miles wide by seven, and imperfectly separated by the chain of the Western Isles, from the waters of the Bay of Fundy.

As regards the geological features of these several areas, the first needs but little consideration here. North of MacAdam Junction the rocks are mainly granite, boulders of which in great numbers, and often of very large size, thickly strew the tract surrounding and south of that railway centre. Further south the river traverses two wide belts of slates, of which the more northerly are pale of colour and carry obscure organic remains, appearing to indicate a Devonian age, while the more southerly are darker, and though yielding no fossils, are believed to be Cambro-Silurian. Through these, at many points, protrude small bosses of granite, which about St. Stephen become more considerable. Near the town last named they contain large bands of diorite and serpentinous rocks containing considerable bodies of pyrrhotites like those of Sudbury, Ont., which they closely resemble, and carry ores of nickel, though the percentage of the metal, so far as at present known, is too small to admit of profitable extraction.

II.

Below St. Stephen, at which point we enter upon the second or estuarine division of the St. Croix, the rocks on the west side of the stream are mainly granite all the way to the southern part of Robbinston, in the state of Maine, and are well seen in the Devil's Head and again in Doucette (Dochet) or St. Croix island, upon which Champlain and his followers spent their first and most unfortunate winter in Canada.

On the eastern side these granites reappear at Oak point, as also on the shores of Oak bay, either side of Waweig inlet, but in the upper part of this bay, upon both sides, the rocks are Silurian and yield characteristic fossils. Near the head of this bay, on the eastern side, are kitchen-middens or Indian shell heaps, marking one of the sites of early human prehistoric occupation. About two miles below the entrance of Oak bay, Silurian rocks again occupy the shore, being the western termination of a belt of such rocks extending eastward to and beyond Bocabec bay on the north side of the latter. At the mouth of Bocabec river, east side, are still other shell heaps of Indian origin, from which have been obtained a considerable number of aboriginal relics. A full account of this old encampment-ground and of the articles obtained from it, may be found in one of the bulletins of the New Brunswick Natural History Society.

The same Silurian belt includes Chamcook lake and Chamcook mountain. It is composed in part of massive sandstones, elsewhere fossiliferous, and in part of volcanics, partly interbedded with, but mainly resting on, the latter. Fine exposures of these volcanics may be seen along the line of the Canadian Pacific Railway, which traverses the eastern side of the lake, and consist partly of black diorites and partly of chocolate-coloured, bright-red weathering felspar-porphyries or rhyolites, the latter forming prominent hills. Chamcook mountain itself, and its associated ridges, are composed below of dark sandstones and above of diorite, the relation of the two being well seen on a bluff on the western side of the second Chamcook ridge, where, by the partial removal of the softer underlying strata, the comparatively hard diorites may be seen projecting many feet, like a shelf, over the former. That the agent producing this effect was ice, rather than water, is shown by the fact that the underside of the overhanging ledge is strewn with glacial striæ, having the same north-and-south direction as that of the St. Croix valley. As there is no corresponding ridge for many miles to the westward of the St. Croix, by which the ice might have been confined and forced beneath the overhanging brow, it seems also probable that the ice was that of a continental rather than a local glacier.

III.

We come now to the consideration of Passamaquoddy bay proper. The northern side is everywhere occupied by the Silurian rocks already described, extending eastward from Bocabec harbour and Digdequash inlet to and beyond lake Utopia. They include some prominent hills, such as mount Blair, and with a westward dip, form a series of ridges with parallel intervening valleys, the structure and arrangement suggesting a series of successive downthrows toward the centre of the bay. At the mouth of the Magaguadavic on the northern side, and again at Point Midjic, forming the southern boundary of the same inlet, they are overlaid by small outliers of the Perry group to be presently noticed; but south of this point they reappear on the Mascareen shore, bordering this to the Letite passage as well as forming the northern side of McMaster's and Pendleton's islands. At Clark's point on the Mascareen shore, and elsewhere, they hold characteristic Silurian fossils, while on the islands named the felspar porphyries or rhyolites form somewhat prominent hills similar to those of Chamcook lake, and by their colour (bright red when weathered) form, as seen from St. Andrews or Chamcook mountain, a conspicuous feature in the scenery of Passamaquoddy bay.

On its southern side, Passamaquoddy bay is separated from the Bay of Fundy by the chain of the Western Isles, the largest of which is Deer island, while the smaller, including Adams island, Simpson's island, Casco Bay island, Indian island, and many smaller islands, lie along the southern side of the latter. In Deer island, and again in Campobello, a large island lying to the south and west of the latter, separated by the Eastern Passage, and opposite the town of Eastport, the rocks are much older than any found in this district. They consist largely of diorites and felsites, associated with chloritic and horn-blendic schists and are supposed to be of Pre-Cambrian age; but among the smaller islands, some are Silurian and others of Devonian age. The rocks of Eastport island are of Silurian age, consisting largely of rhyolites resting upon fossiliferous slates similar to those of the Mascareen shore.

The west side of Passamaquoddy bay north of Eastport is made up of red sandstones and conglomerates similar to those of the St. Andrews peninsula and of Upper Devonian age. They extend through the township of Perry, where they contain Devonian plants, and form the shore northward to within a few miles of Robbinston, where they meet and overlie the granites already referred to.

This sketch would be incomplete without some reference to the geology of Grand Manan, for though this island is outside the limits of the area under discussion, it is a place frequently visited by the members of the Biological Station staff, the surrounding waters being one of the most interesting fields on the Atlantic seaboard for marine scientific research. The island lies at the mouth of the Bay of Fundy, and about twelve miles distant from the eastern shore of Campobello. It is about fifteen miles in length, while its breadth varies from two to seven miles. Both physiographically and geologically it embraces two tracts of which the one, the eastern, is low and bordered by numerous islands, while the other or western, is considerably higher, without islands, and fronting the waters of the bay in an almost unbroken line of precipitous bluffs from 300 to 400 feet in height. The rocks of the eastern shore, and of the adjacent islands, where are all the settlements, consist of a series of slates and schists, with some conglomerates, which are believed to be mainly of Pre-Cambrian age, though obscure fossils are said to have been found at one point, near the Swallow-tail light.

The greater portion of the island, however, including all the uplands, and the western shore, which are uninhabited, is made up of rocks of much more recent origin, these being a series of trappean rocks, dolerites, basalts, and amygdaloids, of Triassic age, and similar to those which constitute cape Blomidon and the range of the North mountains and Digby Neck, in Nova Scotia. At some points when the tide is low, they may, as in Nova Scotia, be seen to overlie red sandstones, which are also of Triassic age. The relations of the traps to the older rocks of the islands may be well seen at either the Northern or Southern Head. At both of these points and again at Dark Harbour, midway of the length of the island, the columnar traps constitute some very bold and picturesque scenery.

Not only do the Perry rocks form the western side of Passamaquoddy Bay, but also the whole of the St. Andrews peninsula. As seen about the Biological Station, and elsewhere, they are noticeable for their brownish red colour, for their coarseness, and for the fact that they are made up mainly of metamorphic rocks, derived directly from the underlying formations, including especially granite and rhyolite. In these respects and in their stratigraphical relations they are markedly similar to what, in other parts of New Brunswick, have been referred to the Lower Carboniferous period, and are so represented in the Geological Survey maps; but recent observations elsewhere have tended to confirm the opinion first advanced by the late Sir William Dawson, and based upon their plant remains, that they should more properly be referred to the Upper Devonian. From the fact that they are almost continuously exposed from a point not far above Brandy cove to the lighthouse in Passamaquoddy bay, and are tilted at a considerable angle, it is evident that they must possess considerable thickness, but they are undoubtedly faulted in places, and hence no definite or reliable estimate of that thickness can be made. At many points, especially towards their base, they are penetrated by intrusive volcanic rocks, dolerite, diabase and amygdaloid, occurring apparently both as dykes and sills. They are well exposed at the Biological Station, which is partly built upon one of them, and another has no doubt determined the promontory of Joes point, as well as the "Bar," connecting the mainland with Minister's or Van Horne's island. They are, of course, of later origin than the rocks which they penetrate.

As regards the relation of the geology to the present topography of the region, it may, in conclusion be said, that the position and general outline of Passamquoddy bay were determined by disturbance and upheavals antedating the opening of the Cambrian era, fixing at least the northern, southern, and eastern sides of the basin by ridges, such as the Bocabec hills on the north of those of Deer island and Campo Bello on the south, both converging eastwardly to and beyond St. George.

Of the conditions characterizing the Cambrian era itself we know nothing. In the Silurian age the basin was evidently in existence and occupied by shallow waters in which accumulated sand and mud beds, now more or less filled with marine fossils, over which were spread the rhyolites, porphyries and ash beds, which now constitute such eminences as Chamcook mountain, Mt. Blair and Pendleton's island. In the Devonian age were produced the granitic extrusions which now form the western side of the basin from Devil's Head to the lower part of Robbinston; and somewhat later the coarse rocks of the Perry group, marking at this time considerable subsidences, and the operation of powerful marine currents, as well as the extrusion of igneous masses. No rocks of later age are met with; but evidences of extensive glaciation during the Quaternary era abound. The estuarine portion of the St. Croix river and the channels at either end of Deer island were probably fixed at this time.