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TO

# CANADIAN BIOLOGY

BEING STUDIES FROM THE

BIOLOGICAL STATIONS OF CANADA

1921

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Nos. 1 and 2

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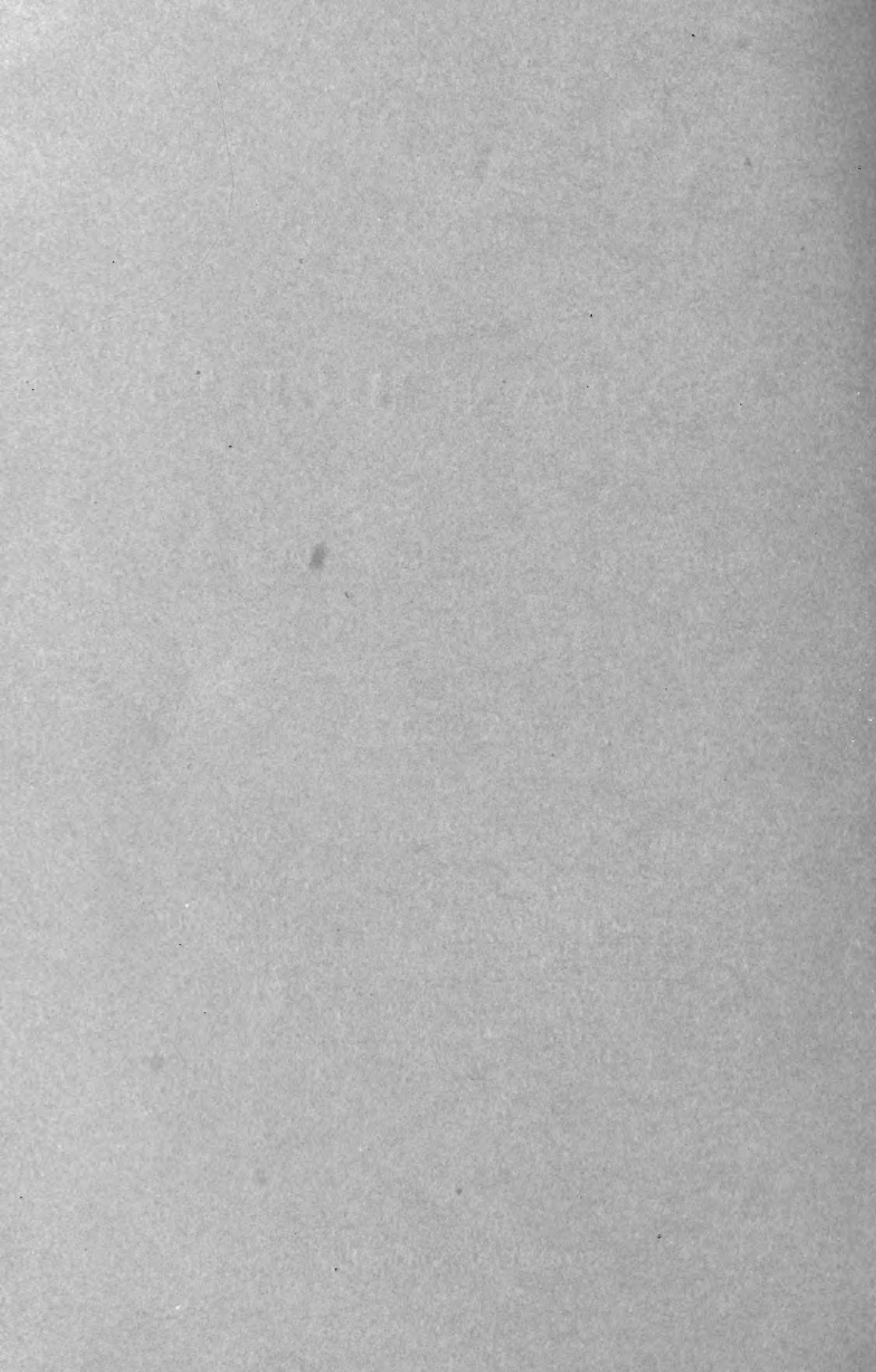
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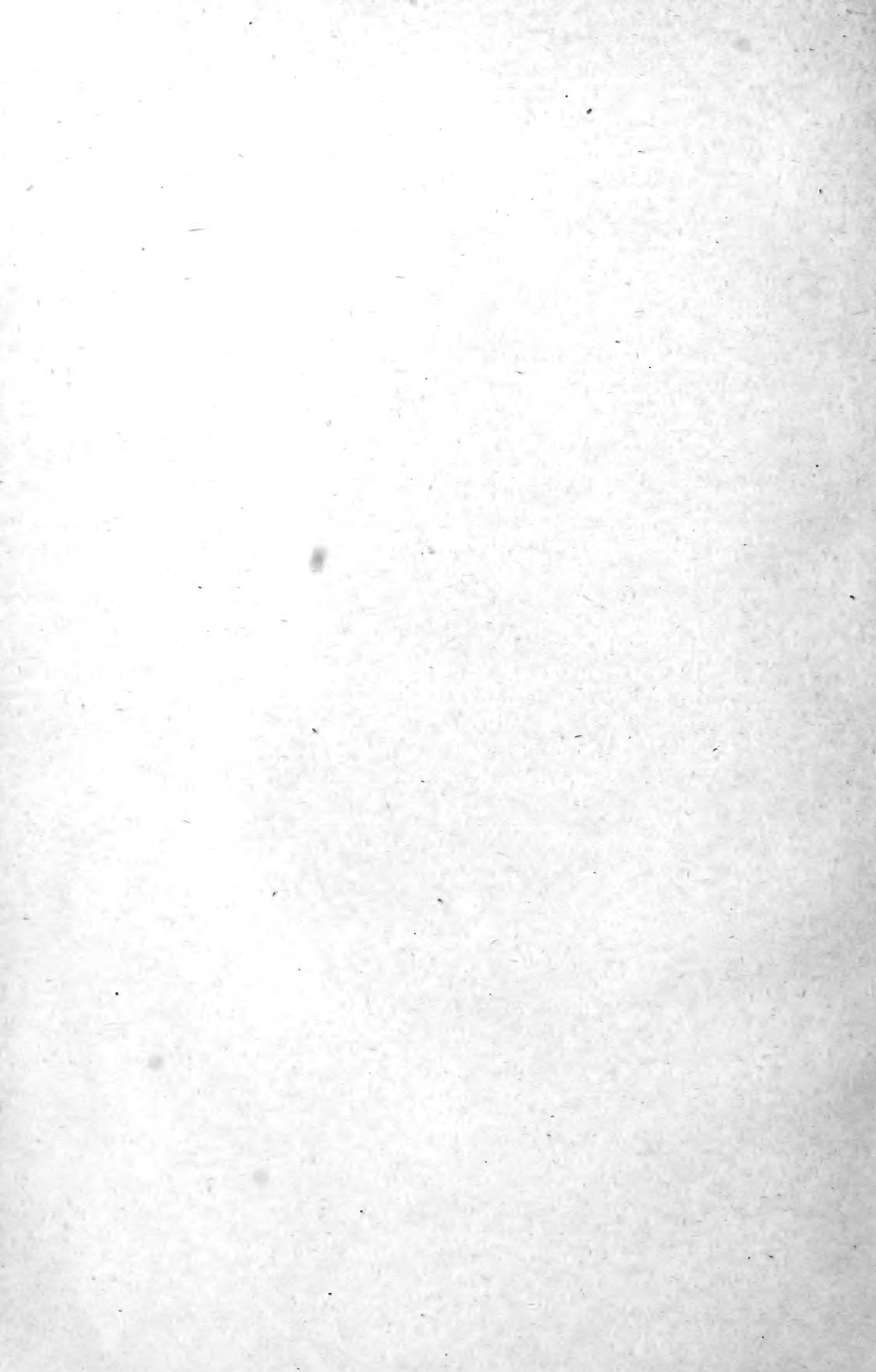
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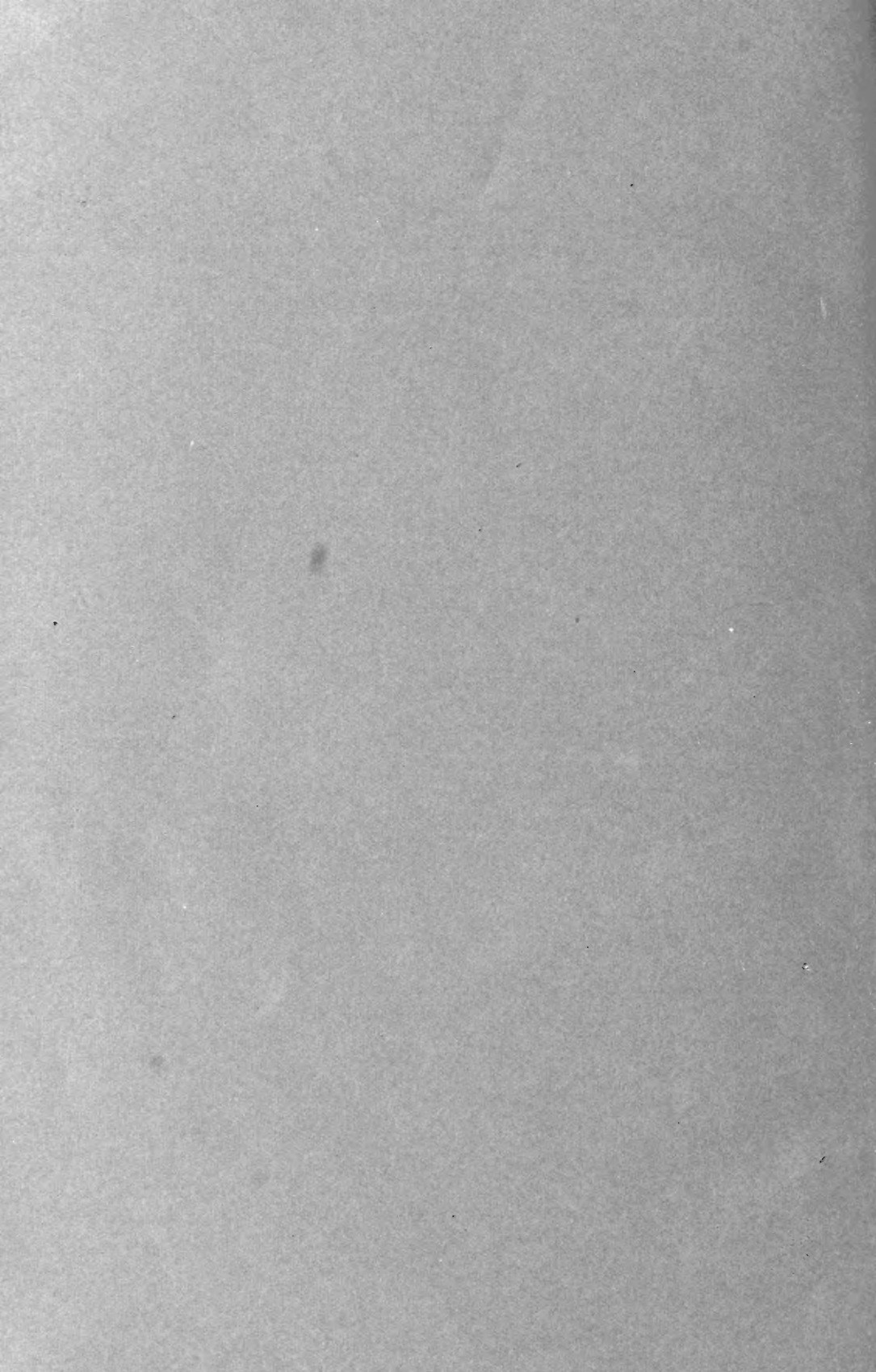
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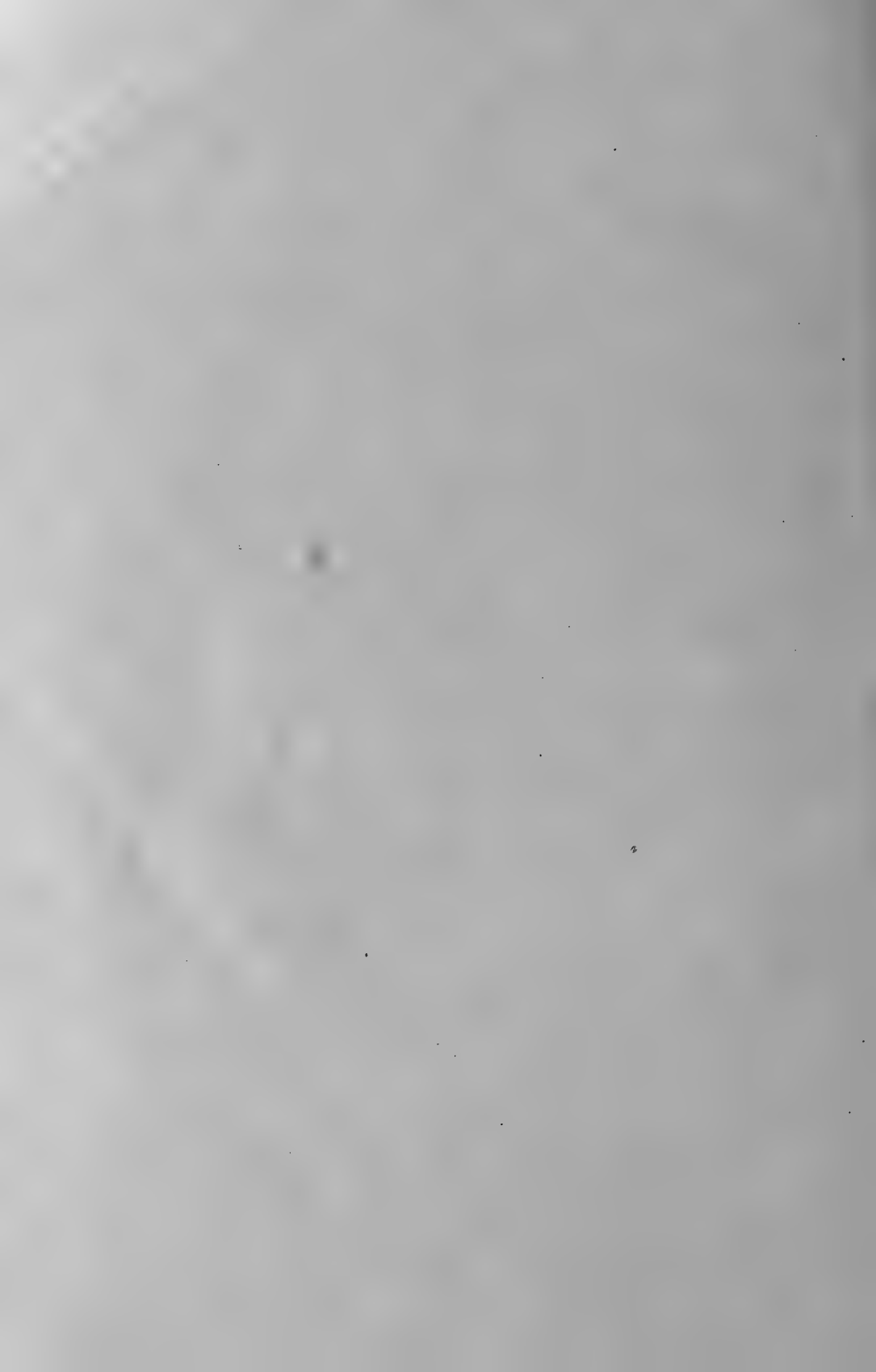
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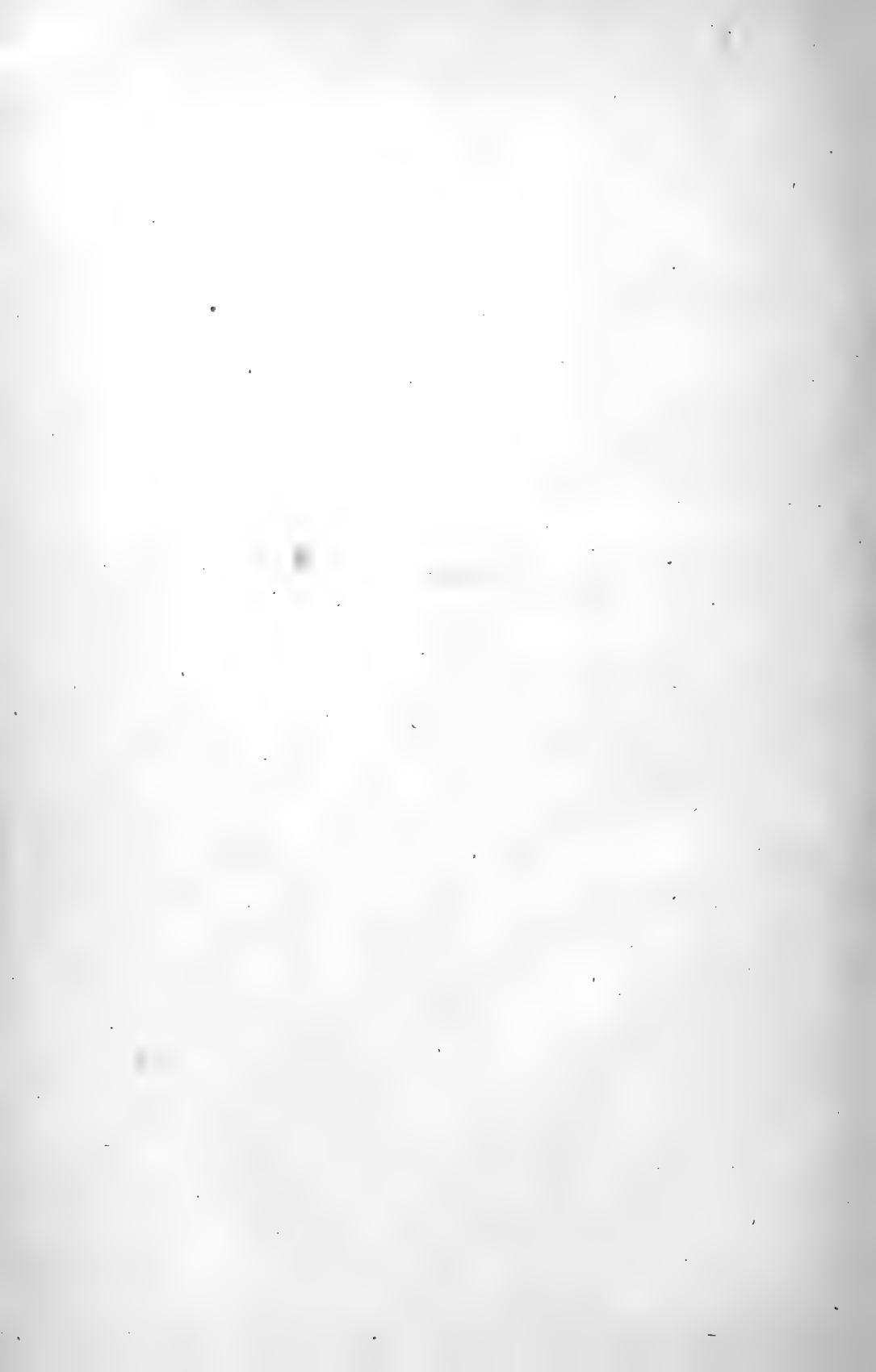
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No. 1

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SOME BACTERIAL ORGANISMS OCCURRING IN THE CLAM (*Mya arenaria*) WHICH MAY PRODUCE "BLACKENING" IN TINS

BY

JESSIE L. SYMONS, M.Sc.  
*McGill University, Montreal*





# Some Bacterial Organisms occurring in the Clam (*Mya Arenaria*) which may produce "Blackening" in Tins.

BY JENNIE L. SYMONS, M.Sc.,  
(*McGill University, Montreal*).

The problem of blackening is a serious one in the canning industry. Blackening is a common form of deterioration, in advanced stages of which the contents of the tin becomes inky black and disintegrated. There is an intense disagreeable odour in which a metallic quality is combined with the odour of putrefaction. Often there is a large amount of gas, causing the cans to be swelled as well as blackened.

The cause of blackening is usually accepted as bacterial action. It has long been studied from this point of view. In 1897, a paper on "Discolouration in Canned Lobsters" was published by Macphail and Bruère.<sup>1</sup> The authors had isolated from spoiled cans four micro-organisms which, upon inoculation into sterile cans, produced the blackened condition. Prescott and Underwood<sup>2</sup>, in the same year, isolated from swelled tins of clams and lobsters nine species of bacteria, which led to similar conditions if introduced into normal cans. These organisms were found to be very resistant to heat. The authors of both papers pointed out the necessity of accurately determined minimal periods of processing. This determination involves a study of the bacteria concerned. It is also important to know the source of the micro-organisms which appear in the cans in order to ascertain the chances of preventing infection.

The investigation described in this paper was undertaken at the suggestion of Dr. A. G. Huntsman, Curator of the Atlantic Biological Station at St. Andrews, N.B. Its aim has been a bacteriological examination of freshly dug clams (*Mya arenaria*), such as are taken to the factories for canning, with a view to the isolation and description of any blackening organisms normally present in such clams.

## PROCEDURE.

### *Isolations.*

The clams from which isolations were made were of medium size. They were dug at low tide on the beach near the Biological Station and brought in at once. The exteriors of the shells were thoroughly washed in a stream of running tap water and dried in the air. The edges were then seared in a flame and the muscles holding the shell quickly severed with a knife.\* One half of the shell was then removed, the clam lying in the other half. The mantle was slit and turned back and four small pieces cut\* from the body of the clam were at once transferred with forceps\* to separate tubes of broth. Cuttings were thus made

\* All knives, scissors and forceps used for these purposes were kept standing in a jar of alcohol and sterilized by flaming immediately before use.

at different times from all parts of the clam within the mantle. In several cases a culture was made from a little of the shell liquor withdrawn through the pedal orifice by means of a sterile pipette. No attempt was made to associate an isolated organism with the part of the clam in which it was found.

To simulate factory conditions, a few clams were washed as described above and allowed to stand at room temperature (about 20°C) for 18 hours before further steps were taken. Others were treated similarly and left 48 hours at room temperature before being opened. In both cases the clams were found to be still alive.

Clam peptone broth and beef peptone broth were both used for first cultures in every case. Good growth was obtained in both media. In many instances, it appeared earlier in the clam broth and was more luxuriant. After growth for twenty-four hours at room temperature, plate cultures were made from each tube, both in clam peptone agar and beef peptone gelatin. These plates were examined as soon as growth appeared, usually after from 14 to 18 hours. Plating was done in the late afternoon, the plates as a rule showing growth the next morning. Most of the organisms liquified gelatin rapidly, hence it was necessary to deal with gelatin plates first. Colonies were carefully examined and from each one chosen as representative of a new type, an agar stab, an agar slant and a smear for microscopic examination were made. Seventy-six cultures were thus obtained during four weeks beginning July 24, 1920. Agar stab cultures of each were kept until the opening of the autumn session at McGill University, when laboratory facilities permitted further investigation.

## MEDIA USED.

### 1. ISOLATION MEDIA.

#### *Clam peptone broth and Clam peptone agar.*

These were made according to directions given by Sadler<sup>3</sup> in his paper on "The Bacteriology of Swelled Canned Sardines."

#### *Beef peptone broth.*

Distilled water.

Liebig's meat extract, 0.5 per cent.

Difco peptone, 1.0 per cent.

Sodium chloride, 0.5 per cent.

#### *Beef peptone gelatin.*

Beef peptone broth with 12 per cent. of Difco gelatin.

### 2. MEDIA FOR DETERMINING THE PRODUCTION OF HYDROGEN SULPHIDE.

#### (a) *Lead Carbonate gelatin* (Beijerinck).

Beef peptone gelatin + lead carbonate 0.1 per cent.

#### (b) *Peptone-lead acetate solution* (Pake).

This medium was prepared according to the following directions: Emulsify 30 g. peptone with 200 cc. tap water at 60°C. Wash into a litre flask with 80 cc. tap water. Add 5 g. sodium chloride and 3 g. sodium phosphate. Heat at 100° for half an hour. Filter through paper. Tube. To each tube of 10 cc. add

0.1 cc. of 1 per cent. solution of lead acetate. This produces a yellow precipitate which is blackened if  $H_2S$  is formed. The solutions should be neutral. Difco peptone was used.

(c) *Clam media.*

1 part clam meat + 2 parts sea water.

### 3. MEDIA FOR DIFFERENTIATION.

*Beef peptone agar.*

Beef peptone broth + 1.5 per cent. of Japanese agar.

*Beef peptone gelatin.*

Prepared as already described.

*Beef peptone Broth.* Two kinds were used.

(1) As described above.

(2) Difco nutrient broth 0.8 per cent.  
Sodium chloride 0.8 per cent.  
Distilled water.

*Peptone water (Dunham's).*

Peptone 1 per cent.

Sodium chloride 0.5 per cent.

Distilled water.

*Nitrate Broth.*

Dunham's peptone water + 0.5 per cent.  $KNO_3$ .

*Potato.*

Wedges were soaked 30 minutes in 1 per cent. sodium carbonate, rinsed thoroughly in distilled water and sterilized.

*Litmus Milk.*

Klim adjusted to +1 reaction and sterile litmus solution added.

*Fermentation Media.*

Dunham's peptone water was used as a foundation.

*Dextrose Medium.*

Peptone water + 2 per cent. dextrose.

*Lactose Medium.*

Peptone water + 2 per cent. lactose.

*Saccharose Medium.*

Peptone water + 2 per cent. saccharose.

*Glycerin Medium.*

Peptone water + 6 per cent. glycerin.

To each of these 2 per cent. Andrade indicator was added.

*Mannit protein-free broth.*

Mannit	15.0	grams
$K_2 HPO_4$	0.2	"
$Mg SO_4$	0.2	"
$Na Cl$	0.2	"
$Ca SO_4$	0.1	"
$Ca CO_3$	5.0	"
10% $Fe Cl$ solution	1.0	drop.
Distilled water,	1,000	cc

*Mannit protein-free agar.*

1.5 per cent. washed  
agar added to mannit  
solution prepared as  
described.

Do not filter.

Sterilize at 120° (autoclave) for 10 minutes.

*Reaction of Media.*

Gelatin, Agar, Broth and Milk were adjusted to +1 reaction.

Sugars and glycerin broth were neutralized.

Peptone water and Nitrate broth were left unadjusted (.4 per cent. acid to phenol phthalein).

*Sterilization of Media.*

All media except milk and gelatin were sterilized in the autoclave for 15 minutes under 15 pounds pressure.

Gelatin and milk were sterilized by the discontinuous method in the Arnold Steam Sterilizer.

### SEPARATION OF BLACKENING ORGANISMS.

The first phase of the problem was the search for blackening organisms. Three methods were employed:

*Method 1.*

Streak cultures were made upon plates of lead carbonate gelatin. The result was unsatisfactory. Complete liquefaction followed before definite conclusions could be drawn with regard to blackening. Cultures i.j.r.s.t.u. produced slight darkening of the lead carbonate after two days, then rapidly liquefied the plates.

*Method 2.*

Cultures were transferred from 24 hour broth cultures to the strong peptone solution, recommended by Pake, as a test for the production of Hydrogen sulphide.

Fifteen organisms, viz., 1, 3, 11, 12, 16, 17, 28, 29, 31, b, e, j, r, s, t, turned the precipitate black and were thus differentiated as H<sub>2</sub>S formers. Some others darkened the precipitate to brown only. All cultures were kept under observation for more than four weeks.

The fifteen organisms were transferred from broth cultures to other media, a study being made of preparations in Dextrose broth, Gelatin stick, Litmus milk and potato.

*Method 3.*

Myers<sup>7</sup> called attention to the fact that some organisms produce hydrogen sulphide on one brand of peptone and not on another. This suggested the advisability of testing all organisms in clam meat itself. Tubes were prepared according to Dr. Harrison's suggestion, using clam meat and sea water in the proportions of one to two. They were prepared in triplicate—about seven hundred in all—arranged in the following series:

- A. Clam meat + sea water + iron.
- B. Clam meat + sea water + tin.
- C. Clam meat + sea water + iron + tin.

Chemically pure iron wire was used in small pieces (1/8 in. to a tube) and chemically pure flaked tin. Sterilization was done in the autoclave 15 minutes at 15 pounds pressure.

Dr. Huntsman kindly arranged that fresh clams and sea water for this experiment be sent from St. Andrews, N.B. They arrived in perfect condition and were opened and prepared at once.

Transfers were made from all original stab cultures to beef peptone broth and plated after 24 hours to determine purity. This having been established, tubes of series A.B.C. were seeded in triplicate from broth cultures of all organisms. Three tubes of each series were kept uninoculated as controls.

No.	Fe	Fe	Fe	Sn	Sn	Sn	Fe Sn	Fe Sn	Fe Sn	
1	(+)	(+)		+	+	+	±*	(+)	-	-
3	(+)	+	+	-	-	-		(+)	(+)	+
6	+	(+)	(+)	-	-	-		(+)	+	+
10	(+)	(+)	(+)	±	+	+	± <sup>d</sup>	(+)	(+)	(+)
11	(+)	(+)	(+)	+	+	+		(+)	(+)	(+)
12	(+)	(+)	(+)	±	-	±		(+)(+)*	(+)	(+)
13	(+)	+	±	-	-	-		+	±	+
16	±	±	±	-	-	-		-	-	-
17	(+)	(+)	-	+	+	+		(+)	(+)	(+)
20	(+)	(+)	(+)	±	+	+		(+)	(+)	(+)
26	+	(+)	(+)	+	-	-		(+)	(+)	(+)
28	(+)	(+)	(+)	+	±	+		(+)	(+)	(+)
31	(+)	+	-	±	-	-		-	-	-
d	(+)	(+)	-	(+)	±	-		(+)	(+)	(+)
			Reddish				Reddish			
e	(+)	(+)	(+)	+	+	+	± <sup>e</sup>	(+)	(+)	(+)
f	(+)	(+)	(+)	+	+	±		+	+	+
g	(+)	(+)	(+)	±	±	±		(+)	(+)	(+)
h	(+)	(+)	(+)	+	+	+		(+)	(+)	-
i	(+)	(+)	(+)	+	±	-		(+)	(+)	(+)
j	(+)	(+)	(+)	+	+	+		(+)	(+)	(+)
r	(+)	(+)	(+)	+	+	(+)(+)*		(+)	(+)	(+)
s	(+)	(+)	(+)	(+)	(+)	-		(+)	(+)	(+)
t	(+)	(+)	(+)(+)*	(+)	(+)	(+)		(+)(+)*	(+)(+)*	(+)
u	(+)	(+)	(+)	+	+	+		(+)	(+)	(+)
w	(+)	(+)	(+)(+)*	±	+	+		+	+	+
18	(+)	(+)	(+)	+	-	-		(+)	(+)	(+)
30	(+)	(+)	(+)	±	+	+		(+)	(+)	-
4	-	(+)	(+)	(+)	(+)	±		(+)	+	(+)
							Reddish			

\*Extra tubes.

(+) indicates very deep blackening of all clam meat.

+ indicates deep blackening of part of clam meat.

± indicates dark greenish-brown colour—more characteristic of tin sulphide.

- indicates no blackening.

The seeded clam tubes were left at room temperature until growth was evident—24 to 48 hours—then kept in an unheated room from four to six weeks.

Blackening developed rapidly in many tubes, slowly in others. The final result is seen in the accompanying table.

Twenty-eight of the seventy-six original cultures were thus seen to be capable of producing blackening when provided with the elements to be found

in a can. Among these, with the exception of No. 29, are the organisms separated by Methods 1 and 2, though No. 16 showed such a feeble result in the clam medium that it has been disregarded. No. 13, which showed a positive result by the third method only, was also rejected.

#### CLASSIFICATION

Nothing had yet been done with a view to eliminating repetition of cultures, except the preliminary observation in four media of the fifteen  $H_2S$  formers found by Method 2. Of these all had liquefied gelatin rapidly and fermented dextrose without the production of gas. Variation had been noted in the growth upon potato and litmus milk.

With the aim of separating and determining different forms it was decided to grow subcultures of all organisms simultaneously. Transfers were, therefore, made from the most recent stab cultures of all blackening organisms to peptone water for invigoration. After 24 hours they were thence transferred in duplicate to Gelatin stick, sugars, potato, litmus milk, nutrient broth, agar slants and nitrate broth. Fresh peptone water cultures were made daily until inoculations were completed. Slides for microscopic examination were also prepared. Growth characteristics were noted and comparisons made from day to day, all cultures being kept for six weeks. Plate cultures on agar, gelatin, and starch agar were also prepared and observed.

The most recent descriptive chart of the Society of American Bacteriologists was used as a guide in choosing media and recording results.

For the indol test cultures were grown in Dunham's peptone water for five days and the Nitroso-indol-nitrate test made at the end of this period.

For nitrate reduction, sulphanic acid and naphthylamine hydrochloride were added in equal quantities (3 drops of each) to nitrate-broth cultures 48 hours old.

Controls were used in both these cases.

Reduction was unmistakable in all cultures so that it was not necessary to repeat the tests after longer periods of growth.

Six forms were finally separated, repeated tests being made in many cases. Potato cultures, for instance, were tried both at room temperature and at  $37.5^{\circ}C$ .

#### CHARACTERISTICS COMMON TO ALL THE ISOLATED ORGANISMS.

Preparations stained for flagella revealed the fact that all belonged to the genus *Pseudomonas*, one variety possessing a tuft of polar flagella, the others having a single flagellum attached to one pole. Endospores were not observed in any of the species. All liquefied gelatin rapidly and digested casein, though in one instance the latter process was very slow. All formed hydrogen sulphide and reduced nitrates to nitrites. All fermented dextrose, saccharose and glycerin. At first they gave strong acid reaction, which began to change about the fourth day, the contents of the tube gradually becoming alkaline throughout. In one case only, lactose was fermented, though all cultures grew well and produced turbidity in lactose broth. The common characteristics here noted will not be

mentioned in the detailed descriptions below, which rather aim to point out distinguishing traits.

#### ORGANISMS IDENTIFIED.

##### 1. *Pseudomonas fluorescens* (Flügge) Migula.

The organism was easily stained and appeared as a rod of medium size with rounded ends, which usually occurred in pairs. Six flagella were observed in the polar bundle. On gelatin plates the colonies appeared after two days as round centres of liquefaction. A white mass of bacteria occupied the centre of the depression which was cup-shaped. Deep colonies were white with shadowy margins which, as the microscope revealed, were made up of radiating hairs.

In the gelatin stab cultures, the line of inoculation showed a trace of liquefaction after 24 hours. In 36 hours its margin was clouded by numerous discrete, white, punctate colonies. At the same time a crateriform liquefaction had developed on the surface, with a white film lining the depression. The liquefaction soon became infundibuliform and the medium acquired a distinct fluorescence.

On potato a dirty-greyish growth appeared after 24 hours. Though dull at first it became moist, spreading and shining, deepening in colour to fawn. The potato was at the same time darkened to brown.

Broth was rendered turbid with a strong yellow-green fluorescence and a membranous shining pellicle.

Diastatic action on starch was positive.

On agar slants the growth was of a yellowish-grey colour, moist, shining and spreading, the substratum becoming distinctly fluorescent.

In litmus milk the reaction was distinctly alkaline after 24 hours, the blue colour deepening for a week, then remaining constant; even at the end of 6 weeks no digestion was observable. A white shining pellicle was produced on all liquid media.

##### 2. *Pseudomonas Jaegeri* (Migula).

This organism was somewhat variable in form. As a rule, it was a short thick rod with rounded ends. Flagella were difficult to count; in many cases they were turned back and formed loops along the sides of the organism. In one instance two were plainly observed, attached at one pole.

On gelatin plates, round, creamy-white, zoned colonies developed within two days. They produced a crateriform liquefaction with a dense white mass in the centre. Outside this lay white turbid zones, concentrically arranged and becoming gradually thinner toward the margin. Under the microscope the small dew-drop-like colonies appeared round, finely granular and light brown. The larger colonies had a dense, dark brown central nucleus surrounded by a coarsely-granular zone, outside of which was a finely-granular area with a ciliated margin.

Gelatin stab cultures rapidly became saccate and uniformly turbid. In 96 hours liquefaction was complete. On the surface of the liquefied gelatin a light flocculent pellicle was formed and a heavy, creamy sediment lay in the bottom of the test tube.

Growth on agar plates was characteristic of the old genus, *Proteus*. The

moist, cream-coloured colonies developed a variety of projections, some confluent and arborescent, others circular with irregular, curved, radiating arms. A yellow-green fluorescence was produced in the medium.

On starch plates there was diastatic action and marked green fluorescence in the medium.

On potato a thick, cream-coloured, raised, luxuriant growth developed rapidly and soon covered the entire surface of the medium.

Milk was coagulated quickly with production of acid. Digestion followed, a dull, sage-green layer appearing at the surface and leaving a green ring on the tube. A strong pungent and cabbage-like odour was produced on this as on other media.

Litmus milk gave parallel results.

This organism formed acid and gas in dextrose, saccharose and glycerin. The reaction changed after one week and gas formation ceased, except in glycerin. After five weeks, glycerin cultures were strongly acid and were still producing gas.

In broth fluorescence was noted, as well as turbidity, a dense sediment and a light pellicle.

#### 4. *Pseudomonas sericea* (Mig.) var. *fluorescens*.

This organism was a short, thick, gram-negative rod with a single, delicate, polar flagellum.

Gelatin colonies were at first punctate, bluish-white, later becoming definitely round. Under the microscope they were coarsely granular with grumose centres and a clearly defined margin. Some of the larger colonies had a few club-shaped processes.

On agar the surface colonies were round and concentric with slightly irregular margins. Beneath the surface small, dense, granular, pyramidal colonies were numerous. Under the microscope all appeared to have a grumose structure.

On agar slants a white, lustrous, spreading layer was formed. Growth first appeared as discrete, pearly-white colonies (diameter about 1 mm.) which later became confluent. The water of condensation was turbid, with a white deposit.

In Gelatin stab cultures, a bowl-shaped depression was first produced, a white film lining the cavity. This became broadened until the sides of the tube were reached and proceeded in a horizontal layer to the bottom.

Broth cultures were moderately turbid with a flocculent pellicle and a sediment. A negative result was obtained by the indol test.

Potato cultures had at first a dull slightly granular surface which later became smooth, shining and waxy. The colour varied from pink to buff. In old cultures the buff tone was constant.

Litmus was completely reduced in 18 hours and a white pellicle was formed on the surface of milk cultures of that age. Digestion began at the surface of the medium on the fifth day and was complete in about two weeks. No clotting took place. The reaction was strongly alkaline. The medium became slimy and gradually deepened in colour to a golden-yellow. At the surface a layer containing fluorescent pigment was formed. This layer appeared dark-purplish by transmitted light and sage-green by reflected light. Shaking produced this



effect throughout the tube. A very strong pungent odour suggesting an amine was characteristic of these cultures. Tanner<sup>20</sup> has described a similar effect produced upon litmus milk by one group of his green fluorescent water bacteria. His organisms, however, seem to have differed in other particulars from those described here. They differed, for instance, in their action upon sucrose. Migula has described a form known as *Pseudomonas sericea* as producing alkali and reducing litmus—though he has classified this organism among non-fluorescent forms. In the group under consideration fluorescence, observed chiefly in milk but occasionally upon agar and broth, seemed the only important variation from the type described by Migula. Therefore, the tentative name of *Pseudomonas sericea fluorescens* has been given.

#### 4. *Pseudomonas liquefaciens* (Tataroff, Migula) var. *marina*.

Stained with Loeffler's methylene blue this organism appeared as a short rod, very often occurring in pairs. In a hanging drop it had a dodging and darting rapid movement in a narrow field. It possessed one polar flagellum, two or three times the length of the organism. It was gram-negative.

##### *On Gelatin Plates.*

Colonies appeared in three days, first as round white points with a somewhat cloudy margin. Under the microscope, surface colonies were circular, granular, dense in the centre with radiating, cochleate filaments from the margin. The deep-set colonies had a sunburst appearance, the processes, which were very numerous and tangled, radiating in all directions.

##### *On Agar Plates.*

Growth was evident in 24 hours. Surface colonies were round, moist, raised, cream-coloured, 1 to 2 mm. in diameter, later widening to 15 mm. Microscopically, they were grumose, concentric, dense in the centre, with successively thinner rings outside. Deep-set colonies were dense, disc-shaped, tilted, 0.5 to 1.0 mm. in diameter. Magnified they appeared dark brown, grumose, with rough edges.

In gelatin stab cultures liquefaction was at first crateriform. A cloudy appearance was produced along the line of inoculation by numerous, minute, discrete colonies. The margin of the liquefied area was slightly dentate. The liquefaction became infundibuliform about the third day and was invariably complete in ten days. The sediment was cream-coloured, viscid and abundant.

Nutrient broth was rendered uniformly turbid with a frosty membranous pellicle and a sediment.

Litmus milk became alkaline with reduction of litmus and digestion of casein. In this medium growth was very slow in all cases. Tested soon after isolation and grown in the dark the organism produced a change in the milk on the sixth day. In later cultures, grown at room temperature without protection from light, no change was apparent for four weeks, after which alkalinity, reduction of litmus, and digestion of casein were observed. Preparations in plain milk gave parallel results. A strong ammoniacal odour was characteristic of old cultures.

On potato no growth was obtained, though repeated cultures were made. One vigorous strain, however, which grew more rapidly and luxuriantly than

this type on all media, invariably produced a whitish, spreading growth upon potato in 24 hours.

Tataroff's organism having been isolated from fresh water and this closely allied form from a salt water clam, it seems possible that the variations noted—namely, slower growth in litmus milk and the absence of growth on potato were due to lack of salt in these media.

It is hoped that this will be confirmed at a later date.

##### 5. *Pseudomonas myae*.

Though this form had well-defined characteristics it has not been discovered in the available classifications and descriptions. In many particulars it is suggestive of the *Pseudomonas oogenes* of Migula which has been found in eggs.

In form it was a short rod with one polar flagellum. It was gram-negative.

On gelatin plates white colonies developed in between 2 and 3 days. Liquefaction was bowl-shaped, a dense white deposit occupying the central point in the depression. Around this, a less dense, uniform turbidity gave the remainder of the bowl a frosty-white appearance. Observed microscopically the small deep-set colonies were found to be very dense, spherical, granular masses. The larger colonies seemed often to be built concentrically about such a colony as a central nucleus. Other large colonies were merely grumose in the centre, a loosely granulated zone occupying a comparatively wide area between the central portion and the margin.

On agar plates, small, deep-set, pyramidal colonies were numerous. Surface colonies were of the round, moist, cream-coloured type. Microscopically, they were granular without projections and dense in the centre. Occasionally branching and budding of the colonies was observed.

In litmus milk the litmus was quickly reduced. Clotting and digestion followed rapidly. The whey was perfectly clear without a pellicle, while the clot became deep pink in colour.

*Ps. myae* was the only one of the blackening organisms which fermented lactose.

In gelatin stab a crateriform-filiform liquefaction was well-developed at the end of 24 hours. The liquefied area gradually widened, reaching the sides of the tube in 3 or 4 days. A statiform area thus appeared above an ever-widening central turbid column. In ten days the gelatin was completely liquefied, with a heavy, creamy, viscid sediment.

In nutrient broth there was a light pellicle, marked turbidity and a viscid sediment.

The organism grew delicately upon potato, the growth appearing as a narrow white film along the line of inoculation. It was at first mucoid but soon became flattened, dry and shining, remaining unchanged at this stage for weeks.

The indol test gave a negative result.

##### 6. *Pseudomonas* sp?

Another form, having all of the features mentioned in the general description, was observed. Though it was very motile, the number of flagella was not determined.

This was a small rod which had a tendency to bipolar staining. It frequently formed short chains. It was gram-negative.

On gelatin plates it developed round, bowl-shaped, liquefying colonies, in which there was a uniform white turbidity. A dense white deposit occupied the centre of the colony, and smaller, opaque, white masses of bacteria lay at many points midway between the centre and the circumference.

Under the microscope the whole colony was found to be granular. The dense centre appeared dark brown, the outer zones lighter in colour. Approximately midway between the centre and circumference a denser line, broken at intervals, corresponded with the deposits noted microscopically.

On agar plates colonies were round, moist and cream-coloured. Microscopically they appeared concentrically zoned, with a granular structure. Dense masses like a tilted disc were often embedded in the colony near the centre.

In gelatin stab cultures, liquefaction was fairly rapid. It was at first crateriform but rapidly became infundibuliform. In 6 days liquefaction was complete. A whitish sediment and a uniform white turbidity were characteristic.

On potato luxuriant growth was produced. It was at first yellow and shining, with an even contour; later, it became deeper in colour, spreading and of a painty consistency. The potato itself was darkened.

On litmus milk a light pellicle was formed within 24 hours, followed by reduction of litmus, and the clotting and digestion of casein, proceeding from the surface downward. The clear liquid became pinkish in colour. The clot also, which was at first white, later became pink.

On agar slants, the growth was luxuriant, spreading evenly along the line of inoculation. It was raised, cream-coloured, moist and shining, spreading gradually over the entire slant. There was a creamy-white deposit in the water of condensation. Indol was formed.

#### SUMMARY.

1. Many forms of bacteria occur normally in *Mya arenaria*, the long-necked clam.

2. Six of these, belonging to the genus *Pseudomonas*, are capable of causing blackening, if supplied with a favourable medium, containing iron or tin. This number includes *Pseudomonas fluorescens* (Flügge) Migula., *Pseudomonas Jaegeri*. Mig., *Pseudomonas liquefaciens* (Tataroff. Mig.) var. *marina*., and two forms which, for reasons stated above, have been given the tentative names, *Pseudomonas sericea fluorescens* and *Pseudomonas myae*.

3. All these blackening organisms were facultative anaerobes.

All liquified gelatin.

All reduced nitrates to nitrites.

All formed acid from dextrose, saccharose and glycerin.

A change of reaction from acid to alkaline was characteristic in sugar media, and usually began on the third or fourth day.

All were motile, gram-negative rods.

No spores were observed.

4. Fluorescence was characteristically produced by three of these organisms, namely, *Ps. fluorescens* (Flügge) Mig., *Ps. Jaegeri*, and *Ps. sericea* (Mig.) var.

*fluorescens*. *Ps. myae* and *Ps. sp?* formed an acid curd, followed by digestion of casein, in milk.

*Ps. Jaegeri* was the only gas former among the blackening organisms isolated.

#### NOTE OF THANKS.

The writer of this paper wishes to express her thanks to Dr. Harrison, who outlined the problem and made many helpful suggestions; to Dr. Huntsman, under whose direction the work was begun; to Professor Lloyd, whose practical interest has been a constant encouragement; to Dr. Oertel, who allowed her the facilities of his department; and, finally, to Professor Derick, whose unflinching interest has been an inspiration and whose practical suggestions have been of great value.

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No. 2

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A STUDY OF THE SEA MUSSEL (*Mytilus edulis*, Linn.)

BY

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# A Study of the Sea Mussel (*Mytilus Edulis* Linn.)

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In 1917 the writer began a study of the growth of the sea mussel (*Mytilus edulis*, Linn.) primarily with the object of discovering the commercial possibilities of the mussels of our Atlantic coast. The investigation was conducted chiefly on the mussels of the St. Andrew's region, New Brunswick, with the Marine Biological Station, St. Andrews as a base, but brief surveys were also made of the beds at Digby, Nova Scotia, and at Grand Manan Island, Bay of Fundy. A very limited number of shells from Hudson's Bay were also examined.

The problem soon presented five main aspects, viz., (1) the distribution of the beds and the size and number of mussels in them; (2) the age of the animals forming the beds; (3) the enemies which prey on them; (4) the factors governing their rate of growth; (5) the factors governing their distribution.

## SECTION I.

### DISTRIBUTION.

#### 1. DISTRIBUTION IN ST. ANDREWS REGION.

The early explorers (Ganong 1887 and 1889) of New Brunswick have left some references to the natural history of the region which are of interest when considering the mussel. Jacques Cartier was the first explorer of the coast of Acadia who paid any attention to the animals and plants of the places he visited, but he does not mention any invertebrates. The first published reference to the invertebrates occurs in Lescarbot's "History of New France" 1609 in which, when describing Champlain's voyage, he mentions the abundance of mussels at St. Croix Island (now known as Dochet Island) and Port Royal. Champlain in writing of his own voyage ("Les Voyages du Sieur de Champlain," published at Paris 1613) mentions finding in 1604, cockles, mussels, sea-urchins and sea-snails at St. Croix Island. He mentions also the occurrence at the present Weymouth Harbour, St. Mary Bay, Nova Scotia, of many shell fish, such as mussels, cockles and sea-snails. Another interesting early reference is that of Nicholas Denys, who, in his "Description Géographique et Historique des Côtes de l'Amérique Septentrionale," published at Paris in 1672, mentions the abundance of shell-fish (coquillages) upon the north shore of New Brunswick and of oysters (huîtres) at Cocagne. During the eighteenth century nothing worthy of note appears to have been written on this subject. In the early half of the nineteenth century several lists of mollusca were published, but these were lists for travellers rather than scientific publications, and show signs of being copied one from another. The chief lists were: Robert Cooney (1832); Rev. C. Atkinson (1847); C. L. Hathaway (1846); Abraham Gesner (1847) (this list

was published in Hitchcock's Zoology of Massachusetts, 1835, and includes the mollusca of the whole New England coast); W. H. Perley (1852 and 1854); Alex. Monro (1855).

The distribution given by later writers is as follows:

Willis (1863): "Whole coast; common."

Gould, A. A. (1870): "Extensively distributed throughout all northern seas. Appears to inhabit shallow water. Eastport, common (Cooper)."

Verrill, A. E. and Smith, S. I. (1873): "In Bay of Fundy from littoral zone to 50 fathoms."

Ganong, W. F. (1885): "Passing to the mussel family (Mytilidae) the Bay (*i.e.*, Passamaquoddy Bay) affords at least four species of which far the most abundant is the edible mussel (*Mytilus edulis*). Crowded closely together above ground and clinging by the firm byssus they occupy great beds, all of a dull black colour except where a lighter coloured specimen of the variety *pelucidus* is more conspicuous than its fellows. The nearer low water mark they are the larger they are, while they are found at their fullest perfection by dredging in four or five fathoms."

Whiteaves, J. F. (1901): "Common everywhere, at or a little above low-water mark."

Detweiler, John D. (1915): "Common throughout this region in the littoral zone."

In the following detailed description of the location of the mussel beds as found during the summer of 1917 it will be seen that although in a general way the mussel was "common everywhere" in certain localities it was lacking. As will be pointed out later this was due to the fact that the mussel was re-establishing itself in the regions after being almost entirely exterminated there. It will be noted also that although dredging operations were carried out near some of the large beds no living specimens of *Mytilus edulis* were obtained in this way. The distribution was confined to the littoral zone. This is in harmony with Detweiler (1915) but disagrees with Verrill (1873) and Ganong (1885). What the explanation of this disagreement is, the author is not prepared to say. In other regions mussel beds have been known to be completely exterminated (from causes not always obvious) even within a limited period. An interesting case of this occurred a few years ago at Woods Hole, when only shells and fragments were dredged in the summer of 1908 in several localities where mussels had been abundant during the summer of 1903. All the beds in deep water, however, were not exterminated, *Mytilus edulis* being "abundant and universally distributed in Vineyard Sound at 1-19 fathoms." (Sumner, Osburn and Cole, 1913).

#### *Description of the Mussel Beds of the St. Andrews Region in 1917.*

The investigation of the region was carried out at or about low tide, when, by the combined use of a launch and dinghy, the extent of the beds could be ascertained by direct observation. In this way the whole shore (including portions of the creeks whose mouths were on this shore-line) from Oak Bay to Upper Green Point on the Mascareen shore was explored; also the entire shore of Navy Island and of Minister's Island, a portion of the shore of Bliss Island, the shore of Deer Island, from North Harbour to a point opposite Indian Island,



Wilson's Beach, and points on Macmaster Island and Adam Island. Owing to a dense fog the exact location of the points of observation in the last two cases could not be ascertained (Chart I).

In Oak Bay, in Warwig Creek, a rather extensive bed was found on a muddy, gently sloping shore a short distance below the bridge. Dredging operations were carried on in this creek near the beds but no mussels were obtained although at one place the mussels were growing on either bank opposite the point where the dredging was done. The St. Stephen River was not explored, but a resident of the district informed the writer that the sawdust from the mills along the river rendered it unsuitable for mussels and none grew there. This would appear highly probable.

From Oak Bay along the Canadian shore of the St. Croix River, as far as the Biological Station, no beds were found. It was impossible to make observations at Dochet Island to compare with Champlain's records owing to the war regulations regarding visitors at U.S. Lighthouses and adjoining grounds. At the Biological Station fairly large patches of mussels were found on the bare rocks there, extending nearly to Joe's Point. Extensive dredging operations were carried on opposite this bed and around Joe's Point, but no mussels were obtained. A large clam bed is located between Joe's Point and the wharves of St. Andrews, so that mussels do not have an opportunity of growing there, although it would appear to be a favourable situation for them.

They grew abundantly on the wharves of St. Andrews and formed beds between the wharves when allowed to do so. Beyond the wharves, however, the beds ended and other beds were not found until the vicinity of the bar between the mainland and Minister's Island was reached. (In Kitty Cove a large bed was found, but they were nearly all dead. What had caused their death was not ascertained, but it was observed that the starfish were also dead in large numbers.) On the side of the bar nearest St. Andrews the mussels occurred in small scattered patches, but on the side of the bar nearest Chamcook the bed was an extensive one. Around the northern part of Chamcook Harbour mussels occurred, but none were found on or near Clarke's Ledges.

From Clarke's Ledges to the Bocabec River only one small patch of stunted-looking mussels was seen. This was at Bocabec Bay. In Bocabec River a similar patch was found. At Digdequash Harbour the mussels were growing in a rather large bed on the gently sloping shore. At Hog Island, near Digdequash Harbour, another such bed was found. From there to Upper Green Point, along the Mascareen shore, no mussels were found, nor were any found at Upper Green Point.

An extensive bed was found on the side of Navy Island nearest St. Andrews extending from the Navy Bar Lighthouse to the point opposite the C.P.R. wharves and lying on both sides of this point. There was also a large bed on Niger Reef and on Navy Island near Niger Reef. Dredging operations were carried on around these beds, but failed to obtain any mussels. On the side of the Island remote from St. Andrews no mussels were found.

On Minister's Island only one bed was found. This was continuous with the one on the bar between the island and the mainland and did not extend quite to the entrance of Chamcook Harbour.

On the outer side of Bliss Island, among the sea-weed on the ledges, the mussels were quite abundant. Also on the sheer rocks forming a large portion of the shore patches of mussels were found to occur quite extensively in a strip from two to four feet wide just above low-water mark. In Fisherman's Cove, on the inner side of the island, mussels were found growing on the muddy, gently sloping shore.

On Deer Island, from Northern Harbour to a point opposite Indian Island, the mussels occurred in patches along the sheer rocky shore and on the ledges in a strip from low-water mark to about four feet above it. Only at Clam Cove were any found on the beaches and here only a very few scattered among the sea-weed.

At Wilson's Beach no mussels were observed. At Macmaster Island a large bed was found. The mussels here were growing on the reefs and also on the sloping portions of the shore. On Adam Island only one small patch of mussels was found where observations were made, although the shore here was similar to the outer shore of Bliss Island. As explained previously the *exact* location of these points of observation could not be determined owing to a dense fog.

In all places where mussels occurred the beds ended abruptly when low-water mark was reached. In the case of the beds on sloping shores the upper limit was in the region between one-third and one-half of the distance between low- and high-water marks. It was noticeable that no mussel beds were found on sloping *gravelly* shores, but always where the shore was muddy or sandy (the mussels soon render a sandy shore muddy) or on bare rocks. The writer is not able to offer any explanation as to why the mussels grew on some of the sheer rocky shores, *e.g.*, Bliss Island and not on others, *e.g.*, Adam Island.

The variety *pellucidus* was found in the various beds described, but was not numerous.

#### *Size and Relative Numbers of Mussels in the Various Mussel Beds of the St. Andrews Region in 1917.*

Samples of the mussels were taken from the various beds and the living mussels taken from a known area were counted and the lengths of their shells measured to the nearest half-centimeter. The length of the mussel was considered as the distance from the extreme anterior end of the shell to the extreme posterior end when the shell was placed with the edge from which the byssus protruded parallel with the scale. The samples of which the records are quoted were taken from typical portions of the mussel beds near low-water mark unless otherwise stated.

The mussels in the various localities were all small. The largest ones obtained were only 6.5 cm. in length and only two were taken of this size. These were found in a sample taken from the rocky bottom beside Niger Reef, from an area of 102.5 sq. cm. Only 20 living specimens were obtained in the sample, which was taken from a small patch of mussels growing just at low-water mark somewhat isolated from the rest of the bed. In the main bed the mussels were of the usual small size (none obtained being over 4.5 cm. in length), but from the above mentioned sample 17 out of the 20 mussels taken were 5 cm. or over in length. In general the largest mussels were obtained from the reefs and rocky

edges such as occur on the outer side of Bliss Island. Samples 1, 2, 3, Table I., are typical as to the length and number obtained from a given area of such beds. From the beds lying on a sloping shore the majority taken were between 2 cm. and 3.5 cm. in length as seen in Fig. 1. Samples 4, 5 and 6 are typical for these beds.

TABLE I.  
The number and size of sea mussels in typical samples in beds of St. Andrews region in 1917.

Sample number	Area.	Location.	Number of Mussels in Sample of Lengths.											Total number of mussels			
			cm. 0.5	cm. 1	cm. 1.5	cm. 2	cm. 2.5	cm. 3	cm. 3.5	cm. 4	cm. 4.5	cm. 5	cm. 5.5		cm. 6	cm. 6.5	
1	157.5 cm. <sup>2</sup>	Ledges of outer shore of Bliss Island.		1	1	3	11	11	15	18	5	1					65
2	157.5 cm. <sup>2</sup>	Sheer rock of outer shore of Bliss Island.					1	2	2	2	8	17	3	8			43
3	235.5 cm. <sup>2</sup>	Sheer rock of southern point at entrance to Clam Cove.	7		8	6											56
4	157.5 cm. <sup>2</sup>	Bed on eastern bank of Warwig Creek.		1	2	12	55	43									113
5	157.5 cm. <sup>2</sup>	From bar extending from Navy Island to Navy Bar Light-house.			4	13	25	36	23	22	3						126
6	157.5 cm. <sup>2</sup>	From bed on McMaster Island.			16	22	25	33	12	10	1						119

As will be pointed out later, the reason so few mussels were obtained in the beds over 4.5 cm. in length was that the beds were composed of young individuals since, as will appear, mussels frequently grow larger in that region.

*Description of the Mussel Beds of St. Andrews Region in 1918.*

In 1918, in the St. Andrews region, it was found that the sea-mussel instead of occurring in isolated patches about Passamaquoddy Bay now regularly formed part of the fauna of its littoral zone. The large beds were located as previously and were in a thriving condition. The mussel had extended up the St. Croix River also as far as Oak Bay. On the ledges about Dochet Island and along its rocky shores the mussels were abundant, forming a bed of considerable size. The mussels (as observed from a launch) appeared to be of the usual size and type found in the beds of St. Andrews. (Owing to the United States war regulations *re* lighthouse property a sample was not obtained.)

A trip to L'Etang revealed that the mussels were common there and in Black Harbour, but no large beds were found.

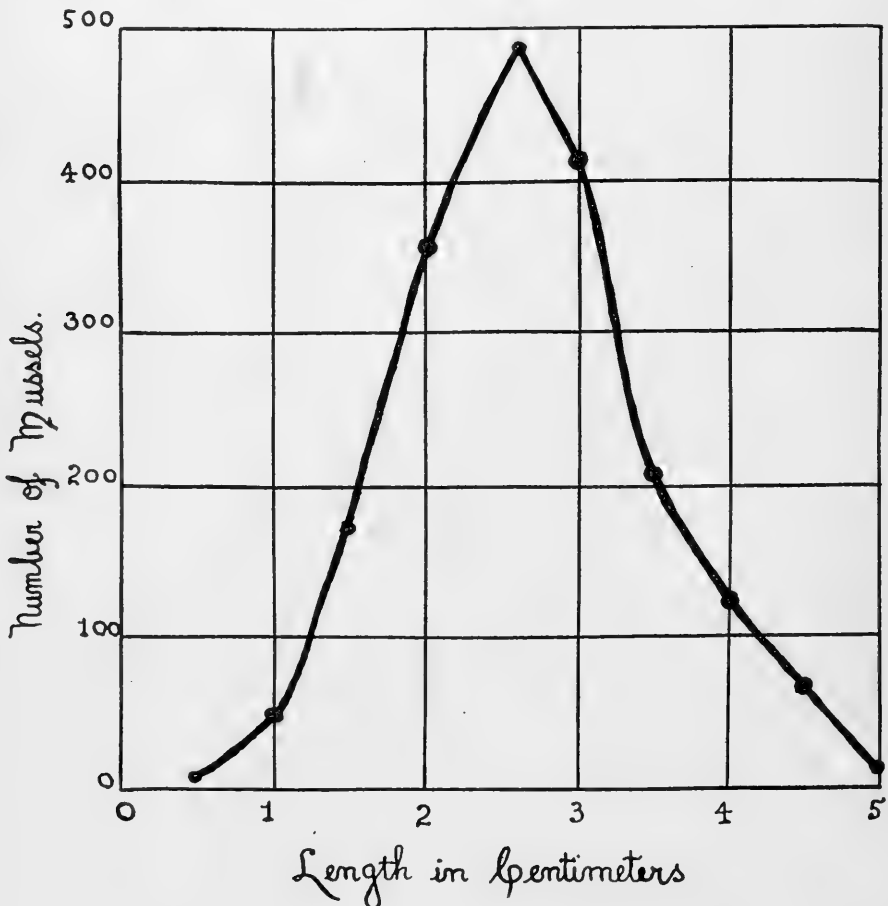


Fig. I.—Frequency Curve of Mussels of various sizes in St. Andrews Region, 1917.

The mussels were always found as previously, occurring only in the littoral zone except in special locations such as anchor chains, which afford some protection against certain of their enemies, *e.g.*, starfish.

## 2. DISTRIBUTION IN DIGBY REGION, NOVA SCOTIA.

In August, 1918, I paid a short visit to Digby, Nova Scotia, with a view to making a survey of the mussel beds in the Annapolis Basin. Owing to the difficulty experienced in obtaining suitable boats for trips and the slowness with which one could proceed close inshore at low-water (due to the quantities of eel-grass which infest the shore) it was found possible to visit only the beds close to Digby, and one bed reported at Gulliver Hole, a few miles down the coast outside the Basin.

Through the co-operation of the Maritime Fish Corporation I was enabled to secure the guidance of the mussel fisherman, Mr. Portie Weir, while visiting the mussel beds. For this assistance I am much indebted.

For many years the sea-mussel has been known as common to this region. Its distribution has been given as follows:

Willis, 1863: "Whole coast; common."

Verkruzen, 1878: "Annapolis Basin and Digby Gut, common."

Ganong, 1889: "Very abundant everywhere on coast of Acadia."

Three kinds of mussels had been reported to me as occurring in this region—a large blue one, a large red one, and a small black one. Consequently, I expected to find *Mytilus edulis*, *Modiola modiolus* and possibly *Modiola nigra* were the mussels reported. I found, instead, only *Mytilus edulis*, large eroded specimens being called "blue" mussels, those stained a reddish brown (the cause of the stain has not been ascertained) being the so-called "red" mussels, while the small sea-mussels growing close inshore were the "black" ones. I found also several specimens of the lighter, horn-coloured variety of *Mytilus edulis*, *viz.*, *Mytilus edulis pellucidus*, growing in the various beds.

The best mussel beds are the one in Joggins Cove and the one in Smith Cove (Chart 2). These beds are of the same type. The shore is a very gently sloping muddy one with a considerable quantity of eel grass growing on it, particularly in Joggins Cove. There are, moreover, a large number of shallow tide pools. In these the mussels grow in large numbers and to a good size (Table 2). Sometimes patches of mussels extend from pool to pool, but the greater number are found in the pools often half-buried in the soft mud. In Joggins Cove the wreckage of an old weir furnishes an anchorage for a large colony. These mussels were reported by the mussel fisherman to be "finer and larger" than those growing on the muddy bottom. This colony suggested, of course, the buchôt method of mussel culture and raises the question as to whether or not some modification of that method could not be used profitably in this region. Much of the muddy bottom furnishes no surface on which the spat can attach themselves, hence only a portion of the bottom produces mussels. Every available bit of brush or other solid structure is densely covered so there would appear to be no lack of spat.

There is also a large bed of good-sized mussels on the flats extending from

Bear Island to the mainland. These grow in a similar manner to those in Smith Cove and Joggins Cove. It has been used very little, however, owing to the fact that they are slightly further away from the home of the mussel fisherman.

The "blue" mussels grow along the rough rocky shore of the point bounding Smith Cove on the side nearer Digby. Only a narrow strip of them survive in this unfavourable location and these are exposed only at the fullest tides so that although of good size (Table 2) they are of little importance commercially. Another patch of eroded mussels occurs on Bear Island on the side of the point nearest Digby.

The "black" mussels grow all around Bear Island and also at about the upper limits of the bed in Smith Cove. They resemble the St. Andrews mussels in shape and are too small for marketing (Table 2). They would probably fatten if removed to the better locations and could thus be used as a source of supply for *seed* mussels.

A large bed of mussels was reported as probably existing up Bear River, but was not visited. It was known to exist in 1916. Another bed was reported at Goat Island. Above Goat Island it is said no beds exist.

#### *Mussels at Gulliver Hole.*

A bed of large mussels was reported at Gulliver Hole, down the coast outside of the Annapolis Basin. This proved to be only a patch of mussels growing on the rocks, the mussels resembling those in Passamaquoddy Bay.

#### *Size of the Mussels.*

From a consideration of Table II it will be seen that the larger-sized mussels in the beds near Digby are between 6 cm. and 7 cm. in length, some being found even larger, viz., 8 cm. in length, in the sample of "blue" mussels. It will be seen also that the mussels from Gulliver Hole are of a fairly good size, the majority of the larger ones being between 5.5 cm. and 6 cm. in length.

It is of interest to compare the size of these mussels with those of St. Andrews region. The majority of the larger mussels there in 1917 (from beds of similar location also, *i.e.*, on the gently sloping shores) were between 2 cm. and 3.5 cm. in length. Even those similarly situated to those at Gulliver Hole were appreciably smaller, being for the most part between 4.5 cm. and 5 cm.

The difference in size between the mussels of the St. Andrews region and those from the beds producing the large mussels at Digby (*e.g.*, Smith Cove) is not alone due to the difference in length; there is a distinct difference in the relative proportions of length, depth and thickness of the mussels. Those from Digby are relatively deeper and thicker in proportion to their length than those from St. Andrews. Mussels of this shape I refer to as the Digby type, having first observed this difference in proportion in mussels from Digby, while the relatively shallower mussels which I observed first in St. Andrews region I refer to as of the St. Andrews' type. In Plate I. are shown four mussels which illustrate this difference in shape; Nos. 1 and 2 are mussels from Passamaquoddy Bay and illustrate well the St. Andrews type, while Nos. 3 and 4 are mussels collected at Loggieville, N.S., and are of the Digby type.

TABLE II.

The size of sea mussels in beds of Digby region in 1918.

Sample number	Location and character of sample.	Number of Mussels in Sample of Lengths.												Total No. of mussels in sample.			
		cm. 1	cm. 1.5	cm. 2	cm. 2.5	cm. 3	cm. 3.5	cm. 4	cm. 4.5	cm. 5	cm. 5.5	cm. 6	cm. 6.5		cm. 7	cm. 7.5	cm. 8
1	Joggins Cove, typical.	1	1		1	2		2									21
2	Smith Cove, selected large													1	8	3	16
3	"Blue" mussel bed near Smith Cove, typical.									1				2	1	3	12
4	"Black" mussels of Smith Cove, typical		1			1	1	3	5								12
5	Gulliver Hole, typical						1							5	5	2	14

### 3. DISTRIBUTION AT GRAND MANAN ISLAND, BAY OF FUNDY.

The sea-mussel has been known to occur at Grand Manan for some time, for Stimpson (1854) in referring to their distribution mentions them as "very abundant" at Grand Manan. I was, therefore, anxious to examine any beds existing there at the present time.

During the first week of September, 1918, I was able to visit Grand Manan Island, Bay of Fundy, to investigate the mussel beds there. Owing to stormy weather at the end of that week it was only possible to make trips on September 3rd and 4th so that only a small portion of the coast was investigated. Through the co-operation of Inspector Calder of Welchpool, Campobello Island, New Brunswick, the use of the patrol boat "G" of Grand Manan was granted for these investigations. I am much indebted to Captain Green and the other members of the crew of the "G" for their kindness and assistance during the trips.

The North-western coast of Grand Manan is very rocky and bare, the rock rising sheer out of the water for a considerable height. Such a location is very untavourable for mussels so that it is unlikely that any beds occur there. On the eastern and southern coasts, however, extensive shoals occur and consequently along these coasts I expected to find mussel beds.

At Seal Cove, where I made my headquarters, no mussels were found. The shore there is sandy and so wave beaten as to afford a poor anchorage for mussels.

The first trip made was to Cheynne Passage, between Ross Island and Cheynne Island, where a large mussel bed had been reported. A bed of large mussels was found there extending across the channel as indicated in Chart 3. The mussels were found growing among the sea weeds (kelp, dulce and sea-lettuce). Many dead shells (frequently 5 cm. or more in length) were found among the living shells. The larger mussels grew in the deeper water while at the upper limits of the bed the mussels were smaller, as is usual. Horse mussels (*Modiola modiolus*) were found in the deeper parts of the channel. They were of a good size but were exceedingly difficult to procure as they attach themselves very firmly and frequently wedge themselves between rocks. In the shallow water the mussels were practically all sea mussels (*Mytilus edulis*). Only one starfish was seen in the neighbourhood of the beds, but large numbers of sea-urchins were observed in the deeper portions of the channel.

Another bed (known in this paper as the White Head bed) was found on the western side of the shoal between Cheynne Island and White Head Island. Here the bottom appeared the same as at Cheynne passage, with similar seaweeds, but the mussels proved smaller (Table III) and less abundant. The number growing in the deeper water was noticeably less than in Cheynne passage. Great numbers of gulls were observed idling about. They are reported to feed on the mussels of this region, it being said that they fly up with the mussels, drop them on the rocks, thus breaking the shell, and then devour the contents.

The shore and bar off Redhead (Chart 3) was examined but no sea-mussels were observed.

Two bars off the eastern coast of Wood Island (Chart 3) were examined but no mussels were found on either. The bottom was of fine and coarse gravel. It is said that a few years ago mussels grew abundantly on these bars. Under the gravel a layer of fine black mud was found which suggested "mussel mud." One portion of one bar shifts during heavy storms so it seems possible that the beds reported to have been there may have been destroyed by the bottom shifting.



*Size of the Mussels.*

From a consideration of Table III it will be seen that the majority of the larger sized mussels of Cheynne Passage are between 5 cm. and 6.5 cm. in length (a few even reaching 8 cm. in length), while those of the White Head bed are

TABLE III.

The size of sea mussels in beds at Grand Manan in 1918.

Sample number	Location and character of sample.	Number of mussels in sample of lengths.													Total number of mussels in sample.			
		cm. 1	cm. 1.5	cm. 2	cm. 2.5	cm. 3	cm. 3.5	cm. 4	cm. 4.5	cm. 5	cm. 5.5	cm. 6	cm. 6.5	cm. 7		cm. 7.5	cm. 8	cm. 8.5
1	Cheynne passage one cluster.							2	1	2	2	5		2				14
2	Cheynne passage several other clusters.							2	3	5	7	6	2	2				27
3	Cheynne passage selected large											7	7	3	3	1	1	22
4	White Head several clusters															1		113

somewhat shorter, the majority of the larger sized ones being between 4 cm. and 5 cm. in length although even here one specimen was found 8 cm. in length. It may appear from a consideration only of the data given in Table III that if the same number of mussels had been measured from Cheyenne Passage a similar result might have been obtained. This, however, is highly improbable, as the samples measured were typical and the mussels were noticeably larger throughout the bed. The fact that the deeper parts of the channel were thickly covered with mussels in itself would tend to raise the average length of the mussels of that bed since the larger ones were found in such locations. What caused such a marked difference in the size of the mussels of the two beds I am unprepared to say. It is possible that the mussels of the White Head bed may be younger than those of Cheyenne Passage. Shells have been preserved for further investigation of this point.

In general the size of the mussels at Grand Manan appears to be greater than in the St. Andrews region, where in 1917 very few were found over 5 cm. in length and the greater majority being as pointed out between 2 cm. and 3.5 cm. in length. It will be noted also that they are of about the same length as those found in the better beds at Digby, N.S.

It is of interest to compare the lengths of the mussels from Cheyenne Passage and the White Head bed with the general length for the Passamaquoddy Bay region as given by Gould (1870), viz., 2  $\frac{1}{10}$  inches (*i.e.*, approx. 6.2 cm.); and also with the findings of Ganong (1885), viz., "in abundance 3  $\frac{1}{2}$  inches (*i.e.*, approx. 8.9 cm.) long and even longer." It will be noted that the size for the Grand Manan mussels corresponds very closely to Gould's general length but falls short of the length as given by Ganong.

In shape the mussels at Grand Manan are of the Digby type, *i.e.*, deeper in proportion to their length than those of the St. Andrews region (Figs. 3 and 4, Plate I.); as at Digby the mussels near the upper limits of the bed tend toward the typical St. Andrews shape (Figs. 1 and 2, Plate I.).

## SECTION II

### AGE OF MUSSEL BEDS.

#### 1. *Age of Mussel Beds of St. Andrews Region.*

The age of the mussel beds of the St. Andrews region was definitely determined in 1919. This was done by means of the annual "check marks" on the shells by which the writer has found it possible not only to determine the age of sea-mussels but also their rate of growth during each growing season.

A mussel bed typical of those of the St. Andrews region is conveniently located near the eastern side of the wharf of the Biological Station. This has, therefore, been used as a type bed. It is situated in the littoral zone about low-water mark and is laid bare at nearly every tide. The mussels studied were taken from that portion of the bed lying nearest low-water mark.

Material was collected for the purpose of determining the age of the mussels in this bed July 14, 1919, from a typical portion of it. This material included all the individuals growing on a small area of the bed and was collected before the spat of 1919 was conspicuous. The results of the examination of it are as follows:

Year class * of shell.	Number	% of total population
I.	28	18.8
III.	63	42.3
IV.	44	30.2
V.	13	8.7

In this material it will be noted that shells belonging to the fifth year class are the oldest. In examinations of other material from this bed examples of shells in the sixth year class were found but their occurrence was very rare, so that they represent a negligible portion of the whole population. It will be seen also that the majority of the mussels of the bed belong to the third and fourth year classes, *i.e.*, are individuals that were spawned and settled in the bed while it was thinly populated and so had a good opportunity to develop. In Table IV. the above results are arranged to show when each season's growth in the various year classes was made and the relative numbers of the various year classes in each year considered.

TABLE IV.

Showing relative numbers of each year class and when each season's growth of each year class was made in the mussel population of a typical bed at Biological Station St. Andrews, N.B., July 14, 1919.

Year	Relative Number of Mussels of Year Class					
	I.	II.	III.	IV.	V.	VI.
1919	Unknown	28	63	44	13	Negligible
1918	28	63	44	13	Negligible	
1917	63	44	13	Negligible		
1916	44	13	Negligible			
1915	13	Negligible				
1914	Negligible					

The figures given in Table IV. are, of course, only approximately correct since they are based on an examination of a relatively small number of the mussels and since also they represent only the members of the various year classes which have survived up to July, 1919. They serve, however, to give some indication of the density of the population in preceding seasons and the relative numbers of the various year classes during those seasons.

From these results it seems evident that the bed was destroyed possibly in 1914 and at least before the spawning season of 1915 and that only a small number of individuals spawned in 1914 survived. This deduction is supported by the condition of the beds in the region in 1917. As indicated in Section I. in that year the beds consisted of small mussels, the majority of which had a shell length of between 2 centimeters and 3.5 centimeters. Moreover, mussels

were not found along considerable stretches of the shore as then pointed out. In 1918 the writer found that practically all parts of the shore possessed a number of mussels, even unfavourable locations (e.g., gravelly shores) possessing an appreciable number. In view of the rate of increase in length of the shell of the sea mussel per growing season at St. Andrews, viz., 10.8 m. these facts indicate that the mussels of the region were practically wiped out by some unfavourable condition and that in 1916 and the following seasons they were re-inhabiting the region.

## 2. Age of Mussel Beds at Digby, Nova Scotia.

The shells of mussels collected in the survey of 1918 at Digby, Nova Scotia, have been studied in order to determine the rate of growth for that region. This study revealed that the average rate of increase in length of the shells per growing season is 16.0 mm. It will be seen, therefore, that the larger sized mussels of from 6 cm. to 8 cm. in length are in their fourth, fifth or sixth growing season, the age depending on whether or not the conditions which had obtained during their various growing seasons were favourable.

## SECTION III

### ENEMIES OF THE SEA-MUSSEL AT ST. ANDREWS, N.B.

During the free-swimming larval stage of the sea-mussel it forms part of the plankton and consequently large numbers are undoubtedly destroyed by those forms which feed on the plankton. After becoming well-established in some suitable location for growth it is still subject to the attacks of several animals. At St. Andrews, fish, other molluscs and echinoderms are the chief offenders. A few mussels are probably destroyed by the gulls and crows which occasionally frequent the beds at low-tide.

Fish destroy a large number of mussels. Professor A. G. Huntsman (1920) informs me that they form "a not inconsiderable part of the food of the flounder (*Pseudopleuronectes*) at St. Andrews," and results obtained by Clemens and Clemens (1921) in their study of the eel pout (*Zoarces*) at St. Andrews show that in an examination of 75 specimens, 12 of them (i.e., 16%) were found to contain sea-mussels, the largest number found in a single specimen being 122. It seems probable that further study will show that other fish prey on the mussels in this region.

The molluscan enemies observed devouring the mussels at St. Andrews are: *Purpura lapillus*, *Buccinum undatum* (common whelk) and *Polynices heros* (round whelk or "cockle"). Each one of these attacks the mussel in a somewhat different way. The *Purpura* bores a small round hole about the size of a common pin head in the shell and thus gains access to the animal within. These holes are made in any convenient portion of the shell. Very frequently they are found near the umbo. If the *Purpura*, while attacking a mussel, is disturbed before the animal is injured the mussel appears to plug the inner end of the hole bored by the *Purpura* with a pearly excretion, since shells have been found with small holes (considered to have been made by a *Purpura*) which have been plugged in this manner.

The common whelk wears down the posterior or siphon end of the mussel shell by a rasping action of its teeth. This method scratches the shell, removing the epidermis at the edge.

The round whelk, like the *Purpura*, bores a hole in the shell. Only three shells whose inhabitants have fallen victims to round whelks have been examined by the writer. In these the hole is a large oval one, the largest examined being 4.5 mm. along the greater diameter and 3.2 mm. along the lesser diameter. In each case the hole was made about midway between the anterior and posterior ends of the shell near the edge from which the byssus protrudes.

The echinoderms observed destroying the mussel at St. Andrews were the starfish (chiefly *Asterias vulgaris* and *Asterias forbesii*) and the sea-urchin (*Strongylocentrotus droebachiensis*). The starfish, when destroying a mussel, opens its shell by means of a steady pull exerted on each valve by the tube feet. The shell left after the animal has been destroyed is clean and unmarked.

The sea-urchin has not commonly been credited with attacking mussels. Field (1911), in reviewing the various forms which prey on the mussel, makes no mention of the sea-urchin. Ganong (1899) mentions that in Europe it is said to attack sea-mussels, but, gives no authority for this statement. Wilcocks (1884) quotes "Mr. Harding" in a list of enemies, including the "echinus or sea-egg," but gives no exact authority for this reference so it is of little value. Scott (1901), in his investigation of the food of the sea-urchin at St. Andrews, found that the principal food consisted of sea-weed. He found no evidence of the urchins eating any mollusca and summarizes his conclusions after reviewing the literature of the subject thus: "Although practically all who have investigated the food have concluded that the urchins are herbivorous, there is, seemingly, among zoologists a general belief that they are carnivorous."

The sea-urchin is abundant at St. Andrews, and about low-water large numbers of them may be seen on the mussel beds. If disturbed they appear to have been simply resting on the mussels rather than attacking them. So habitually do they haunt the mussel beds, however, that the writer became very suspicious that they were feeding on the mussels, in spite of repeated failure to obtain proof of this.

The first evidence that sea-urchins eat mussels was obtained from an urchin found clinging to a bag containing small mussels suspended from the float of the wharf. This sea-urchin was brought into the laboratory and placed in one of the tanks in running sea-water with a number of small mussels. The following morning the contents of the digestive tract were examined. One small-sized mussel shell was found in it. Subsequently a number of sea-urchins were collected from the mussel beds and the contents of their digestive tracts examined immediately. This examination failed to reveal any traces of mussels (either of the soft parts or of the shell).

In order to obtain further evidence two sea-urchins were placed in a small aquarium in running sea-water with a number of small mussels (8.5 mm.—10.5 mm. in length). The following day no evidence could be seen in the aquarium of any of the mussels having been destroyed. Three more urchins were added. The next day the remnants of at least eight mussel shells were found in the

aquarium. During the subsequent experiment on the rate at which the sea-urchin destroys the mussels (see Table VII.) it was found that the method which the urchin employs when destroying the mussel is to chip away the mussel shell, beginning usually (if not always) at the posterior or siphon and to chew up the mussel shell bit by bit. In some cases the whole shell is chewed up in this fashion, in other cases the shell is only partially destroyed, the soft part of the mussel being eaten from the remaining part of the shell. If a sea-urchin is disturbed in an attack on a mussel before it has been seriously damaged, the mussel shows a scratched and ragged edge. Many old mussel shells show that they have been attacked by sea-urchins. Evidence of such attacks is frequently found on the winter check marks.

An attempt was made during the summer of 1919 to obtain some data regarding the rate of destruction of the mussels by their molluscan and echinoderm enemies. This attempt was only partially successful. The forms used in the experiments conducted were *Purpura*, the common whelk, the round whelk, starfish and sea-urchins.

The experiments were conducted from August 28th to Sept. 19th. During this time no "hot waves" occurred so that no difficulty was encountered in keeping the animals cool. In the experiments with the starfish and round whelks the animals were placed in large shallow wooden tanks in running sea-water. The sea-urchins were placed in a small aquarium in running sea-water to a depth just immersing the animals. The *Purpura* and whelks were placed in small aquaria in sea-water to a depth of from 5 to 7 cm. This water was renewed three or four times per day. The mussels used were given no special surface to which to attach except in the case of the experiment with the *Purpura*. In this experiment the mussels were allowed to attach to a piece of rock before beginning the experiments. No food other than the mussels was furnished any of the animals used in the various experiments.

The result of the experiment with the *Purpura* and mussels is shown in Table V.

During the experiment on the rate of destruction of mussels recorded in Table V. a number of the *Purpura* did not appear to feed for some days. When placed in the aquarium some of the *Purpura* immediately attached themselves to its sides (some not being covered by the water) and remained clinging thus apparently without any change in position until their removal from the aquarium September 8th. When discarded they appeared healthy. Those that have been considered as feeding on the mussels were moving on the rock to which the mussels were attached and were attacking them. Shortly after the removal of the other *Purpura* two of these on the rocks made their way to one side of the aquarium and both remained clinging there until September 13th, when one was knocked to the bottom. On September 14th both were again clinging to one side of the aquarium. By September 16th, however, it was found near the mussels. On September 19th one of the other *Purpura*, which had been feeding on the mussels, was found clinging to the side of the aquarium. In Table V., in estimating the number of *Purpura* feeding, no account has been taken of these two latter movements since one tends to counterbalance the other and any resulting error is probably very slight.

The rate at which the mussels were destroyed from September 2nd, 2 p.m., till September 8th, 3 p.m., was 0.9 mussels per *Purpura* per 24 hours. The rate at which they were destroyed from September 8th, 3 p.m., till September 19th, 9.30 a.m., was 0.9 mussels per *Purpura* per 24 hours.

The experiment with the common whelk was unsuccessful. Five whelks were placed in a small aquarium with a few medium sized mussels (6 or 8 mussels of from 2 cm. to 2.5 cm. in length) on Aug. 29th. None of the mussels were eaten from that time until Sept. 19th (*i.e.*, during 21 days) when the experiment

TABLE V.

Showing rate at which *Mytilus edulis* L. was destroyed by *Purpura lapillus* under laboratory conditions.

No. of <i>Purpura</i> in Aquarium.	No. Feeding on Mussels.	Date of Observation.	Time of Observation.	No. of Hours since Previous Observation.	No. of Mussels Destroyed since Previous Observation.	Length in mm. of Mussels Destroyed.	Notes.
19	..	Aug. 30	3 p.m.	..	..	....	....
19	0	Aug. 31	3 p.m.	24	..	....	....
19	1	Sept. 2	2 p.m.	47	1	8.5-10.5	....
19	1	Sept. 5	9 a.m.	67	1	"	....
19	2	Sept. 6	9 a.m.	24	4	"	....
19	4	Sept. 8	3 p.m.	54	9	"	removed 15 <i>Purpura</i>
4	4	Sept. 8	3.05 p.m.	..	..	....	....
4	2	Sept. 10	3 p.m.	48	4	8.5-10.5	....
4	2	Sept. 13	?	?	6	"	....
4	4	Sept. 16	5 p.m.	145*	3	"	....
4	2	Sept. 19	9.30 a.m.	64.5	6	"	....

\*This number of hours was calculated from 3 p.m. Sept. 10th.

was ended. From Sept. 7th-13th one of the whelks died; with this exception the whelks and mussels appeared healthy during the experiment. The whelks were active and moved freely about in the aquarium.

The experiment with the round whelk was begun Sept. 12th and ended Sept. 19th. A number of mussels ranging in size from 8.5 mm. to 20.1 mm. length were placed in a large wooden tank with 8 or 10 round whelks. On Sept. 15th one mussel shell was removed, the animal having fallen a victim to a round whelk. On Sept. 19th two other shells were removed, the animals within

TABLE VI.

Showing rate at which *Mytilus edulis* L. was destroyed by *Asterias* under laboratory conditions.

No. of Starfish in Tank.	No. Feeding on Mussels.	Date of Observation.	Time of Observation.	No. of Hours since Previous Observation.	No. of Mussels Destroyed since Previous Observation.	Length in mm. of Mussels Destroyed.	Notes.
2	2	Aug. 28	3.15 p.m.	....	..	.....	....
2	2	Aug. 29	10.55 a.m.	19.6	4	8.5-10.5	....
2	2	Aug. 30	11.00 p.m.	24.9	9	"	....
2	2	Sept. 1	8.30 p.m.	45.5	16	"	....
2	2	Sept. 2	10.00 a.m.	13.5	7	"	....
2	2	Sept. 3	10.00 a.m.	24	8	"	....
2	2	Sept. 4	9.00 a.m.	23	3	"	....
2	2	Sept. 5	10.00 a.m.	25	10	"	....
2	2	Sept. 6	9.00 a.m.	23	4	"	Removed all mussels.
2	2	Sept. 6	9.05 a.m.	....	....	....	Added larger mussels.
2	2	Sept. 8	3.00 p.m.	46	6	22.0, 22.5 23.5, 22.0 21.5, 18.5	....
2	2	Sept. 10	3.00 p.m.	....	....	Results spoiled	....
2	2	Sept. 13	3.45 p.m.	72.8	6	25.5, 20.0 22.0, 21.5 21.5, 21.5	....
2	2	Sept. 16	4.15 p.m.	73.5	7	18.5, 25.0 26.5, 19.5 25.5, 19.5 20.5	....
2	2	Sept. 17	3.00 p.m.	22.7	5	25.5, 18.5 16.5, 17.5 19.5	....
2	2	Sept. 19	9.30 p.m.	42.5	3	19.5, 15.5 16.0	....



having been eaten, while another mussel was removed from the grasp of a whelk a hole having been partially bored in one valve of the mussel shell. During the experiment the round whelks all appeared healthy and moved freely about in the tank. It is evidently impossible to form an estimate of the rate at which they eat mussels from this experiment.

The result of the experiment with the starfish is shown in Table VI.

One of the starfish used in this experiment had been kept in the tank for some days without food until the day before the experiment was begun, when it

TABLE VII.

Showing rate at which *Mytilus edulis* L. was destroyed by *Strongylocentrotus droebachiensis* under laboratory conditions.

No. of Sea-urchins in aquarium.	No. Feeding on Mussels.	Date of Observation.	Time of Observation.	No. of Hours since Previous Observation.	No. of Mussels Destroyed since Previous Observation.	Length in mm. of Mussels Destroyed.	Notes.
4	4	Sept. 1	9.30 a.m.	....	....	....	88 mussels placed in aquarium
4	4	Sept. 2	9 a.m.	23.5	12	8.5-10.5	....
4	4	Sept. 3	9.30 a.m.	24.5	17	"	....
4	4	Sept. 4	9 a.m.	23.5	10	"	....
4	4	Sept. 5	10 a.m.	25	11.5	"	Remaining mussels removed
4	4	Sept. 6	5 p.m.	....	....	....	Placed 35 mussels in tank
4	4	Sept. 8	3 p.m.	46	6	16.5-25.6	....
4	4	Sept. 10	?	?	6	"	....
4	4	Sept. 13	4 p.m.	121*	2	"	....
4	4	Sept. 16	4.30 p.m.	72.5	3	"	....
4	4	Sept. 17	2.45 p.m.	10.5	1	"	....

\*This number of hours was calculated from 3 p.m. Sept. 8th.

was given four small mussels. On Sept. 4th the starfish were found to have moved away from the mussels, which probably accounts for the small number eaten from Sept. 3rd to Sept. 4th. By Sept. 6th the mussels were not as numerous as formerly in the tank.

The rate at which the small mussels were destroyed (Aug. 28th-Sept. 6th)

was 3.6 mussels per starfish per 24 hours. The rate at which the larger mussels were destroyed (Sept. 6th-Sept. 19th) was 1.2 mussels per starfish per 24 hours.

The results of the experiment with the sea-urchin are given in Table VII.

The rate at which the small mussels were destroyed (Sept. 1st-Sept. 5th) was 3.1 mussels per sea-urchin per 24 hours. The rate at which the larger mussels were destroyed (Sept. 6th-Sept. 17th) was 0.7 mussels per sea-urchin per 24 hours.

#### SUMMARY.

1. At St. Andrews the sea-mussel is preyed upon by the flounder, eel pout, *Purpura*, common whelk, round whelk, starfish and sea-urchin.

2. Under experimental conditions the common whelk did not eat the mussels; the round whelk ate a limited number of small mussels; the *Purpura*, starfish and sea-urchin ate both small and large mussels freely.

#### SECTION IV.

##### THE RATE OF GROWTH OF THE SEA MUSSEL (*MYTILUS EDULIS* L.) UNDER VARIOUS INTERTIDAL AND FLOATING CONDITIONS AT ST. ANDREWS, NEW BRUNSWICK.

During the summer of 1919 experiments were conducted at the Biological Station, St. Andrews, New Brunswick, to ascertain the rate of growth of the sea mussel (*Mytilus edulis* L.) under various intertidal and floating conditions. For these experiments the mussels were allowed to attach either to blocks of wood or pieces of rock (when rock was used, that having a rough "honey-comb" surface was selected). The most satisfactory wooden blocks used were approximately 2.5 inches wide by 8 inches long and had narrow grooves chiselled on the surface to which the mussels attached. The edges of these grooves were left as rough as possible, to give the mussels a surface to which they could readily fasten themselves. The grooves also furnished some protection against wave action. The mussels used were from 8-12 mm. in length. These young mussels attach themselves readily. It was found that they would fasten themselves to the rocks in from three to six hours, but for their attachment to the wooden blocks from two to three days were required. While the mussels were attaching themselves the blocks (weighted to prevent floating) or rocks were placed in aquaria and the mussels (measured) were placed over them with sufficient sea-water to cover them to a depth of two or three centimeters. The water was renewed frequently. Each day the mussels were left without water for periods of two or three hours. This appeared to facilitate their attachment and also prevented them becoming unaccustomed to exposure.

Sets of mussels were placed under the following conditions: One set was suspended from the floating breakwater, the mussels being placed at various levels from the surface; another set was fastened to a pole anchored to the bottom and thus kept at an approximately constant distance from the bottom; two other sets were fastened to the wharf at various intertidal levels, one set being exposed to direct sunlight, the other being constantly shaded; another

set was placed in tidal pools, the pools being situated at different intertidal levels. During these experiments it was found necessary, owing to the depredations of *Purpura lapillus*, to protect the mussels (by means of wire netting) on the blocks forming the series on the wharf up to a level of 17.6 feet above low-water datum. Similarly it was found necessary to protect the mussels in the lower six tidal pools, *i.e.*, those in the zone whose upper limit was 17.6 feet above low-water datum.

TABLE VIII.

Showing rate of increase in length of *Mytilus edulis* L. during breakwater series experiment in 1919.

Block	1	2	3	4	5
Depth in feet below surface.....	1	2	3	6	9
No. on block when set out July 8.....	69	64	50	56	55
No. on block Aug. 4.....	38	44	18	33	41
Percentage on block Aug. 4.....	55.0	68.7	36	58.8	74.5
No. on block Sept. 9.....	21	29	17	28	31
Percentage on block Sept. 9.....	30.4	44.1	34	51.8	56.3
Average length in mm. when set out July 8.....	11	11	10.5	10.5	10.5
Average length in mm. Aug. 4.....	16.6	16.3	16.3	15.6	15.0
Average increase in length in mm. July 8-Aug. 4, <i>i.e.</i> , in 27 days.....	5.6	5.2	5.8	5.1	4.5
No. examined Aug. 4.....	10	13	6	5	18
Average increase in length in mm. per day, July 8- Aug. 4.....	0.21	0.19	0.22	0.19	0.56
Average length in mm. Sept. 9.....	27.2	25.7	25.0	24.1	21.5
Average increase in length in mm. July 8-Sept. 9, <i>i.e.</i> , in 64 days.....	16.2	14.7	14.5	13.6	11.0
No. examined Sept. 9.....	12	15	13	18	18
Average increase in length in mm. per day, July 8- Sept. 9.....	0.25	0.24	0.23	0.21	0.17

*Breakwater—Series.*

In this experiment five blocks (Nos. 1, 2, 3, 4 and 5), to which measured mussels were attached, were nailed crosswise to a scantling which was fastened to the floating breakwater at the Biological Station in such a manner that the

blocks were at depths of 1, 2, 3, 6 and 9 feet respectively from the surface. The results of this experiment are recorded in Table VIII. Unfortunately the whole series was lost during the second week of October so that it was impossible to obtain the rate of the growth late in the season.

TABLE IX.

Showing rate of increase in length of *Mytilus edulis* L. during anchored pole series experiment in 1919.

Block.....	11	12	13	14	15	16	17	18	19	20
Minimum depth in feet from surface.....	2	3.16	4.32	5.48	6.64	7.80	8.80	9.80	10.80	11.8
Number on block when set out Aug. 4.....	66	125	?	85	119	85	72	95	14.4	0.8
Number surviving Sept. 15.....	25	101	110	27	75	22	66	64	27	113
Percentage surviving Sept. 15...	37.8	80.8	?	31.7	63.8	25.8	81.6	67.3	18.8	12
Average length in mm. when set on Aug. 4.....	9.5	9	9	9	9	10	10	10	10	9.5
Average length in mm. Sept. 15.	16.8	17.0	16.3	15.8	14.9	16.0	16.3	16.4	15.3	
Average increase in mm. Aug. 4, <i>i.e.</i> , 42 days.....	7.3	8.0	7.3	6.8	5.9	6.0	6.3	6.4	5.3	no sample taken
Number examined Sept. 15.....	10	27	27	8	17	5	19	11	2	
Average increase in length in mm. per day Aug. 4-Sept. 15	0.17	0.19	0.17	0.16	0.14	0.14	0.15	0.15	0.13	
Number surviving Oct. 18.....	22	11	32	26	8	..	..	..	..	..
Average length in mm. Oct. 18..	16.4	20.0	21.2	20.6	22.9	..	..	..	..	..
Average increase in length in mm. from Aug. 4-Oct. 18, <i>i.e.</i> , in 33 days.....	6.9	11.0	12.2	11.6	13.9	..	..	..	..	..
Average increase per day in length in mm. from Sept. 15 to Oct. 18.....	0.091	0.15	0.19	0.24	..	..	..	..	..	..

From the results of this experiment it is evident that the most advantageous depth for the growth of the sea mussel is 1 foot from the surface. The irregularity which is contrary to this conclusion occurring in the rate of increase in length at a depth of 3 feet noted on August 4th, is probably due to the small number of measurements on which this rate is based. It will be observed also that, with the exception mentioned above, the rate of increase in length decreases as the

depth from the surface increases. It will be noted, too, that the percentage surviving September 9th on the block 1 foot from the surface was noticeably less than on the blocks at greater depths. The greater wave action at the surface probably accounts for this.

#### *Anchored Pole Series.*

In this experiment ten blocks (Nos. 11 to 20), to which measured mussels were attached, were nailed lengthwise along a pole. This pole was anchored in the cove at the Biological Station so as to float upright ten feet from the bottom. It was so located that the mussels were never exposed even at low water. Therefore the mussels on this pole were at a constantly varying depth from the surface. The results from this experiment are shown in Table IX.

Considering the results of the examination of material taken September 15th it will be seen that the greatest rate of increase in length occurred at the upper end of the pole and that the rate of increase in length shows a tendency to decrease as the lower end of the pole is approached. It will be noted that there is a considerable irregularity in the results when considered with reference to this tendency. This is probably largely due to the fact that many of the mussels moved from their original positions on the blocks and wedged themselves between the blocks and the pole, thus obtaining more sheltered positions. It was impossible when collecting the mussels for examination to make note of these individual differences. It will be observed that the rate of increase in length at the upper end of the pole, viz., 0.17 mm. increase in length per day, corresponds with that at 9 feet from the surface in the breakwater series September 9th.

The material collected October 18th unfortunately represents only a portion of this series. It will be seen that it indicates that the rate of growth from September 15th to October 18th was distinctly slower on the whole than from August 4th to September 15th. The fact that the increase in length of the mussels examined from the upper block was less October 18th than that of those examined September 15th may be due to the small numbers examined September 15th. From the limited data available it is impossible to judge whether the increased rate of increase in length observed as the depth from the surface increases is significant or not.

#### *Wharf Series.*

In this experiment two sets of eleven blocks (Nos. A1, B1, to K1, and Nos. A2, B2 to K2) on which measured mussels were attached were put out in two vertical series July 4th. The blocks used were pieces of weathered shingles about 2.5 inches wide and 10 inches long. One set of blocks (known as the south pile wharf series) was fastened on one of the south piles of the wharf of the Biological Station. In this location they were constantly exposed to direct sunlight during the day. The other set (known as the below beams wharf series) was fastened below the beams on the east side of the wharf. In this situation the whole series was constantly shaded. Corresponding members of each series were placed at the same level above low-water datum. The results of the experiment are shown in Tables X. and XI.

It will be noted that the highest level above low-water datum at which the mussels survived until July 31st was 19.2 feet in the sunny exposed location (*i.e.*, south pile wharf series) and 21.0 feet in the shaded location (*i.e.*, below beams wharf series). It will be seen; also, that the number surviving at any level was small. This was due to two causes, *viz.*, the mussels were set out on shingles which furnished unsuitable surfaces for firm attachment and they were unprotected from the depredations of the *Purpura*, which wrought great havoc among them, especially at the lower levels.

TABLE X.

Showing upper limit of survival of *Mytilus edulis* L. during the first south pile wharf series experiment in 1919.

Block.....		A1.	B1.	C1.	D1.	E1.	F1.	G1.	H1.	I.1	J1.	K1.
Height in feet above low water datum.		9.5	11.1	12.7	14.2	15.9	17.6	19.2	21.0	22.6	24.3	26.0
Average length in mm. when set out July 4.....		12	12	12	12	12	12	10.5	10.5	10.5	10.5	10.5
No. set out on block July 4.....		?	?	?	?	?	?	73	59	57	?	53
Number sur- viving July 5	On block.....	20	17	16	49	?	?	?	?	?	?	?
	Near.....	5	4	6	2	?	?	?	?	?	?	?
	Total.....	25	21	22	51	?	?	?	?	?	?	?
Number sur- viving July 7	On block.....	20	12	14	28	11	48	22	21	43	124	54
	Near block.....	1	3	6	4	1	4	3	0	0	0	0
	Total.....	21	15	20	32	12	52	25	21	43	124	54
Number sur- viving July 15	On block.....	5	1	2	2	9	21	3	5	0	102*	61*
	Near block.....	..	2	5	3	..	..	..	..	..	..	..
	Total.....	5	3	7	5	9	21	3	5	0	102*	61*
Number surviving July 31.....		0	0	0	2	1	4	3	0	0	0	0

NOTE.—Numbers marked \* included a large proportion of dead mussels.

So few of the first sets survived until July 31st that two other sets (blocks Nos. A3, B3 to 13 and A4, B4 to L4) were put out in the same locations, but on the type of blocks used in the anchored pole series. In addition to the grooves on the surface to which the mussels attached these blocks had holes bored in these surfaces to provide greater protection. The blocks within the zone of activity of the *purpura* (*i.e.*, up to 17.6 feet above low-water datum) were also protected by wire cages. The results obtained in the second south pile wharf series are given in Table XII.

TABLE XI.

Showing upper limit of survival of *Mytilus edulis* L. during first below the beam series experiment in 1919.

Block.....	A2	B2	C2	D2	E2	F2	G2	H2	I2	J2	K2
Height in feet above low water datum.....	9.5	11.1	12.7	14.2	15.9	17.6	19.2	21.0	22.6	24.3	26.0
Average length in mm. when set out July 4.....	10.5	11	11	11	11	11	11	11	11	11	11
Number on block when set out July 4.....	51	41	61	54	58	49	37	69	29	42	?
Number surviving July 7.....	34	16	44	44	29	44	11	58	25	38	27
Number surviving July 15.....	6	6	11	11	11	22	1	27*	10	34*	25*
Number surviving July 31.....	?	5	3	0	2	8	2	7	0	0	0

NOTE.—Numbers marked \* included large proportion of dead mussels.

TABLE XII.

Showing rate of increase in length of *Mytilus edulis* L. during second south pile wharf series experiment in 1919.

Block	A3	B3	C3	D3	E3	F3	G3	H3	I3
Height in feet above low water datum.....	9.5	11.1	12.7	14.2	15.9	17.6	19.2	21.0	22.6
Average length in mm. when set out Aug. 19.....	9	9	9	9	9	9	9	9	9
Number set out.....	95	84	84	69	77	63	77	103	86
Number surviving Aug. 21.....	94	80	80	61	75	45	?	?	?
Number surviving Sept. 1.....	?	?	?	?	?	?	29	?	26
Number surviving Sept. 16....	50	?	?	?	?	?	3	15	3
Number recovered Oct. 28.....	94	59	44	21	19	21	3	10	0
Percentage recovered Oct. 28...	99	70.4	52.3	30.4	24.7	33.3	3.9	9.7	..
Average length in mm. Oct. 28.	10.8	12.5	10.6	9.7	9.7	10.2	10.8	9.1	..
Average increase in length in mm. from Aug. 19 to Oct. 28, i.e., in 50 days.....	1.8	3.5	1.6	0.7	0.7	1.2	1.8	0.1	..
Average increase in length in mm. per day from Aug. 19 to Oct. 28.....	0.036	0.071	0.033	0.015	0.015	0.024	0.036	0.0028	..

It will be observed that in the second south pile wharf series experiment, the mussels survived at 21 feet above low-water datum, while in the first south pile wharf series experiment, the highest level at which they survived was 19.2 feet above low-water datum. This was probably due to the fact that during the second experiment the weather was cooler than during the earlier one. The second set was, therefore, not exposed to as high a temperature when uncovered as the first set. It will be noted also that the number surviving shows a decided tendency to decrease as the exposure to which the mussels were subjected increases. The irregularities occurring in the percentage, surviving at the higher levels, is probably due to slight differences in the various blocks favouring attachment and protection for the mussels. It will be seen, also, that the rate of growth shows a tendency to be higher at the lower levels than at the higher ones. While this tendency is evident, it is subject to several irregularities. Since the rate for block "G3" is based on only three mussels is of little value and is probably too high.

Unfortunately, owing to some misunderstanding of instructions, the second below-beams-wharf series was not preserved at the same time as the second south-pile-wharf series, but instead was left until November 21st. Consequently it is impossible to compare the rate of growth at the various levels as had been intended. The rate of growth per day is not very significant either, since growth (as will be shown later) was at most very slow during November. The results of the experiment are given in Table XIII.

TABLE XIII.

Showing rate of increase in length of *Mytilus edulis* L. during second below beams wharf series experiment in 1919.

Block	A4	B4	C4	D4	E4	F4	G4	H4	I4
Height in feet above low water datum...	9.4	11.0	12.6	14.1	15.8	17.4	19.1	21	22.6
Average length in mm. when set out Aug. 19.....	10	10	10	10	10	10	10	10	10
Number set out.....	56	91	70	95	94	95	72	76	67
Number recovered Nov. 21, '19.....	35	55	36	22	7	9	0	4	0
Percentage recovered Nov. 21, '19.....	62.5	60.4	51.4	23.1	7.5	9.5	..	5.3	..
Average length in mm. Nov. 21.....	13.9	13.7	13.0	13.2	10.7	11.3	..	11.1	..
Average increase in length in mm. from Aug. 19 to Nov. 21 <i>i.e.</i> , in 94 days..	3.9	3.7	3.0	3.2	0.7	1.3	..	1.1	..

It will be seen that in this series the highest level at which the mussels survived was 21 feet above low-water datum, *i.e.*, at the upper limit of survival in the second south-pile-wharf series experiment, and in the first below-beams-wharf series experiment.



The writer has no data available to account for the non-survival of any mussels on block "G4." It is probably purely due to accident. It will be noted that the percentage of mussels surviving and their increase in length decreases as the level above low-water datum increases and that the percentage surviving at the higher levels is very small. It is evident, therefore, that exposure is detrimental to the growth of the mussel.

TABLE XIV.  
Showing conditions in tidal pool series experiment in 1919.

Pool.	Height in feet above low water datum.	Surface dimensions in feet.	Surface in square feet.	Greatest depth in feet.	Average depth in feet.	Volume in cubic feet.	Temperature in °C., July 21	Time of taking temperature observations, July 21.
1	7.3	6 x 6	36	0.33	0.25	9.00	23.5	12:25 p.m.
							24.0	1:15 p.m.
2	9.3	5.5 x 2.5	13.75	0.33	0.25	3.64	26.5	1:20 "
							27.0	1:58 "
3	12.0	3 x 3	9	0.29	0.20	1.8	24.0	1:25 "
							24.0	2:02 "
							24.5	2:40 "
4	13.9	5 x 3	15	0.37	0.33	4.95	26.5	1:30 "
							27.5	3:08 "
5	15.2	6 x 3	18	0.20	0.12	2.16	26.2	2:05 "
							27.0	3:23 "
6	16.7	5 x 2.6	15	0.20	0.12	1.80	28.0	1:36 "
							28.5	3:42 "
7	18.1	7 x 2.6	18.2	0.20	0.12	2.18	29.0	1:42 "
							29.2	4:03 "
8	19.3	5.5 x 4.5	24.75	0.41	0.25	6.39	28.0	1:49 "
							28.0	4:03 "
9	20.0	4 x 2	8	0.37	0.25	2.0	20.5	1:55 "
							18.5	4:27 "

*Tidal Pool Series.*

The tidal pools used in this experiment were shallow pools in the intertidal zone at the Biological Station. In Table XIV. are recorded the height above low-water datum, the surface, depth, etc., of the various pools. The temperature observations of July 21st were taken to ascertain the maximum temperature of the water in the pools during the experiments. July 21st was a bright sunny day and one of the hottest of the summer. Low water occurred at noon, thus giving the water in the pools every opportunity to become warm. The final temperature reading for each pool was taken just before the incoming tide entered it. With one exception (pool 9) this was the highest temperature recorded for each pool. In pool 9 it was lower than the earlier reading. This was due to the fact that in the morning and early afternoon the pool was exposed to the sun, but in the late afternoon it was shaded. The temperature of the incoming tide was 13.7° C at 4:18 p.m. Pool 3 was surrounded by sea-weed (*Fucus*) and a small amount was about pool 2. The other pools were free from it.

The mussels used for this tidal pools experiment were allowed to attach to pieces of rock sufficiently heavy to remain in the pools without shifting their positions. The first set was put out (unprotected) in the pools July 4th. The *Purpura* destroyed all those in the lower six pools so that it was necessary to put out a new set. In Table XV. are recorded the results for the upper three pools of the first set.

TABLE XV.

Showing rate of increase in length of *Mytilus edulis* L. during first tidal pool series experiment in 1919.

Pool	7	8	9
Height in feet of pool above low water datum.....	18.1	19.3	20.0
Number set out in pool July 17.....	?	64	57
Number recovered Sept. 10.....	23	55	53
Percentage recovered Sept. 10.....	?	85.9	92.9
Average length in mm. when set out July 17.....	11	11	10.5
Average length in mm. Sept. 10.....	14.4	14.3	15.1
Average increase in length in mm. from July 17 to Sept. 10, <i>i.e.</i> , in 55 days.....	3.3	3.3	4.6
Average increase in length in mm. per day from July 17 to Sept. 10.	0.061	0.060	0.084

Mussels in tidal pools were feeding as shown by carmine in water.

A second set was placed in the pools August 5th; of these the lower six were protected by cages of wire netting. This proved effective, except in the case of pool 3. It was found necessary August 20th to provide a fine meshed

inner cage for the mussels of this pool. A number of the mussels were removed from the pools September 11th, while a number were left in the pools until October 7th, except in the case of pool 3. So few survived the depredations of the *Purpura* that it was necessary to remove them all from this pool September 11th. The results of this experiment are recorded in Table XVI.

TABLE XVI.

Showing rate of increase in length of *Mytilus edulis* L. during second tidal pool series experiment in 1919.

Pool	1	2	3	4	5	6	7	8	9
Height in feet of pool above low water datum.....	7.3	9.3	12.0	13.9	15.2	16.7	18.1	19.3	20.0
Number set out in pool Aug. 5	150	68	112	86	69	51	69	60	65
Number recovered Sept. 11...	143	51	18	57	61	49	65	46	57
Percentage recovered Sept. 11.	95.3	75	16.0	66.2	88.3	96.0	94.2	76.6	87.7
Number again set out in pool Sept. 11.....	103	32	0	32	23	30	41	46	24
Number recovered Oct. 7.....	82	18	....	21	3	28	33	22	19
Percentage recovered Oct. 7...	79.6	56.2	....	65.6	13.0	93.3	80.5	47.8	79.1
Average length in mm. when set out Aug. 5.....	10.5	10.5	11	10.5	10.5	10.5	10.5	10.5	11
Average length in mm. Sept. 11	13.5	12.1	11.3	11.8	11.7	12.1	12.6	12.4	12.6
Average increase in length in mm. from Aug. 5 to Sept. 11, <i>i.e.</i> , in 37 days.....	3.0	1.6	0.3	1.3	1.2	1.6	2.1	1.9	2.6
Number examined Sept. 11...	40	19	18	25	38	19	24	15	33
Average increase in length in mm. per day from Aug. 5 to Sept. 11.....	0.080	0.046	0.087	0.036	0.035	0.044	0.058	0.054	0.073
Average length in mm. Oct. 7.	14.1	12.9	....	12.3	12.8	13.6	13.3	13.0	14.7
Average increase in length in mm. from Aug. 5-Oct. 7 <i>i.e.</i> , in 63 days.....	3.6	2.4	....	1.8	2.3	3.1	2.3	2.5	4.2
Number examined Oct. 7.....	82	18	....	21	2	28	33	22	19
Average increase in length in mm. per day from Aug. 5 to Oct. 7, .....	0.056	0.038	....	0.028	0.035	0.049	0.037	0.040	0.067

It will be seen that the rates of increase in length of the mussels in these pools show no correspondence to the differences existing among the pools regarding their surfaces, depths, volumes, maximum temperatures attained, or amount of exposure between tides.

#### *Anchored Float Series.*

An attempt to determine the time at which growth became very slow was made. A number of blocks to which measured mussels were attached were set out in the middle of September. These were fastened to an anchored float, so that they were submerged near the surface. The blocks were taken in at intervals of about two weeks after October 18th until December 5th. The results obtained (given below) show that after Nov. 4th growth was very slight.

<u>Date of examination</u>	<u>Average length of mussels in mm.</u>	<u>No. examined</u>
(When set out middle of Sept.)	12	13
Oct. 18, '19	15.2	20
Nov. 4, '19	17.4	20
Nov. 18, '19	17.5	23
Dec. 5, '19	17.2	

#### SUMMARY.

1. The greatest rate of growth occurred in mussels constantly submerged 1 foot from the surface.
2. The rate of growth in constantly submerged mussels decreases as their distance below the surface increases.
3. The rate of growth of mussels subjected to exposure between tides decreases as the amount of exposure increases.
4. The rate of growth of mussels in tidal pools at various intertidal levels varies, but apparently irregularly.
5. The rate of growth of mussels in intertidal pools and in locations where they are subject to intertidal exposure is much less than that in any location where they are constantly submerged.
6. The upper limit at which mussels survive at St. Andrews when subject to intertidal exposure is between 19.2 and 21.0 feet above low-water datum, depending on the conditions of shelter of their location.
7. When subjected to intertidal exposure the percentage of mussels surviving is much less near the upper limit of survival than at the lower levels.
8. Growth became exceedingly slow during November in 1919.

#### SECTION V.

##### FACTORS GOVERNING THE DISTRIBUTION.

The distribution of the mussel beds in the littoral zone at St. Andrews, N.B., presents an example of a nice balance among the various factors which affect their existence. In Section IV. it was shown clearly that the rate of growth is

greater when the mussel is never exposed yet the sea mussel has not been found of recent years in the St. Andrews region below low-water datum.

A consideration of the distribution of its chief predatory enemies shows how delicately adjusted is the balance determining the lower limit of the beds. Below low-water datum the mussels are constantly menaced by their enemies among the fish, and by the starfish, sea-urchins and whelks. The mussels above low-water datum, when exposed by the tide, are entirely free from fish depredations and the menace from starfish, sea-urchins and whelks is at least greatly lessened. This weakening of the action of their enemies is sufficient to allow the mussels to form beds in the littoral zone, although there they must endure the detrimental effects of exposure between tides as well as the attacks of the *Purpura* and the occasional attacks of crows and gulls. The upper limit of the beds is evidently determined by the effect of exposure on the young mussel larvae since primarily the beds are formed by the development of the young mussels where they settle when leaving the free-swimming mode of life. Which is the detrimental factor acting during exposure that determines the death of the young mussel the writer has not investigated. It may be the action of light, heat (and consequent drying), or lack of food, etc., or the combination of all these. The upper limit of the beds is naturally not as sharply defined as the lower one since the protection against exposure is not equal in all locations and since also drifting mussels detached during storms may fasten themselves and survive above the upper limit at which the younger ones would be killed.

In concluding, the writer wishes to express her indebtedness to Professor A. G. Huntsman (under whose direction the work was undertaken) for many helpful suggestions during the conduct of the work, and to the various assistants at the Biological Station, particularly Capt. Mitchell and Engineer Bartlett, whose hearty co-operation was invaluable.

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PLATE I



Photographs of Mussels, illustrating the two types. 1 and 2, St. Andrews type from Passamaquoddy Bay; 3 and 4, Digby type from Loggieville, N.S.





CHART I. The Mussel Beds of Passamaquoddy Bay Region in 1917

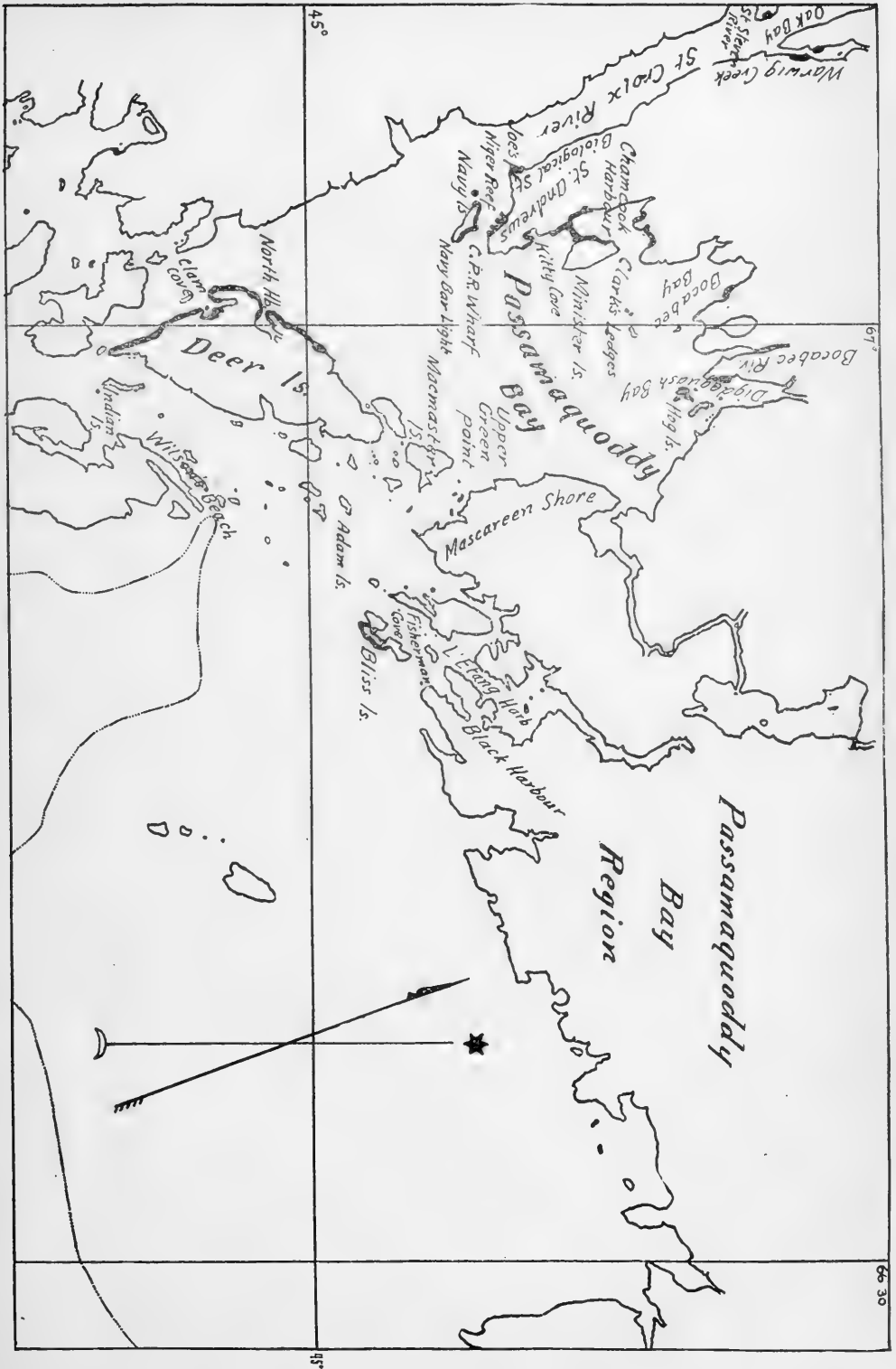




CHART II. MUSSEL BEDS OF THE DIGBY REGION.

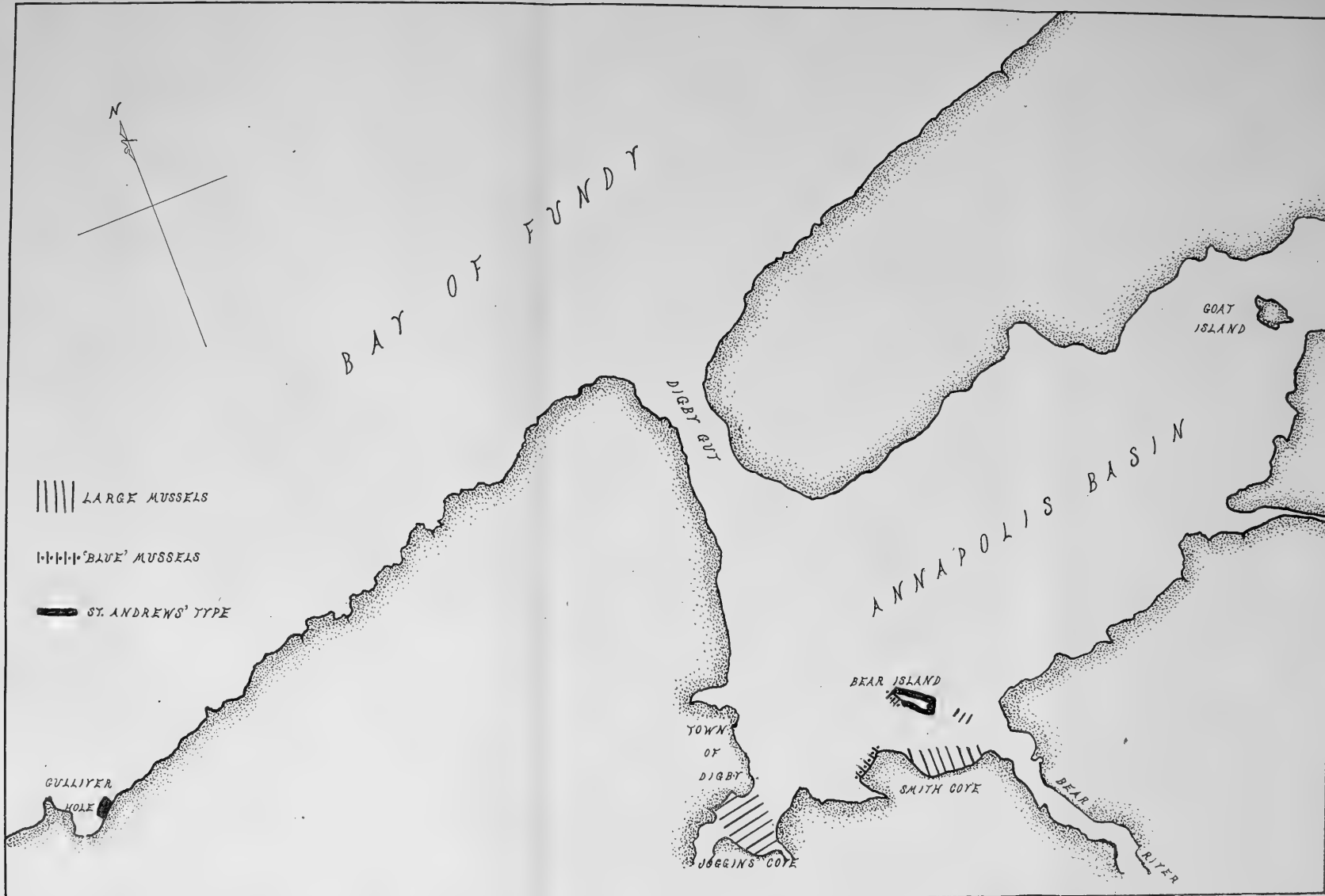
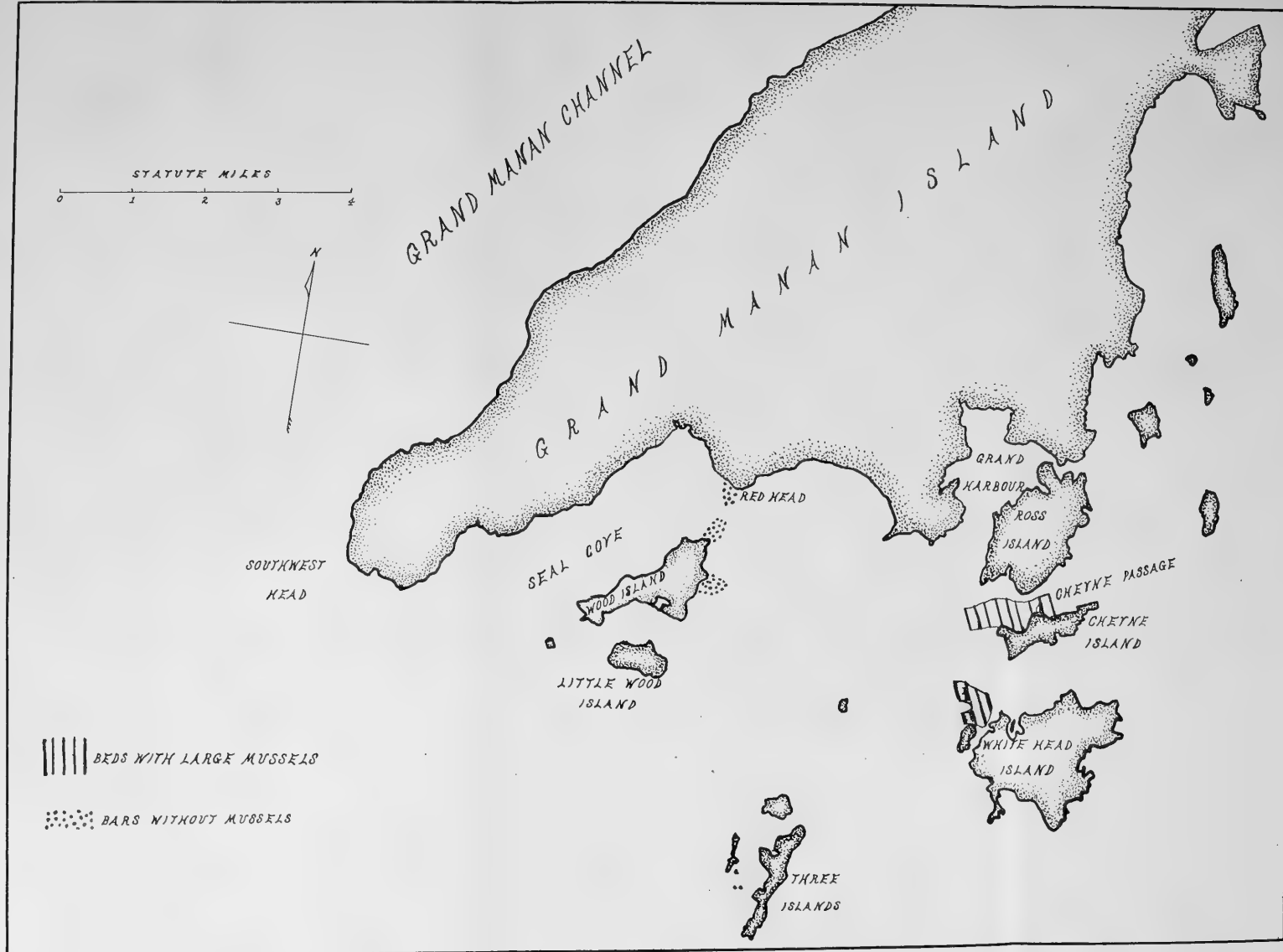




CHART III. MUSSEL BEDS OF GRAND MANAN ISLAND.





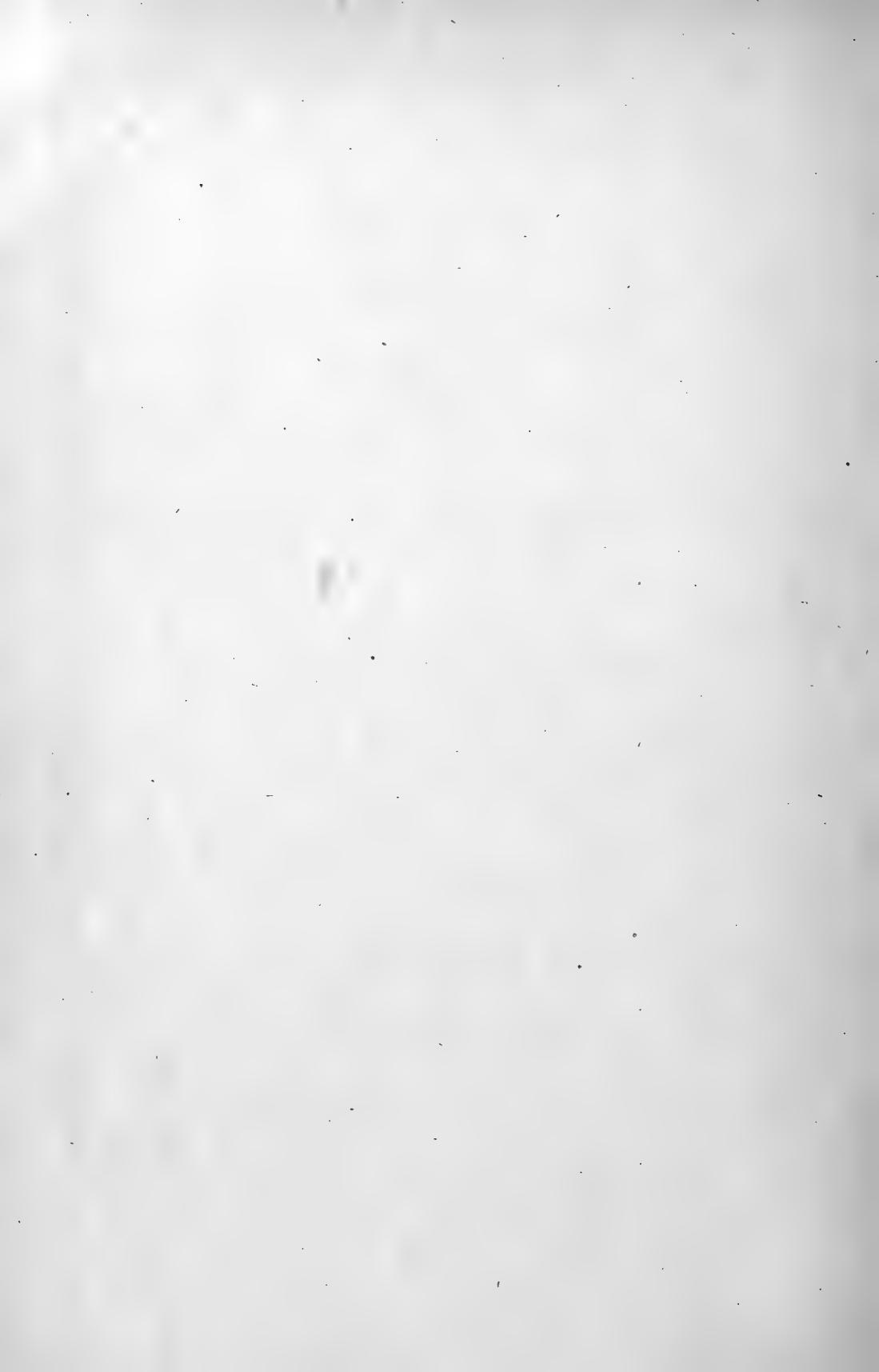
No. III

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THE FISHES OF THE BAY OF FUNDY

BY

A. G. HUNTSMAN,  
*Biologist to the Biological Board of Canada*





# The Fishes of the Bay of Fundy.

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The Bay of Fundy is a peculiar body of water in a number of respects. From its broad opening into the Gulf of Maine, its rather straight sides converge towards its head, and at the same time the depths decrease considerably. It has, indeed, the shape of a half cone, considerably flattened out and with the plane surface horizontal. This shape lends itself to a very full development of the tidal oscillations, which has made it famous for its high tides.

On its southeastern or Nova Scotian side are two very different bays. At its mouth and opening more properly into the Gulf of Maine is St. Mary bay, a small edition of the Bay of Fundy itself, but with its symmetry disturbed somewhat by two lateral openings, Grand and Petit passages, in its outer half. Being so broadly open to the Gulf of Maine and having very little fresh water entering it, it scarcely presents estuarine conditions, and has throughout water of comparatively high salinity, with, in summer, the temperature steadily rising towards its head. The Annapolis basin, on the other hand, presents rather different conditions. Opening into the Bay of Fundy not far inward from the level of the head of St. Mary bay by a rather narrow but deep gut, and having as its natural prolongation to the northeast, parallel with the shore of the Bay of Fundy, the gradually narrowing Annapolis river, which drains a considerable area, it presents in its outer parts conditions not unlike those of St. Mary bay, but changing rather abruptly into the estuarine conditions of the Annapolis river.

At its head the Bay of Fundy forks, one branch consisting in succession of Minas channel, Minas basin, and Cobequid bay, and the other of Chignecto bay, with two branches, Shepody bay and Cumberland basin. In these waters the tides are very heavy, and a rather gradual change to warm estuarine conditions occurs.

On the northwest or New Brunswick side of the bay is an inlet, St. John harbour, through which the major portion of the fresh water entering the bay passes. This water comes from the St. John river, which exhibits a series of enlargements or extensions not far from its mouth, a narrow passage through the rock. These features result in the formation at the mouth of a falls reversing with the tide, the amount of water poured through the mouth not being sufficient to greatly alter the level of the water in the adjacent extensive reaches of the river. Some of these reaches, as for example the Kennebecasis bay, are comparatively deep and the bottom water consists of the densest water entering the river during the year. This permits of the development of a salt or brackish water below the nearly fresh water of the surface.

At the mouth of the Bay of Fundy on its north side where New Brunswick and Maine meet is the inlet of Passamaquoddy bay, into which several rivers empty, the St. Croix being the largest. A large number of islands to a great

extent block the mouth of this bay, and farther off are the Wolves islands and Grand Manan with its retinue of smaller islands. To this region has been given the name of Western archipelago.

It is this part of the Bay of Fundy which has been most thoroughly investigated, the Canadian Atlantic Biological Station being located on the St. Croix river near the point where it opens out into Passamaquoddy bay. At the present time this region is virtually without certain important fishes whose life history requires easy access to fresh water. The shad, salmon, alewife, and striped bass are now quite rare, although they were formerly abundant (see Atkins, 1887, p. 700). The action of the heavy tides through the archipelago mixes the water rather thoroughly, and determines cool surface conditions. Warm water species are notably absent except as strays, for example, the pipefish, cunner, sand flounder (*Lophopsetta*), and butterfish (*Poronotus*). On the other hand deep water forms occur far into the inlet and in shallow water. The wrymouth (*Cryptacanthodes*) lives in the intertidal zone, the rosefish and thorny skate go far into the St. Croix river, the hagfish (*Myxine*) enters Passamaquoddy bay, and the rat-tail (*Macrourus*) is sometimes found at the surface in the approaches to the bay. Another effect of the unusual conditions is the presence in this district regularly each year of enormous quantities of young herring, giving rise to the sardine fishery which is centred in the Western archipelago. In the outer waters of this district the young herring, and to some extent even the older herring, may be obtained throughout the year, an evidence of the equalness of the temperature. The rather peculiar character of the water seems to be associated with the practical absence of the larvæ of fishes having pelagic eggs, although many of the eggs themselves may be found more or less regularly. This fact demonstrates the failure of the district as a spawning ground for these species, which must occur, therefore, only as immigrants in stages later than larvæ. As compared with other parts of the Canadian Atlantic coast, Passamaquoddy bay supports at least two invertebrates, whose proper home is farther south, these being the starfish, *Asterias forbesi*, and the Ascidian *Caesira manhattensis*. In the group of the fishes there are no particularly southern species that are endemic in the bay. On the contrary, it supports a northern form, *Myoxocephalus scorpius*, that is absent from the warmer bays of the coast.

The Kennebecasis bay on the St. John river, some distance above the reversing falls, presents conditions not occurring elsewhere around the Bay of Fundy. It is the only place where we have found the medusa *Aglantha* and the Amphipod *Parathemisto* breeding. It is interesting also that only here are the hake (*Urophycis*) to be found in the winter. They are fished regularly by hook and line through the ice as was related by Adams (1873, p. 256), who erroneously considered these hake to be *Merluccius*. Cod, grayfish (*Squalus*), and skate (*Raja diaphanes*) are sometimes taken with the hake.

The bays or basins on the Nova Scotian side of the Bay of Fundy present warmer conditions than those on the New Brunswick side, particularly toward their heads. Correlated with this is the occurrence endemically in these Nova Scotian bays of such southern species as the hermit crab, *Pagurus longicarpus*, and the gastropod, *Ilyanassa obsoleta*. In Minas basin live also the crab, *Libinia*

*emarginata*, and the squid, *Loligo pealei*, that are not found elsewhere (except as immigrants in the case of the latter species) on the Canadian coast. Among the fishes there are several that appear to be endemic only on the Nova Scotian side of the bay. Only in St. Mary bay is the cunner (*Tautoglabrus*) to be found in abundance and of all sizes. The occurrence of young pipefish (*Syngnathus*) in the Annapolis river affords ground for presuming that that species is a regular resident of the Annapolis basin at least. The butterfish (*Poronotus*) and the sand flounder (*Lophopsetta*) seem to be permanent inhabitants of the basins on the Nova Scotian side of the bay, and doubtless breed successfully there, as both small and large individuals are found.

In the Bay of Fundy proper, that is, the main portion exclusive of the tributary waters, the fish fauna shows on the whole what would be expected from its long funnel shape, namely, a change from open salt water forms at its mouth to brackish water forms at its head. The outer deep water basin with a depth of more than fifty fathoms ends at the level of the mouth of the St. John river, and the large catches of the important bottom-feeding salt water fishes, namely the cod, haddock and hake (*Urophycis*), are restricted to the shoal water bordering this deep basin, the catches decreasing rather abruptly above this basin. All three species are caught, nevertheless, quite to the head of the bay. On the other hand, the halibut that enter the bay exhibit a different distribution. A moderate number reach Grand Manan, but with this exception they are virtually absent from the New Brunswick shore. On the Nova Scotian side they are taken from the mouth of the bay to Minas channel, although above Digby the quantity taken is small.

Of the fishes that feed in midwater or near the surface, the pollock and herring are the only ones occurring in large quantities. They are taken principally in the tide rips of the Western Archipelago and of the mouth of St. Mary bay. Moderate quantities are to be obtained quite to the head of the bay. The swordfish scarcely enters the bay. The tuna is an uncertain immigrant occurring most frequently on the Nova Scotian side, and only rarely on the New Brunswick shore. The mackerel enters the bay fairly regularly but is almost wholly confined to the Nova Scotian coast and is of quite uncertain local occurrence even there. As compared with the mouth of the bay or the exposed coast it is usually taken in as great or even greater abundance far up the bay or inside the basins. The grayfish (*Squalus*) has a somewhat similar distribution, but invades the waters of the New Brunswick coast more regularly than does the mackerel.

Of the fishes spawning in fresh water only two, namely the salmon and the shad, enter the Bay of Fundy proper to any extent. The bass, alewife, smelt and tomcod scarcely pass out of the estuaries. The shad and the salmon migrate out into the salt water of the bay, the latter going considerably farther than the former. Their distribution in the bay is in relation to the rivers from which they come. On the New Brunswick side the chief river is the St. John. From its mouth the salmon and shad are distributed along the coast for some distance to the southwest, but it is the exception for many even of the salmon to be taken beyond Point Lepreau. They are, practically speaking, absent

to the northeast. In Chignecto bay at the head of the Bay of Fundy occur the salmon originating in its tributary rivers. These salmon are most abundant on the southeast or Cumberland shore, and perhaps even migrate to some extent around Cape Chignecto into Minas channel. The Minas basin system furnishes a large number of both salmon and shad. The latter are caught as far out as Minas channel, but the former go much farther, being taken along the coast of Kings and Annapolis counties, apparently as far at times as Digby gut. The majority of these outside of fresh water are taken on the north shore of Cobequid bay, and on the south shore of Minas channel and its continuation in the Bay of Fundy, that is, the coast of Kings county. The salmon of the Annapolis basin are taken in salt water principally along the coast of Digby county southwest from Digby gut.

There is evidently a distinct tendency for the salmon and shad to spread along the coast oceanward from the mouth of the estuary, that is in the Bay of Fundy to the southwest toward the Gulf of Maine.

Although our knowledge on this point is far from complete, it is already evident that a large proportion of the species of fishes occurring in the Bay of Fundy do not pass through their entire life history in that bay and its tributary waters, and may therefore be considered as immigrants. Each species presents a more or less special case, but we may make a provisional classification of all the species on this basis. Such a classification is admittedly artificial and subject to revision.

#### A. Species endemic in the Bay of Fundy and its tributary waters.

##### 1. Species endemic in the Western Archipelago and its tributary waters.

*Apeltes*, *Aspidophoroides*, *Clupea*, *Coregonus*, *Cryptacanthodes*, *Cyclopterus*, *Fundulus*, *Gasterosteus aculeatus* and *bispinosus*, *Hemirhamphus*, *Liopsetta*, *Liparis*, *Lumpenus*, *Menidia*, *Microgadus*, *Morone*, *Myoxocephalus aeneus* and *scorpius*, *Myxine*, *Neoliparis*, *Osmerus*, *Petromyzon*, *Pholis*, *Pomolobus pseudoharengus*, *Pseudopleuronectes*, *Pungitius*, *Salmo*, *Salvelinus*, *Sebastes*, *Ukaria*, and *Zoarces*. 31 species.

##### 2. Species occurring, if at all, in the Western Archipelago only as immigrants:

*Acipenser*, *Alosa*, *Lophopsetta*, *Myoxocephalus octodecimpinosus*, *Pomolobus aestivalis*, *Poronotus*, *Raia erinacea*, *Roccus*, *Syngnathus*, and *Tautoglabrus*. 10 species.

#### B. Immigrants in the Bay of Fundy.

##### 1. Decidedly northern species:

*Anarhichas minor*, *Cetorhinus*, *Eumicrotremus*, *Gymnocanthus*, *Mallotus*, *Somniosus*, and *Triglops*. 7 species.

##### 2. Species endemic in the latitude of the Bay of Fundy:

*Ammodytes*, *Anarhichas lupus*, *Brosmius*, *Enchelyopus*, *Gadus*, *Glyptocephalus*, *Hippoglossoides*, *Hippoglossus*, *Isurus*, *Limanda*, *Lophius*, *Lycodes*, *Macrourus*, *Maurollicus*, *Melanogrammus*, *Merluccius*, *Pollachius*, *Raia diaphanes*, *radiata*, and *stabiliforis*, *Scomber*, *Scomberesox*, *Squalus*, *Thunnus*, *Urophycis tenuis* and *chuss*, *Vulpecula*, and *Xiphias*. 28 species.

### 3. Decidedly southern species.

*Albula*, *Anguilla*, *Archosargus*, *Brevoortia*, *Carcharias*, *Carcharodon*, *Galeorhinus*, *Mola*, *Pomolobus mediocris*, *Prionotus*, *Stenotomus*, and *Tautoga*. 12 species.

In the following account of the various species we give in brief form the present knowledge of their distribution in the Bay of Fundy, and of their occurrence at various stages in their life history, as well as an indication of the gear by which the adults may be taken. Very little has been published concerning the fishes of the Bay of Fundy, therefore this account is mainly based upon the investigations that have been made from the Canadian Atlantic Biological Station at St. Andrews, New Brunswick. Only the waters within easy reach from the Station have been at all thoroughly examined, and they are the same as those whose fish fauna has been made known through the labours of collectors of the United States Fish Commission with Eastport, Maine, as a base. The fishes of the remainder of the bay are known to us largely through special expeditions from the Station, namely, that in August and September, 1916, to St. Mary bay, Yarmouth, St. John and the Annapolis basin; that in the summer of 1919 to St. Mary bay; and that in September, 1920, to Minas channel and basin. To Professor Philip Cox, of Fredericton is due the credit for identification of much of the material that has been collected as well as for an active share in its collection, and to Mr. A. H. Leim of the University of Toronto we are indebted for information as to the species taken in the weirs at Scotsman bay, Minas channel, where he was engaged in a study of the shad during the summer of 1920. Through the courtesy of Mr. W. A. Found, Assistant Deputy Minister of Fisheries, Department of Marine and Fisheries, we have been able to obtain from the Fishery Officers specimens of fishes from their respective districts. We may mention Mr. B. B. Brittain, of St. John, Captain Edward Chute, of Harbourville, Kings County, N.S., Mr. J. G. D'Entremont, of Pubnico, Yarmouth County, N.S.; Mr. W. A. Fraser, of Grand Manan, and Mr. T. C. Rose, of Urbania, Hants county, N.S.

#### *Myxine limosa*, Girard.

Not uncommon on soft mud bottom and rather deep water in the Bay of Fundy. It has been recorded from Grand Manan (Putnam, 1874, p. 129; Goode and Bean, 1895, p. 3) and from Eastport (Kendall, 1908, p. 1). From a number of records we may mention the following: Off Head harbour, Campobello island, 60 fathoms, August, 1911; off Fish head, Grand Manan, June, 1912; off Bliss island, 35 fathoms, July, 1912; off Campobello island, 50 fathoms, January and February, 1919; Passamaquoddy bay, 18 fathoms, April 16, 1919. The egg has been obtained off Campobello island, but no young have been seen.

#### *Petromyzon marinus*, L.

Not seen very often. Perley (1852, p. 225) gives it for the St. John river, and Cox (1893, p. 42) described it as occurring on squirrel-hake in Kennebecasis bay. Mr. Leim has found the larvæ very abundant in the Shubenacadie river. Dr. Cox has obtained the adults in the Passamaquoddy region, and Kendall (1908, p. 1) records it from Eastport.

*Galeorhinus laevis* (Valmont)

syn. *Mustelis canis*.

A single specimen was taken on a long line in the St. Croix river near the Biological Station in July, 1913. An immigrant from the south.

*Vulpecula marina*, Valmont

syn. *Alopias vulpes*.

Perley (1852, p. 222) mentions it as frequent in Cumberland and Minas basins, and Kendall (1908, p. 6) records it from Eastport.

*Carcharias taurus*, Raf.

syn. *C. littoralis*.

Taken in a weir near St. Andrews, Passamaquoddy bay, in 1913. A stray from the south.

*Isurus (Lamna) nasus* (Bonn.)

syn. *Lamna cornubica*.

Reported from Passamaquoddy bay by Prince and MacKay (1901).

*Carcharodon carcharias* (L.)

Goode (1884, p. 679) has reported it from Eastport.

*Cetorhinus maximus* (Gunn.)

Perley (1852, p. 222) reported a specimen taken off Musquash harbour, St. John county, in August, 1851, and Verrill (1871, p. 6) reported three specimens as having been taken near Eastport and Lubec in 1868.

*Squalus acanthias*, L.

Of somewhat uncertain occurrence and few in number in Passamaquoddy bay, not being found every year. Appears from the end of July to the end of August (by the first of July in the Bay of Fundy) and leaves by the end of October. Only adults are seen. The females contain eggs in an early stage, or well developed young with the yolk not yet all absorbed, but no intermediate stages. More abundant in the Bay of Fundy, particularly on the east coast. Observed in Minas channel, at Harbourville, Kings County, in St. Mary bay, and at Port Maitland, Yarmouth County. As none smaller than a length of 56 cm. has been observed, there is nothing to indicate that it breeds in the Bay of Fundy. Taken on long lines and in gill nets.

*Somniosus microcephalus* (Bl. & Schn.)

Kendall (1908, p. 10) has reported this species from Eastport. Dr. Cox obtained two specimens in 1915, one from a weir in Passamaquoddy bay, and the other from long lines set in the North channel off Campobello island during the first week in June. An immigrant from the north.

*Raia erinacea*, Mitchill.

Very abundant in the Bay of Fundy and Passamaquoddy bay, occurring in the latter from May to December or even January, and in the Bay of Fundy somewhat longer. Young skates have never been found in Passamaquoddy bay, but what appear to be the young of this species have been taken just outside Passamaquoddy bay off Campobello island in 50 fathoms, although only during February and March. Similar young skates were taken in Minas channel in September, 1920. Doubtless the head of the Bay of Fundy is a breeding ground from which the young descend toward the mouth of the bay during winter. Taken in seines, weirs, shrimp and beam trawls and on long lines. Also observed in Minas channel and basin, at Harbourville, Kings County, and in Annapolis basin and St. Mary bay. Perley (1852, p. 225) reported it from Grand Manan.

*Raia diaphanes* Mitchill.

syn. *R. ocellata*.

Abundant both in the Bay of Fundy and Passamaquoddy bay, occurring in the latter from May until November. No young are seen, but the half grown are difficult to separate from *R. erinacea*. Taken in weirs and shrimp trawl, and on long lines. Also in Minas channel and St. Mary bay.

*Raia radiata*, Donovan.

Frequently taken with the other skates in Passamaquoddy bay from May to November, but never in shallow water, always in depths of 10 fathoms or more. It seems to remain in the Bay of Fundy throughout the winter, as we obtained it off Campobello island in February and March of 1919, the only adult skates which we secured at that time of the year. Captured in the shrimp trawl and on long lines. We have also taken it in St. Mary bay, but only in the deeper water (20 to 30 fathoms). No young, identified as this species, have been taken. Cox (1896 a, p. 75) reports having obtained it off St. Martins in St. John county, near the head of the Bay of Fundy.

*Raia stabuliformis*, Garman

syn. *R. laevis* Mitchill.

Adults of this species are never abundant, but are found very generally in Passamaquoddy bay and the Bay of Fundy. In the former they are to be found from May until November, and somewhat longer in the latter. No young have been found. Taken in weirs and shrimp trawl, and on long lines, or captured almost stranded by the ebbing tide in shallow water. Also taken in Minas basin and channel, at Morden, Kings county, and in St. Mary bay. Jones (1879, p. 97) with Gilpin as authority, reported it from the Nova Scotian coast in the Bay of Fundy, and Perley (1852, p. 224) gave near the eastern end of Campobello island and the Annapolis basin as localities for its occurrence.

*Acipenser sturio*, L.

In the St. John river and doubtless in the rivers at the head of the Bay of Fundy. Mr. Leim observed two small sturgeons, doubtless of this species, taken in Scotsman bay, Minas channel, in 1920. They are known also in the Annapolis river, which they are said to ascend as far as Middleton.

*Anguilla chrisypa*, Raf.

Elvers have been taken in the open water of Passamaquoddy bay in April and are found ascending the streams during the summer. The adults are common in all the accessible fresh waters and in much of the brackish water, but are rarely taken in the salt water. This is well shown by the results of our comprehensive operations in St. Mary bay in 1919. While elvers—6 cm. long—were obtained at Sandy cove and Brighton, the adults were taken only at the head of tide in the Sissibou river and in the stream at Little River. Also in St. John and Annapolis rivers and at Pubnico, Yarmouth county.

*Albula vulpes* (L.)

Recorded by Halkett (1913, p. 45) from Black's Harbour in Charlotte county. Doubtless a Gulf Stream immigrant.

*Clupea harengus*, L.

Common nearly everywhere in the bay, the young passing far up the estuaries. The young, known as sardines, are extremely abundant near the mouth of the bay, but chiefly on the New Brunswick side, and centreing in the Western Archipelago. Spawning at the present time seems to be limited to the autumn, and to take place at the mouth of the bay (Grand Manan and southern Nova Scotia) and at its head in Minas basin. The adults are largely restricted to the same region. The young leave Passamaquoddy bay during the winter, but may be taken just outside in the Bay of Fundy all winter, as may also the adults. Taken in seines, weirs, gill nets and shrimp trawl.

*Pomolobus mediocris* (Mitchill)

Perley (1852) reported this species from near Campobello island, but we have never observed it. A doubtful record.

*Pomolobus pseudoharengus* (Wilson)

Abundant at some points, but restricted to the neighbourhood of rivers suitable for spawning. The young are frequently met with, and appear to travel far in salt water, as we have taken them in water 50 fathoms deep, off Campobello island in December of 1917, and again in March of 1919. Rare in Passamaquoddy bay at the present time. Taken also at St. John, in Kennebecasis bay; in Minas channel, at Harbourville, Kings county; in Annapolis basin and St. Mary bay; and at Port Maitland and Yarmouth. Taken in seines, weirs, gill nets, and shrimp trawl.



*Pomolobus aestivalis* (Mitchill).

Seemingly restricted to the larger rivers. Cox has found it in the St. John river, and we have had specimens from St. John harbour and the Shubenacadie river. However, Bensley (1901, p. 61) has reported it doubtfully from Passamaquoddy bay, and Kendall (1908, p. 39) has recorded it from Eastport in two collections.

*Alosa sapidissima* (Wilson)

Spawning in the large accessible rivers, as the St. John, Petitcodiac, Shubenacadie and Annapolis, its distribution in salt water being restricted largely to the regions near the mouths of these rivers. Rarely taken in Passamaquoddy bay, where it must be considered as a stray from the St. John, whose fishery does not extend beyond the border of the county at Lepreau. The shad from the Shubenacadie and neighbouring rivers go to sea for a greater distance, probably owing to the peculiar hydrographic conditions at the head of the bay. The fishery extends through Minas basin and channel to the Annapolis county line or farther. Taken in gill nets and weirs. Formerly in the St. Croix river (Atkins, 1887, p. 700).

*Brevoortia tyrannus* (Latrobe).

Perley (1852, p. 208) referred to this species being sometimes taken in the weirs in St. John harbour, and in 1919 we received from Overseer Brittain a specimen of this species taken in that harbour on August 12th. We have never seen it in the Western Archipelago. Kendall (1908, p. 40) gives Goode, 1877, as authority for its occurrence in Passamaquoddy bay, which seems at variance with Goode's account of the species in 1884. An immigrant from the south.

*Coregonus quadrilateralis*, Richardson.

Two specimens of a *Coregonus* doubtfully identified as this species by Dr. Cox, were seined in mid-channel at the mouth of the Sissibou river, St. Mary bay, on September 8, 1919. In James and Husdon bays it is customary to find whitefish and ciscos in brackish or salt water, but this appears to be the first recorded instance of this kind for our Atlantic coast.

*Oncorhynchus gorbuscha* (Walbaum).

This Pacific species has been introduced by the United States Bureau of Fisheries into the waters of northern New England. The fish have been observed at Lubec and in Cobscook bay (Fisheries Service Bulletin, No. 67, 1920). Humpback salmon were reported to have been taken in weirs in Passamaquoddy bay, both in 1919 and in 1920, but we were unable to secure any specimens for examination.

*Salmo salar* L.

Its abundance in the salt water is determined by the proximity of a river system suitable for spawning. Now rare in the Western Archipelago since the damming of the St. Croix river, the few that are taken being doubtless

strays from the St. John river or escaped fish from the landlocked form that is to be found in the Chamcook and other lakes of the district. The St. John river provides a fishery along the coast of the Bay of Fundy chiefly to the south west from St. John harbour. The rivers of Minas basin provide a fishery not only in the basin, but through Minas gut into Minas channel and down the coast of Kings and Annapolis counties. The sea fishery provided by the Annapolis river is relatively unimportant.

*Salvelinus fontinalis* (Mitchill).

Abundant in many of the streams around the bay. We have never obtained it in the salt or brackish water around the Bay of Fundy, as it may be obtained in the southern part of the Gulf of St. Lawrence.

*Mallotus villosus* (Müller).

Of very irregular occurrence in the Bay of Fundy. Perley in his investigations of the Bay of Fundy obtained reports (1852, p. 136 and 138) of its occurrence on the coast of St. John county, at a number of points all east of St. John. None have been taken there in recent years although the tradition persists.

In the Western Archipelago we have obtained several records in recent years. In May, 1915, and again in October, 1916, a few were taken among small herring in the approaches to Passamaquoddy bay. In October and November of the latter year, they were taken in rather large numbers in the herring weirs in the Passamaquoddy region (Kendall, 1917, p. 28). From fishery officers reports of their occurrence about that time at a number of points along the coast of Charlotte county, but not at Grand Manan island, have been obtained. The only other part of the Bay of Fundy where they were noticed was the coast of Kings county, where large quantities are said to have been taken in May and June of 1917, but not in 1918.

In January, February and March of 1919, we obtained a number of specimens with the shrimp trawl in water 50 fathoms deep off Campobello island, Charlotte county, and in April of that year, Kendall (1919, p. 70) records that they were taken in the Penobscot river in southern Maine.

As the capelin must be considered as invading the Bay of Fundy from the outer coast of Nova Scotia and entering the bay at its mouth on the Nova Scotian side, it would be expected that they should occur more frequently in Yarmouth and Digby counties. Perley (1852, p. 164) states: "No capelin has ever been seen at Brier Island." The fishery officers of those counties informed me in 1919 that no capelin are taken there. However, for the season of 1903 the Digby reporter for the Fisheries Intelligence Bureau stated that "Caplin were reported in good fishing on May 22," (36th Ann. Rep. Dep. Mar. and Fish. Fisheries, p. 307).

*Osmerus mordax*, (Mitchill).

Found generally around the shores of the bay, but not abundant. It is restricted to a very narrow shore zone, and is further limited by lack of suitable streams for spawning. We have obtained it not only around Passamaquoddy

bay, but also at the following places: outside St. John harbour, in Kennebecasis bay above St. John, in Minas channel, Annapolis basin, and St. Mary bay, and at Yarmouth. It is also landlocked in Chamcook and Utopia lakes, which drain into Passamaquoddy bay. Taken in seines, weirs, gill nets and shrimp trawls.

*Maurolicus pennanti* (Walbaum).

Has been recorded from Grand Manan by Cox (1896 b, p. 55) and again by Prince (1913, p. 1143 and 1144). From Dr. Cox we have also obtained additional records, namely, from stomach of pollock at Welchpool, July 13, 1914, and on the beach at Wilson's Beach, July 27, 1914—both on Campobello island. An immigrant from the midwater of the northern Atlantic.

*Fundulus heteroclitus* (L.)

Restricted to brackish water and hence not very common in the Bay of Fundy. It can be obtained usually in the brackish tidal pools, as at St. Andrews. Also in Annapolis basin and St. Mary bay. The variety *macrolepidotus* has been reported by Cox (1896 a, p. 56, as *F. nigrofasciatus*) from the mouth of Little river, St. John county.

*Scomberesox saurus* (Walbaum).

Recorded by Cox (1896 a, p. 60) as having been taken in the vicinity of St. Stephen. This would mean somewhere in the Western Archipelago. We have not met with it. It has been found off southern Maine. An immigrant from the open ocean.

*Pungitius pungitius* (L.)

For the most part restricted to brackish and fresh water and consequently rarely seen along most of the coast. Chiefly in ponds or in streams in the intertidal zone. Taken in Passamaquoddy bay, and also in St. Mary bay. Doubtless very general as no fish is more widespread in distribution in Canada.

*Gasterosteus aculeatus*, L.

Practically restricted to the brackish water, but occurring occasionally in the saltiest water, but always near the shore and near an estuary. Also outside St. John harbour, in Kennebecasis bay and St. Mary bay, and at Yarmouth.

*Gasterosteus bispinosus*, Walbaum.

Often in company with the preceding species in Passamaquoddy and St. Mary bays.

*Aplettes quadracus* (Mitchill).

Restricted to the brackish water and therefore rarely met with. In the estuaries of Passamaquoddy bay, in Kennebecasis bay, St. John, and in St. Mary bay. Taken in the seine.

*Syngnathus fuscus*, Storer.

Adults have been taken on several occasions at the outlet of Passamaquoddy bay, near Campobello island, and also in Passamaquoddy bay:—Wilson's Beach, autumn of 1912; Bocabec, July 4, 1912. Kendall (1908, p. 65) has reported this species from Eastport and notes the large size of the specimen found. No young have been found, and only very large individuals ever reach the district from their successful breeding grounds. However, we obtained the very young in the Annapolis basin in 1916. This and other estuaries of the east coast of the bay are doubtless breeding centres for this species.\*

*Menidia notata* (Mitchill).

Largely restricted to brackish water and hence not very common. In the Western Archipelago we have only found it in warm, brackish, tidal pools. Elsewhere not so restricted. At St. John—outside the harbour (Sheldon's beach), and in Kennebecasis bay. In the Annapolis basin—at Goat island and above Annapolis. In St. Mary bay—at Brighton and in the Sissibou river.

*Ammodytes americanus*, DeKay.

Rather uncommon in the Bay of Fundy, probably from lack of suitable sandy coast. We found it abundant at Woodward's cove, Grand Manan, and a single specimen has been taken at the Atlantic Biological Station in the St. Croix river. Kendall (1908, p. 70) has taken it near Eastport. We have also obtained it in St. Mary bay. Taken by hand at low tide and in the seine.

*Scomber scombrus*, L.

Usually only a few individuals are seen each season in the Western Archipelago. They enter Passamaquoddy bay. On the east coast of the Bay of Fundy they are more regularly seen and frequently in very large numbers. They pass far up to the head of the bay and even to the New Brunswick side. A summer immigrant, usually from June to August. No larvæ have been found. The young (tinkers) occur in St. Mary bay and at Yarmouth. Eggs have not been found in the Western Archipelago, but only in the Annapolis river. It is doubtful whether any successful breeding takes place in the Bay of Fundy. Taken in weirs and gill nets. Specimens examined from Passamaquoddy bay, Harbourville, Kings county, St. Mary bay and Port Maitland.

*Thunnus thynnus* (L.)

An immigrant from the open ocean that appears in summer. It is fairly regular in its appearance on the Nova Scotian side of the Bay of Fundy near the mouth. It is occasionally seen in Passamaquoddy bay, where we have observed it, and Kendall (1908, p. 73) has obtained it near Eastport.

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\*In August of 1921 Mr. Leim took both adults and young at Bass River in Cobequid bay.

*Xiphias gladius*, L.

Its fishery ends in Yarmouth county, and it rarely, if ever, enters the Bay of Fundy.

*Poronotus triacanthus* (Peck).

Found occasionally in the Bay of Fundy and Passamaquoddy bay, but not every season, and only in the half grown state. Large spawning individuals have been taken in St. Mary bay in July. The larvæ have not been observed. Caught in the weirs. Bensley (1901, p. 62) has reported it from Passamaquoddy bay, Kendall (1908, p. 88) from Eastport, Cox (1896 a, p. 59) from St. John harbour, and Goode and Bean (1879, p. 16) from the Annapolis basin, where also we took it in 1916. Also from Scotsman bay and Canada Creek, Kings county, and Lobster bay, Yarmouth county. It is more abundant on the Nova Scotian side of the bay and doubtless breeds there.

*Roccus lineatus* (Bloch)

Confined to the large warm estuaries and the neighbouring fresh water—namely, the St. John, Shubenacadie, and Annapolis rivers with the adjacent estuaries. We have never seen it in the Western Archipelago, although Atkins (1887, p. 700) reports it as formerly abundant in the St. Croix river.

*Morone americana* (Gmelin).

In the Bay of Fundy region this species seems to be entirely land-locked, occurring only in fresh water. It is abundant in Bocabec lake, which drains into Passamaquoddy bay, and Perley has reported it (1852, p. 182) as occurring in many of the lakes and streams connected with the St. John river. Kendall (1908, p. 97) has taken it near Eastport.

*Stenotomus chrysops* (L.)

Knight (1867, p. 12) gives a hearsay report that "porgies are occasionally seen in St. Mary's bay," and Kendall (1908, p. 103) has reported it from Eastport. We have not met with it. An immigrant from the south.

*Archosargus probatocephalus* (Walbaum).

A coastal fish of the southern States that has been reported by Cox (1896 a, p. 71) from St. John harbour.

*Tautoglabrus adspersus* (Walbaum)

Very common and of all sizes in St. Mary bay, which must be a successful breeding place and centre of dispersal. Known to the fishermen in Annapolis basin, but not common, and taken only on lines, no small specimens being seen. Not known to the fishermen in the Western Archipelago and very rare, only very large specimens occurring there occasionally (Grand Manan and St. Croix river). The eggs have been taken in Passamaquoddy bay, but no larvæ have been found. Taken in seine, lobster and hoop traps, gill nets, shrimp and beam trawls, weirs and on long lines. Also from Pubnico harbour, Yarmouth county.

*Tautoga onitis* (L.)

Recorded by Perley (1852, p. 191) as having been introduced into St. John harbour, but it is not known there now. Except for a single specimen taken in Passamaquoddy bay in 1909 or 1910, there is no evidence of its normally entering the Fundy region.

*Mola mola*, Linn.

The fish has never been observed in the Bay of Fundy in the work carried on by the Atlantic Biological Station. Cox (1896 a, p. 75) has reported it from St. John harbour. It must only very rarely enter the Bay.

*Sebastes marinus* (L.)

Quite common and of all sizes in the Bay of Fundy, Passamaquoddy bay, and the St. Croix river, at depths of five fathoms or more, the females frequently found with eggs containing eyed young. The spawning individuals at least move out into deep water in the latter part of the summer, when the larvæ can be found at the mouth of the Bay of Fundy and up its centre for some distance. This fish is not abundant enough for the records to be conclusive, but the latter indicate that the adults may be in Passamaquoddy bay from April to December, and longer outside. The young may remain in both places throughout the year. Caught on long lines and in the shrimp trawl. Reported by Perley (1852, p. 184) to the east of St. John, and we found it in 1919 in St. Mary bay. Also at Grand Manan and off Seal island, N.S.

*Triglops ommatistius*, Gilbert.

We obtained several specimens of this species in April and July 1919, in Passamaquoddy bay, with the shrimp trawl in about 15 fathoms of water, but otherwise we have not seen it. An immigrant from the north.

*Myoxocephalus aeneus*, (Mitchill).

Common in shallow water in the Bay of Fundy and at the mouth of Passamaquoddy bay, but very rare in as far as St. Andrews. All sizes are found. Common in St. Mary bay and the Annapolis basin, but rare in Minas basin, although both adults and young were found. Taken in the seine and shrimp trawl.

*Myoxocephalus scorpius* (L.)

syn. *M. groenlandicus*.

Very common in shallow water everywhere and of all sizes. Large individuals are occasionally taken in depths as great as 15 fathoms. A half-grown individual was taken in 50 fathoms off Campobello island in February, 1919. The only fish remaining near the shore during the coldest part of the year. The larvæ are found as early as February and on through the spring. Taken in weirs, seine, and gill net, and on long lines. We have taken it in the Annapolis basin and St. Mary bay, and at Yarmouth; also at St. John, N. B. and Abbott's harbour, near Yarmouth, N.S. It does not occur at the head of the bay where collections were made east and west of Cape Blomidon.

*Myoxocephalus octodecimspinosus* (Mitchill).

Very common in the Bay of Fundy and in Passamaquoddy bay during the summer in shallow water, and abundantly at moderate depths where the previous species is rare or absent. The young have never been observed in the Western Archipelago, but have been taken in the Annapolis basin and Minas channel. It must in the western part of the bay be considered as a regular immigrant. It remains in Passamaquoddy bay very late in the autumn, and a few even appear to stay through the winter. The half grown appear in Passamaquoddy bay and just outside in some years at least during the winter, although during the summer it is practically the adults alone that are taken. Caught in the seine, gill nets, shrimp and beam trawls, weirs, and on long lines. Observed also in Minas channel, at Canada Creek, Kings county, and in Annapolis basin and St. Mary bay.

*Gymnocanthus tricuspis* (Reinh.)

Kendall (1908, p. 124) has reported it from Eastport. A stray from the north.

*Hemitripteris americanus* (Gmelin).

All sizes from very small ones (4.6 cm. or even less) up are found; but not in large numbers, both in the Bay of Fundy and in Passamaquoddy bay in summer. The recently hatched young have not been observed. Taken in the seine, weirs and shrimp trawl, and on long lines. Also found in Minas channel (the very young in Minas basin), at Harbourville, Kings county, in the Annapolis basin and St. Mary bay, and at Yarmouth. Cox (1896 a, p. 40) states that it is by no means rare in St. John harbour.

*Aspidophoroides monoptygius* (Bloch).

Found occasionally in the Bay of Fundy and in Passamaquoddy bay, being taken in the shrimp and beam trawls in from 15 to 100 fathoms. The larvæ occur in Passamaquoddy bay from April to June at least. Kendall (1908, p. 125) has reported it in two collections from Eastport.

*Cyclopterus lumpus*, Linn.

Very abundant in all stages both in the Bay of Fundy and in Passamaquoddy bay in or near floating masses of rockweed and near shore. Taken in the herring weirs, with the seine and by hand. Found also at St. John, Canada Creek, Kings county, in St. Mary bay and at Yarmouth. Halkett (1907, p. 340) also has reported it from St. John harbour, Cox (1920, p. 7) from Passamaquoddy bay and St. John harbour, Kendall (1908, p. 126) from Eastport, and Perley (1852) from Grand Mañan.

*Eumicrotremus spinosus* (Müller).

Putnam (1874, p. 338) has mentioned having seen specimens from Eastport; and Garman (1892, p. 35) has figured a specimen taken at the same point. A stray from the north.

*Neoliparis atlanticus*, J. & E.

Rather common in both the Bay of Fundy and Passamaquoddy bay, often found clinging to lobster pots. The larvæ have been observed in Passamaquoddy bay in April.

*Liparis liparis* (L.)

Not uncommon in the Bay of Fundy to a depth of one hundred fathoms and in Passamaquoddy bay in as shallow water as five fathoms, but not yet observed in the larval stage. Taken in the dredge and shrimp trawl. Kendall (1908, p. 127) found it near Eastport and Cox (1896 b, p. 55) received a specimen from Grand Manan.

*Prionotus carolinus* (L.)

The only record is that of a single specimen obtained at Campobello island in August, 1911. A stray from the south.

*Pholis gunnellus* (L.)

Abundant at all stages in shallow water both in the Bay of Fundy and in Passamaquoddy bay. The larvæ are obtained in the early summer. Also taken in Minas and Annapolis basins, St. Mary bay, and Lobster bay, Yarmouth county. Captured by hand at low tide, and in the seine. (Cox, 1896 a, p. 59) found it in St. John harbour.

*Lumpenus serpentinus* (Storer).

In 1919 it was taken with the shrimp trawl in the Bay of Fundy beginning in January, and in Passamaquoddy bay from April to August. It was found in St. Mary bay in August and September of the same year. Also taken in the beam trawl. Larvæ identified by Dr. Cox as belonging to this species have been taken in April. Kendall (1908, p. 133) has recorded the species from Eastport.

*Ulvaria subbifurcata* (Storer).

Common among seaweed on rocky shores in the Bay of Fundy, but only rarely found in Passamaquoddy bay. Captured by hand at low tide and in the seine. Also observed in St. Mary bay.

*Cryptacanthodes maculatus*, Storer.

Occasionally taken on long lines in the Bay of Fundy at considerable depths. Also found living in burrows in soft mud flats in the lower part of the intertidal zone at the mouth of the Magaguadavic river in Passamaquoddy bay. The larvæ have been taken in the latter bay in the early spring. Reported from St. John harbour by Cox (1896 a, p. 39) and again by Halkett (1907, p. 340).

*Anarhichas minor*, Olafsen.

Goode and Bean (1895, p. 301) have reported this species from Eastport.



*Anarhichas lupus*, L.

Not uncommon at Grand Manan, and occasionally at Campobello island. The young have not been seen. Also off Seal island, Yarmouth county. Taken on long lines. Kendall (1908, p. 135) lists it from Eastport.

*Zoarces anguillaris* (Peck).

Common at all stages in Passamaquoddy bay and the Bay of Fundy, being found on hard bottom from moderately deep water to the intertidal zone, where the younger individuals in particular can be found lurking under rocks. It leaves Passamaquoddy bay for deeper water by October or the beginning of November, breeding during its absence. The very young are obtained in the spring. The adults appear at the same time, just outside the bay in April and inside the bay in May. Taken by hand at low tide, on long lines, in lobster pots, and in the shrimp and beam trawls. Also observed in Minas channel and basin, and at Canada Creek, Kings county.

*Lycodes verrillii*, Goode & Bean.

Obtained with the shrimp trawl in the Bay of Fundy off the approach to Passamaquoddy bay in April and May of 1919, in from 35 to 50 fathoms on a muddy bottom, but evidently quite rare.

*Merluccius bilinearis* (Mitchill).

Common in midwater and near shore both in the Bay of Fundy and in Passamaquoddy bay at all stages from yearlings on, but varying greatly in abundance from year to year. The spent adults enter the Bay in late summer and frequently strand on the beach during the night. They leave in the late autumn. The immature may remain throughout the year in the Bay of Fundy. No larvæ and no very young have been found. Taken in weirs, gill nets, and shrimp trawl, and on long lines. Also observed in Scotsman bay (Minas channel) at Harbourville, Kings county, and in the Annapolis basin. Perley (1852, p. 213) found it to be abundant around the island of Grand Manan. Bean (1880, p. 81) listed it from Eastport, and Cox (1896a, p. 74) reported it as occasional in St. John harbour.

*Pollachius virens* (L.)

Large individuals abundant in the tide rips in the Bay of Fundy during summer. Yearlings found in shallow water in the Bay of Fundy. Half grown individuals enter Passamaquoddy bay in moderate numbers. No larvæ or very young have been found. Specimens examined also from Canada Creek, Kings county, St. Mary bay, Port Maitland and Yarmouth. Taken in seine and weirs, and on long lines.

*Microgadus tomcod* (Walbaum).

Rather common and of all sizes near the shore, particularly near estuaries, where the larvæ may be obtained in the spring. Taken in, the seine, weirs, gill

nets, shrimp trawl, and on long lines. Also observed at St. John, in Minas channel and basin, Annapolis basin, and St. Mary bay, and at Pubnico harbour, Yarmouth county.

*Gadus callarias*, L.

Abundant at Grand Manan, but decreasing in abundance toward Passamaquoddy bay. All sizes from yearlings on. Chiefly the intermediate sizes in Passamaquoddy bay. No larvæ have been found, although the eggs are to be found in the spring. A few young individuals have been taken in Passamaquoddy bay and in Minas basin in the late summer, and they appear to be fairly common in St. Mary bay. The quantity of cod taken diminishes very rapidly from the mouth to the head of the Bay of Fundy, but a few go very far in, occurring in Minas basin. Taken in seine, weirs, gill nets and shrimp trawl, and on long lines. Also at Canada Creek, Kings county, Annapolis basin, St. Mary bay, and Port Maitland, Yarmouth county.

*Melanogrammus aeglefinus* (L.)

Found regularly and frequently in abundance in the Bay of Fundy and in Passamaquoddy bay, except during the winter. Those commonly seen are quite large. Intermediate sizes are very rare. Yearlings are occasionally found in the Western Archipelago and at times in the cavities of *Cyanea*. They have also been taken in St. Mary bay. Larvæ and very young have never been found. Taken on long lines. Records also from Hall's Harbour, Kings county, St. Mary bay, and off Seal island, Yarmouth county.

*Urophycis tenuis* (Mitchill) and  
*Urophycis chuss* (Walbaum)

These closely related species both occur commonly in immense quantities on soft bottom both in the Bay of Fundy and in Passamaquoddy bay during the summer. The majority of the specimens taken seem to be referable to the first species. All sizes from yearlings on are found. The younger individuals appear in the spring and are found near shore and far into the estuaries, while the larger ones keep off shore chiefly on soft bottom, occurring in depths as great as 100 fathoms. No larvae have been found, and only a few very young have been taken, and that in the Bay of Fundy. Also at St. John, in Minas channel and basin, at Harbourville, in Annapolis basin and St. Mary bay, and at Yarmouth. The adults enter the bay in the early summer, appearing in Passamaquoddy bay usually some time in July. They leave in October. They seem to enter the St. John river in the autumn. In any event they are to be found throughout the winter in Kennebecasis bay, where they are fished through the ice.

The younger individuals do not leave Passamaquoddy bay as early as the adults, and in some seasons they may be found as late as the latter part of December, and return to some extent as early as April. They remain in the Bay of Fundy all winter. Taken in weirs, seines, gill nets, shrimp trawl, beam trawl, and on long lines.

*Enchelyopus cimbrius* (L.)

Found generally, but not in abundance, chiefly in the Bay of Fundy and occasionally in Passamaquoddy bay, at considerable depths on soft bottom. All sizes are found. It remains throughout the year. Eggs are common in Passamaquoddy bay in the summer, but no larvae have been obtained. The very young are common at the surface near the centre of the Bay of Fundy in the autumn. Taken in shrimp and beam trawls and on long lines. Also taken in St. Mary bay and in as shallow water as 6 fathoms.

*Brosmius brosme* (Müller)

Not uncommon at considerable depths on hard bottom at the mouth of the Bay of Fundy, as at Grand Manan and St. Mary bay. Rare inside. It has been taken at Campobello, but is not known in Passamaquoddy bay. Only adults are found. Taken on long lines. Also off Seal island, Yarmouth Co.

*Macrourus bairdii*, Goode and Bean

Two records for the Bay of Fundy are available. Kendall (1908, p. 145) records it as having been taken floating near the surface at Eastport. In 1917 a specimen taken in a weir at Lubec was sent to the Atlantic Biological Station. The strong tidal currents through deep narrow channels at the entrance to Passamaquoddy bay must be considered as responsible for bringing this deep water fish to the surface.

*Hippoglossus hippoglossus* (L.)

In the Western Archipelago most of the halibut are taken on the outer side of Grand Manan island, but on the east coast of the Bay of Fundy it seems to occur in quantity well up toward Minas basin. Occasionally individuals (rather small) are taken in Passamaquoddy bay and in the St. Croix river as far up as the Ledge Lighthouse at least. They are too rare for their seasonal movements to be determined, but one was taken off Campobello island in 50 fathoms on December 22, 1917. Otherwise they have all been captured during the summer. On July 7, 1920, a very young individual, only 31 mm. in length, was seined in Passamaquoddy bay. Taken on long lines and in the shrimp trawl.

*Hippoglossoides platessoides* (Fabr.)

Quite abundant both in the Bay of Fundy and in Passamaquoddy bay in moderately deep water (15 fathoms or more) on soft bottom throughout the year. Large individuals are not very common. The eggs occur in the spring, but no larvae have ever been found. Yearlings and older are common. Also taken in St. Mary bay in 1919. Captured on long lines and in the shrimp and beam trawls:

*Limanda ferruginea* (Storer)

In the Bay of Fundy region we have found it only at St. Mary bay in 1919, and there only a few large individuals in deep water. Perley (1852, p. 217) appears to have found it in the upper part of the bay near Parrsboro. Taken in the shrimp trawl. It is doubtless an immigrant.

*Pseudopleuronectes americanus* (Walbaum)

Very abundant everywhere in shallow water and at moderate depths, going deeper in the winter. All stages are common, the larvae most abundant near the mouths of estuaries, where they have been taken in June and July. In Passamaquoddy bay they may be obtained throughout the year in the deep water (about 15 fathoms), but leave the shores in the coldest months—January and February, except during mild winters. In the Bay of Fundy they have been found on soft bottom at depths of from 30 to 50 fathoms only from November to April. Taken in the seine, gill net, weirs, shrimp and beam trawls, and on long lines. Observed also at St. John, in Minas basin and channel, at Harbourville, Kings Co., and in Annapolis basin and St. Mary bay.

*Liopsetta putnami* (Gill)

Abundant in and near estuaries in shallow water on soft bottom. All stages can be taken. It occurs in Minas channel and the Annapolis basin, but appears to be absent from St. Mary bay. Taken in the seine and weirs.

*Glyptocephalus cynoglossus* (L.)

Taken very generally in the shrimp trawl, but not in large quantities, both in the Bay of Fundy and in Passamaquoddy bay in moderately deep water (15 fathoms or more) on soft bottom. The larvae have never been found, but all stages from the time of transformation, and later, occur. As far as our records go, they show its presence in Passamaquoddy bay from April to November, and in the Bay of Fundy throughout the year. Also taken in St. Mary bay in 1919.

*Lophopsetta maculata* (Mitchill)

Exceedingly rare in the Western Archipelago. Bean (1880, p. 79) listed it from Eastport, Goode (1884, p. 199) recorded it from Passamaquoddy bay, and we secured a large individual there in 1912. No young have ever been found in that region. Mr. Leim found it to be common at Scotsman bay in Minas channel in 1920, and its larvæ also occurred there, showing that part of the bay to be its successful breeding place and a centre of dispersal. We have also obtained it in St. Mary bay. Taken in the seine, weirs, and shrimp trawl.

*Lophius piscatorius*, L.

Large individuals are frequently taken on long lines in the Bay of Fundy or found stranded in the intertidal zone. Occasionally they have been taken in Passamaquoddy bay and the St. Croix river. The egg masses have only rarely (two records) been found. Only one young individual has been secured, and that at Campobello island (Connolly, 1920, p. 14). No larvae have been observed. Also captured in the shrimp trawl. It has been taken also in St. Mary bay, Annapolis basin and Minas channel, where it seems to be not uncommon. Previous records are,—Eastport (Kendall, 1908, p. 151); St. John harbour (Halkett, 1907, p. 342); Great Salmon river, St. John Co., and Annapolis basin (Perley, 1852, p. 189); Harbourville, Kings Co., and St. Mary bay (Connolly, 1920, p. 7).

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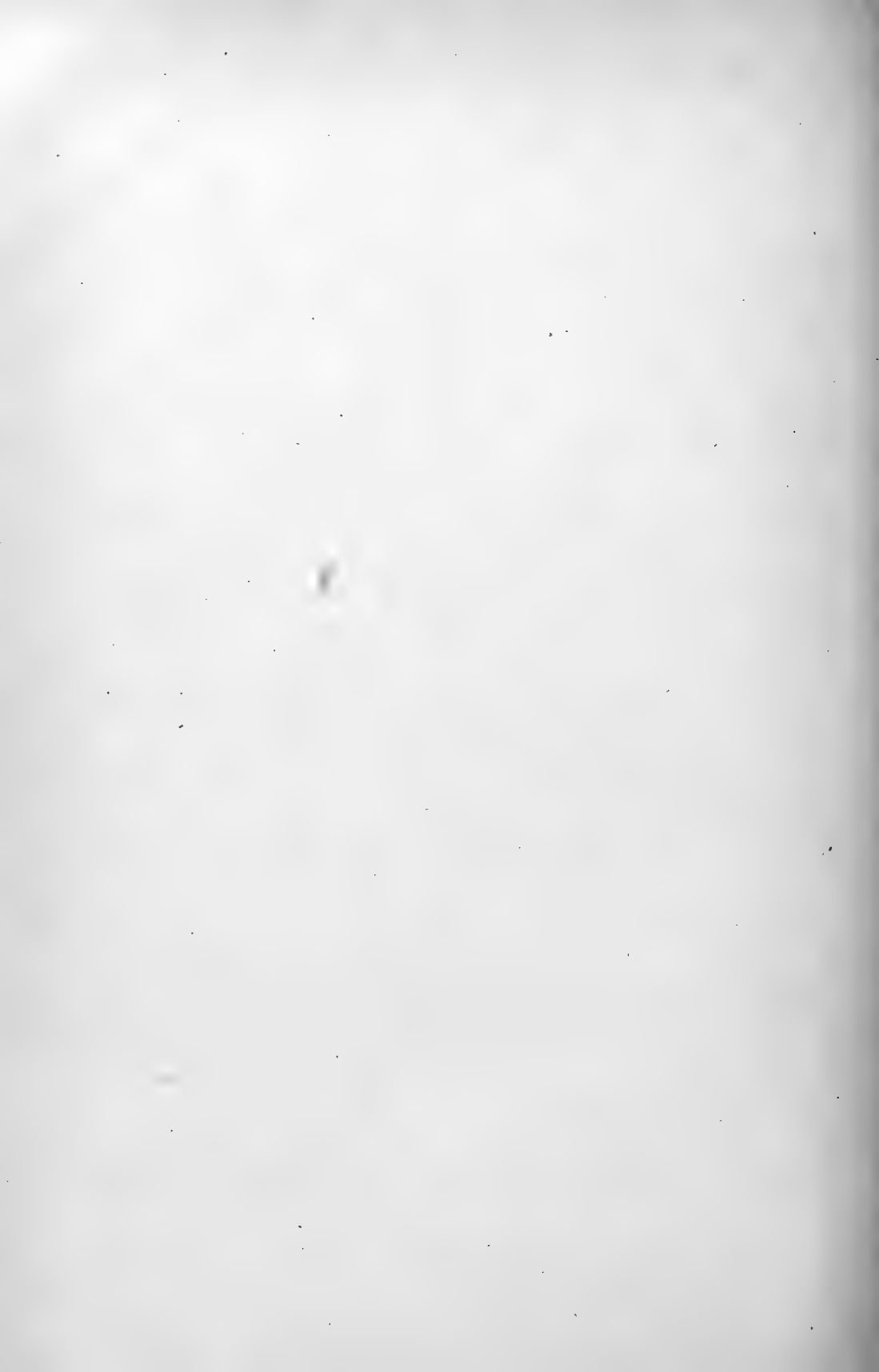
No. IV

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A STUDY OF THE CISCOES OF LAKE ERIE

BY

WILBERT A. CLEMENS  
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# A Study of the Ciscoes\* of Lake Erie.

BY WILBERT A. CLEMENS,  
*University of Toronto*

This study was carried out under the auspices of the Biological Board of Canada in response to a request from the Lake Erie Fishermen's Association for an investigation of some of the problems in connection with the cisco fishing industry. In the request it was desired particularly that some information be obtained as to why smaller ciscoes in general are taken in the eastern end of the lake than in the western part.

The major portion of the work having to do with the measurements of the fish and the taking of scales was carried out at various points on Lake Erie during the summer and fall of 1920, but shipments from various points were examined in Toronto during the years of 1919 and 1920.

The author desires to express his appreciation of the assistance given by many fishermen, in particular by Mr. A. E. Crewe, who kindly provided accommodation for the carrying out of the work during the summer of 1920, freely placed all the material of his catches for examination, and gave assistance in many ways. Other gentlemen who facilitated the work in supplying material and in other ways were: Messrs. Charles Ross, Roy Ross, Wilson S. McKillop, A. B. Hoover, C. W. Barwell, R. Kolbe, and W. D. Bates.

## IDENTIFICATION OF SPECIES

For the separation of the species of shallow water ciscoes (subgenus *Thrisomimus*) as described by Jordan and Evermann† (1911) it appears that three proportional measurements are more or less critical, namely, head in length, depth in length, and depth of caudal peduncle in head. Jordan and Evermann give the following proportions:

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\*The word cisco is here used instead of herring for all members of the genus *Leucichthys* except for the tullibeas, in accordance with the list of standardized names of North American fish as agreed upon by the U.S. Bureau of Fisheries, the Biological Board of Canada and the Canadian Fisheries Association.

†Jordan, D. S., and Evermann, B. W. 1911. A Review of the Salmonoid Fishes of the Great Lakes with notes on the Whitefishes of other Regions. *Bull. U.S. Bureau Fish.*, Vol. xxix (1909). Document No. 737 (1911).

Species	Head in length	Depth in length	Depth of caudal peduncle in head
<i>L. harengus</i> .....	4.33	4.3-4.6	3.0
<i>L. sisco huronius</i> .....	4.66	4.2-4.5	2.9
<i>L. ontariensis</i> .....	4.5	3.7-4.2	2.66
<i>L. artedi</i> .....	4.4	3.5-4.0	2.0-2.5
<i>L. eriensis</i> .....	4.4	3.3-3.5	2.2

Accordingly for each fish examined the necessary measurements were made for the calculation of the above proportions. In addition the girth and the weight were determined and scales removed for age estimation. From June 14 to August 24, 1920, the ciscoes taken in twenty pound nets at the Crewe Bros. Fishery near Merlin were examined daily. In August and November the fish taken at Port Dover, Nanticoke, McKillop's Fishery (near Port Maitland) and Dunnville were examined. The following species have been identified:

(1) *Leucichthys sisco huronius* (J. & E.), Lake Huron cisco.

This species was readily distinguished by the long spindle-shaped body. The average proportions for 60 individuals were as follows: head in length 4.6, depth in length 4.3, depth of caudal peduncle in head 2.95. These figures are practically identical with those given by Jordan and Evermann for Lake Huron. This species is taken rather abundantly in the pound nets at Merlin but very few specimens were seen east of Long Point.

(2) *L. eriensis* (J. & E.). Jumbo cisco.

This is the most abundant species taken in pound nets from Rondeau to Point Pelee. It also occurs in large numbers eastward to Long Point but appears to become very much less abundant beyond. It is noted for the large size attained as compared with the other species of the genus *Leucichthys*. The outstanding characters are (1) the deep body, (2) the more or less pronounced hump at the nape, (3) the deep caudal peduncle, (4) the relatively large scales. The average proportions for 150 individuals were: 4.41, 3.42 and 2.44.

(3) *L. artedi* (Le Sueur). Lake Erie cisco or grayback.

This species occurred in numbers at Merlin next in abundance to *L. eriensis* and appears to occur abundantly throughout the lake. It has been distinguished from the jumbo cisco by (1) the somewhat narrower peduncle, (2) the narrower body with usually little or no hump at the nape, (3) the smaller scales with less of the shiny appearance, (4) the much slower rate of growth as shown in the following table and also later in the discussion of the results of the scale examinations.

<i>L. artedi</i>					<i>L. eriensis</i>				
No.	Date	Length cm.	Weight oz.	Age Years	No.	Date Date	Length c.m.	Weight oz.	Age Years
600	July 8	20.7	6	4	234	July 8	20.8	6	3
601		21.8	6	5	235		21.9	7	3
602		21.0	6	5	237		21.1	7	3
603		21.5	6	5	238		22.2	8	3
604		21.0	6	5	239		22.6	8	3
605		22.2	6	6	240		22.8	9	2
606		21.8	6	5	241	July 9	23.7	9	3
607	July 9	22.8	7	6	242		26.5	12	4
609		22.9	7	5	243		21.5	7	3
610		23.4	7	5	244		24.1	10	3

Figure 1 shows a drawing of a scale from specimen No. 606, *L. artedi* and a drawing of a scale from specimen No. 235, *L. eriensis*.

The average proportions for 50 individuals as they occurred at Merlin were 4.26, 3.7 and 2.86. These figures are somewhat different from those given by Jordan and Evermann and may be due in part to the fact that the young of *L. eriensis* are somewhat difficult to separate from this species, and in the selection of the above 50 individuals rather extreme forms were chosen. There is an indication, however, that *L. artedi* is more closely related to the species of the other lakes than perhaps the figures of Jordan and Evermann show.

(4) *L. prognathus* (Smith). Lake Ontario deep water cisco or longjaw.

In both the pound nets and gill nets from Port Dover to Port Maitland a cisco occurs very abundantly whose exact identity and relationships have not been determined as yet. Dr. B. W. Evermann, to whom ten specimens were submitted for identification, refers them provisionally to the species *prognathus* pending further examination of these and additional specimens. The outstanding features of this form are the following: (1) the long mandible which usually projects beyond the upper jaw and in extreme cases almost hooks over it, (2) the relatively long bony snout, (3) the narrow caudal peduncle, (4) the shiny appearance of the scales, (5) the rather deeply forked caudal fin. In a great many individuals the above characters are extreme as well as other features, as indicated by the following proportions, 4.0, 4.2, and 3.2. In other specimens the proportions are about as follows: 4.3, 3.75, and 2.85. The average for 118 individuals is 4.22, 3.88, and 2.85. However, Dr. Evermann states that *L. prognathus* varies greatly. Only a single longjaw was taken at Merlin during

the summer of 1920 on August 24, and it had the proportions 4.1, 3.3, and 2.8. A fisherman at Point Pelee has stated that he recalled having seen during one spring rather large numbers of small longjaws taken in the pound nets in that region. This would indicate a migration occurring during the winter or spring months when temperature conditions would be rather uniform throughout the lake.

The longjaws examined at Dunnville and Port Dover early in November, 1920, were almost ready to spawn. Typically, members of the subgenus *Cisco* (Jordan and Evermann) are said to spawn in late summer but it would not be surprising to find the deep water forms in the shallower, warmer waters of Lake Erie spawning later than those in the other Great Lakes, especially in a mild fall such as occurred in 1920. Two females of *L. johanna*e received from Warton, Georgian Bay, November 24, 1920, were found not to have spawned.

The following table shows comparative measurements of certain characters of the longjaws in Lake Erie. Measurements are given in decimal fractions of body length.

	PORT MAITLAND						PORT DOVER		
	1032	1042	1037				919	907	918
Head.....	.26	.25	.25	.245	.25	.24	.23	.23	.24
Depth.....	.24	.21	.22				.24	.26	.30
C.P. depth.....	.087	.078	.081	.082	.082	.089	.084	.079	.082
Eye.....	.054	.058	.060	.06	.06	.055	.066	.055	.065
Snout.....	.063	.063	.064	.063	.063	.057	.058	.053	.058
Maxillary.....	.085	.083	.09	.08	.087	.085	.079	.08	.089
Snout to occiput.....	.17	.17	.17	.17	.17	.16	.166	.15	.173
Gill rakers.....	45	46	45	41	41	45	45	45	41
Head in length.....	4.0	4.0	4.0	4.0	4.0	4.1	4.3	4.3	4.1
Depth in length.....	4.2	4.7	4.6				4.1	3.9	3.3
C.P. depth in head.....	3.2	3.2	3.2	3.0	3.0	2.7	2.8	3.0	2.9

(5) *L. harengus* (Richardson). Georgian Bay cisco.

A few individuals were taken which agreed in measurements and description with the Georgian Bay cisco. Jordan and Evermann report this species in Lake Erie and no doubt it occurs in small numbers.

For purposes of comparison and for confirmation of the value of proportional measurements, specimens of *L. ontariensis* were obtained from Port Credit on Lake Ontario, and specimens of *L. harengus* from Warton and Midland on

Georgian Bay. The average proportions of 20 individuals of *L. ontariensis* were 4.5, 3.8, and 2.6. The average for 25 individuals of *L. harengus* were 4.2, 4.3, and 3.1.

The following table shows the measurements of typical individuals of the various species examined. Measurements are given in decimal fractions of body length.

	<sup>1</sup> <i>L. harengus</i>	<i>L. sisco huronius</i>	<sup>2</sup> <i>L. ontari- ensis</i>	<i>L. artedi</i>	<i>L. eriensis</i>	<i>L. prognathus</i>
	21	328	3	666	1026	1038
Head.....	.24	.22	.21	.23	.23	.25
Depth.....	.21	.22	.26	.26	.33	.24
Caudal peduncle length..	.11	.12	.11	.11	.10	.11
Caudal peduncle depth...	.073	.074	.084	.085	.095	.081
Eye.....	.062	.051	.054	.057	.057	.065
Snout.....	.057	.053	.051	.055	.050	.056
Interorbital space.....	.068	.064	.062	.068	.067	.065
Maxillary.....	.079	.074	.066	.081	.073	.086
Snout to occiput.....	.16	.14	.15	.16	.15	.17
Ventral to pectoral.....	.31	.36	.35	.36	.36	.33
Pectoral to P-V distance..	2.25	2.2	2.4	2.2	2.3	1.9
Pectoral length.....	.14	.14	.14	.16	.16	.17
Ventral length.....	.13	.12	.14	.15	.16	.17
Dorsal height.....	.14	.13	.15	.16	.17	.18
Adipose length.....	.053	.06	.062	.064	.073	.053
Anal height.....	.88	.88	.94	.11	.11	.13
Gill rakers.....	49	47	48	43	46	45
Scales.....	9-85-8	9-82-8	9-78-8	8-70-7	8-75-7	8-75-7
Head in length.....	4.2	4.6	4.6	4.3	4.4	4.1
Depth in length.....	4.7	4.5	3.8	3.5	3.1	4.2
C.P. depth in head.....	3.2	3.0	2.7	2.8	2.4	3.0

<sup>1</sup>From Georgian Bay.

<sup>2</sup>From Lake Ontario.

The following table shows proportions as given by Jordan and Evermann and those obtained for the ciscoes in Lake Erie with the exception of *L. harengus* and *L. ontariensis*.

Species	Jordan and Evermann			Lake Erie		
	Head in length	Depth in length	Depth C.P. in length	Head in length	Depth in length	Depth C.P. in length
<i>L. harengus</i> .....	4.33	4.3-4.6	3.0	<sup>1</sup> 4.2	4.3	3.1
<i>L. sisco huronius</i> .....	4.66	4.2-4.5	2.9	4.6	4.3	2.95
<i>L. ontariensis</i> .....	4.5	3.7-4.2	2.66	<sup>2</sup> 4.5	3.8	2.6
<i>L. artedi</i> .....	4.4	3.5-4.0	2.0-2.5	4.26	3.70	2.86
<i>L. eriensis</i> .....	4.4	3.3-3.5	2.2	4.41	3.42	2.44
<i>L. prognathus</i> .....	4.0	3.5	3.5	4.22	3.88	2.87

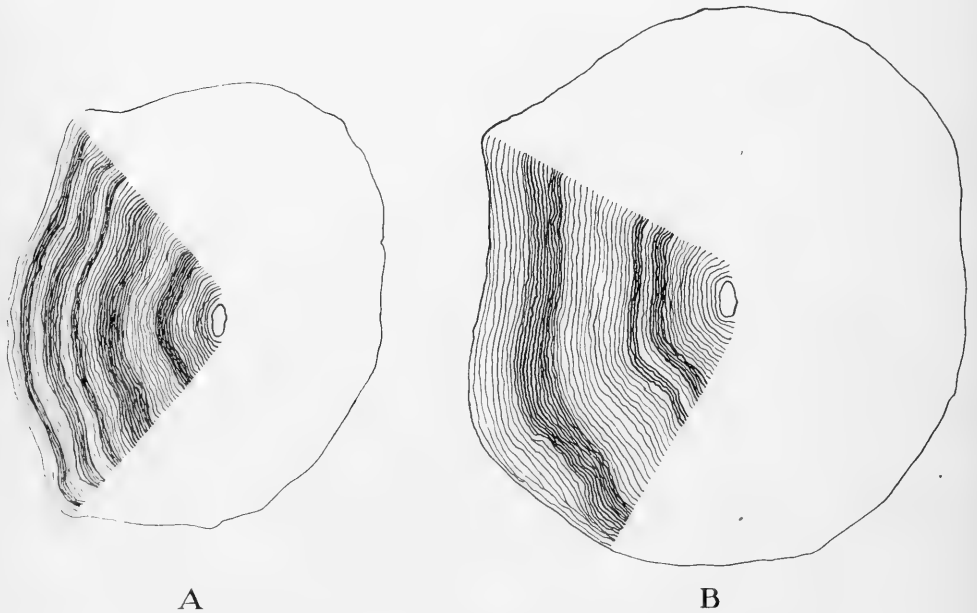


Fig. 1.—Drawings of scales of ciscoes.

*A*, from specimen No. 606, *L. artedi*, showing 5 winter bands, the fish therefore being in its sixth summer. *B*, from specimen No. 235, *L. eriensis*, showing three winter bands, the fish therefore being in its fourth summer.

<sup>1</sup>From Georgian Bay.

<sup>2</sup>From Lake Ontario.

## RATES OF GROWTH

The scales were used in determining the rates of growth of the various species of ciscoes. The growth areas are usually well marked. Scales from approximately the following number of fish of each species were examined: *L. eriensis*

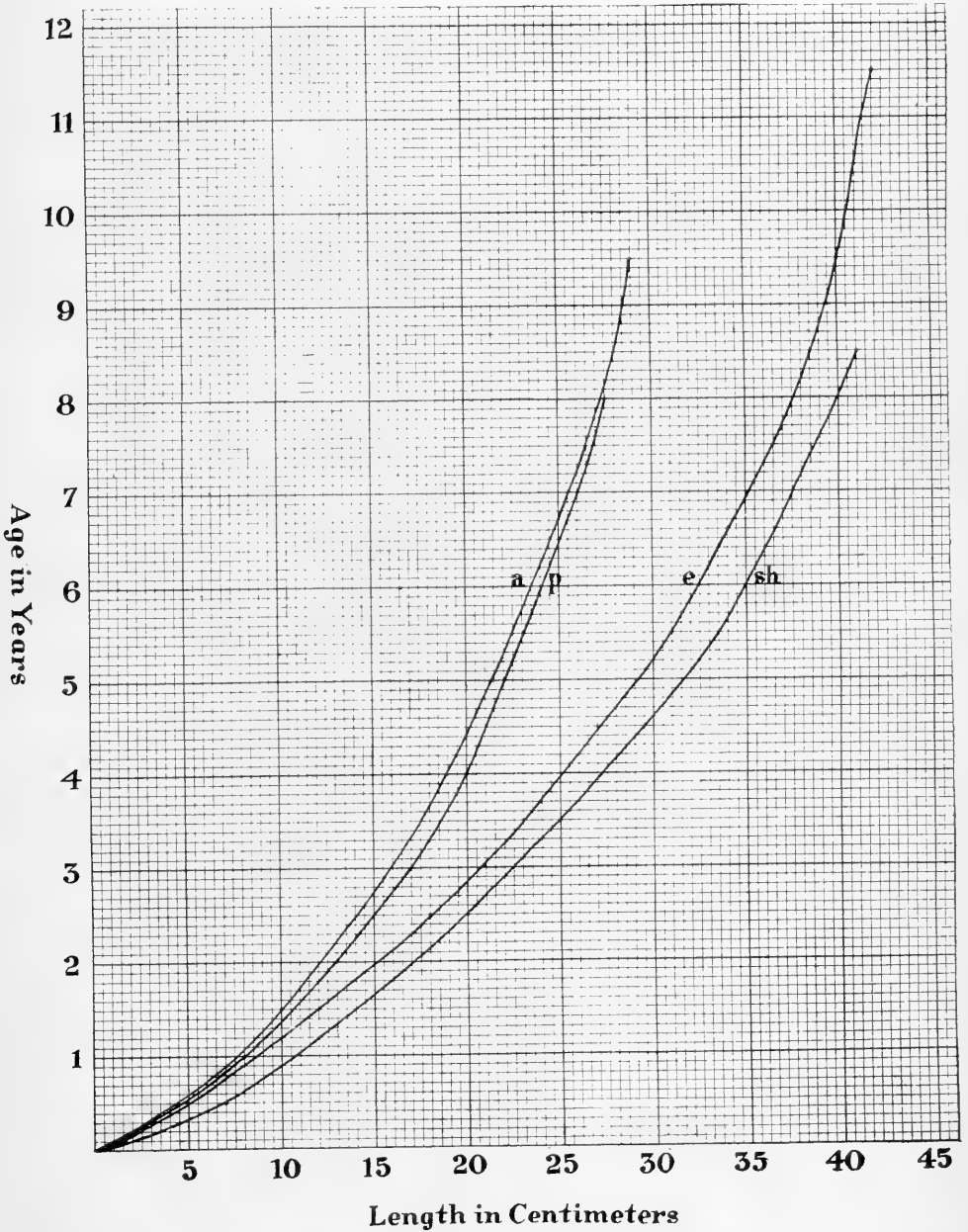


Fig. 2.—Graph illustrating rates of growth of ciscoes in Lake Erie a=*L. artedi*, p=*L. prognathus*, e=*L. eriensis*, sh=*L. sisco huronius*.

140; *L. artedi* 55; *L. sisco huronius* 55; *L. prognathus* 150. The results are shown in Fig. 2. Considerable difficulty was experienced in estimating the rate of growth of *L. sisco huronius*. In the majority of scales some of the winter bands were difficult to distinguish and there was evidence that in some cases at least one winter band was not recorded. It is possible, therefore, that the curve for this species should lie to the left of the curve for *L. eriensis*. Fig. 3 shows the relation of age to weight. The following table gives the data obtained for the three important commercial species in Lake Erie. The length in centimeters is from the tip of the snout to the base of the caudal fin; the girth just anterior to the dorsal fin.

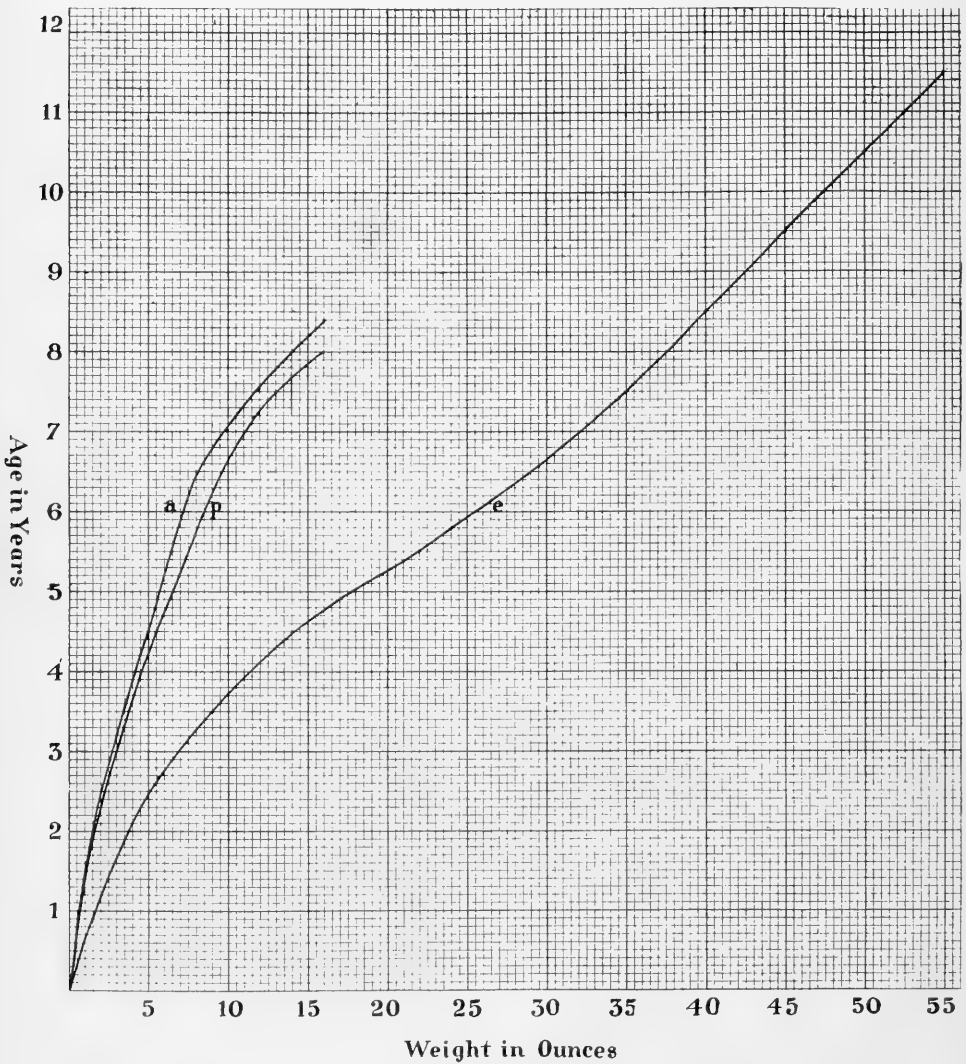


Fig. 3.—Graph illustrating relation of weight to age of ciscoes in Lake Erie. a = *L. artedi*, p = *L. prognathus*, e = *L. eriensis*.



Age	<i>L. eriensis</i>				<i>L. artedi</i>				<i>L. prognathus</i>			
	Length c.m.	Length in.	Weight oz.	Girth in.	Length cm.	Length in.	Weight oz.	Girth in.	Length cm.	Length in.	Weight oz.	Girth in.
1	8.5	4.0	1.5	.....	7.5	3.0	.....	....	8.0	3.0	.....	.....
2	15.0	6.6	3.5	.....	12.5	5.2	.....	....	13.0	5.2	.....	.....
3	20.5	9.1	7.0	6.1	16.0	7.0	3.0	4.5	17.0	7.0	3.0	4.5
4	25	11.4	11.5	7.4	19.0	8.5	4.5	5.2	20.0	8.5	4.5	5.2
5	29	13.3	17.5	8.5	21.5	9.6	5.5	5.8	22	9.8	6.5	5.7
6	32.5	14.8	25.5	9.4	23.5	10.3	7.5	6.3	24	10.7	8.5	6.3
7	35.5	16.0	32.0	10.1	25.5	10.7	9.5	6.7	26	11.4	11.0	....
8	37.5	17.0	37.5	10.8	27.5	11.8	12.5	....	.....	.....	.....	.....
9	39.5	17.6	42.5	11.3	28.5	.....	.....	....	.....	.....	.....	.....
10	40.5	18	47.5	11.8	.....	.....	.....	....	.....	.....	.....	.....
11	41.5	18.5	52.5	....	.....	.....	.....	....	.....	.....	.....	.....

The difference in weight between *L. artedi* and *L. prognathus* is partly due to the fact that the specimens of the latter species were examined chiefly in November and the females were then heavy with spawn.

## SUMMARY

1. Three species form the bulk of the cisco catch in the Canadian waters of Lake Erie, namely, *L. eriensis*, *L. artedi* and *L. prognathus*.

2. *L. eriensis* is the dominant form westward from Long Point, and *L. prognathus* eastward from Long Point. This statement holds in general, for the former appears to prefer the shallower water while the latter is apparently a deep water form. However their ranges tend to overlap and their migrations at times take them into one another's territory. For example, fishermen have reported occasional schools of longjaws as far west as Point Pelee, and, on the other hand, the jumbo is reported as abundant, at times, off Port Maitland. *L. artedi* occurs abundantly throughout the lake, but probably in greatest numbers west of Long Point.

3. *L. artedi* and *L. prognathus* have rates of growth and increases in weight which are practically identical, while *L. eriensis* increases about 1 1/3 times faster in length and two to three times faster in weight.

4. Examinations of the graphs and tables for rates of growth and increases in weight show that the optimum size for the taking of the jumbo cisco is from the fifth summer upward when they are at least 12 inches in length and 1 pound in weight. Whether the food supply would permit of this as the minimum size it is impossible to say. In regard to *L. artedi* and *L. prognathus* a minimum length of about 10 inches and a weight of about 6 or 7 ounces, when the fish are in their sixth summer, would appear to be quite satisfactory.

5. Concerning the occurrence of smaller ciscoes in the eastern end of the lake, this much can be safely said: that in respect to gill net catches the fishermen in the western portion of the lake secure a larger percentage of jumbo ciscoes and, therefore, get large fish, while the fishermen in the eastern end, particularly off Port Maitland, secure chiefly the smaller species, *L. artedi* and *L. prognathus*. The same facts apply to the pound net catches, with the addition that, since the young inhabit the shallow waters and the shallow water area east of Long Point is more limited, there appears to be a concentration of young ciscoes along the shore, particularly in Long Point Bay, and hence the young are apt to be impounded in large numbers in the pound nets.

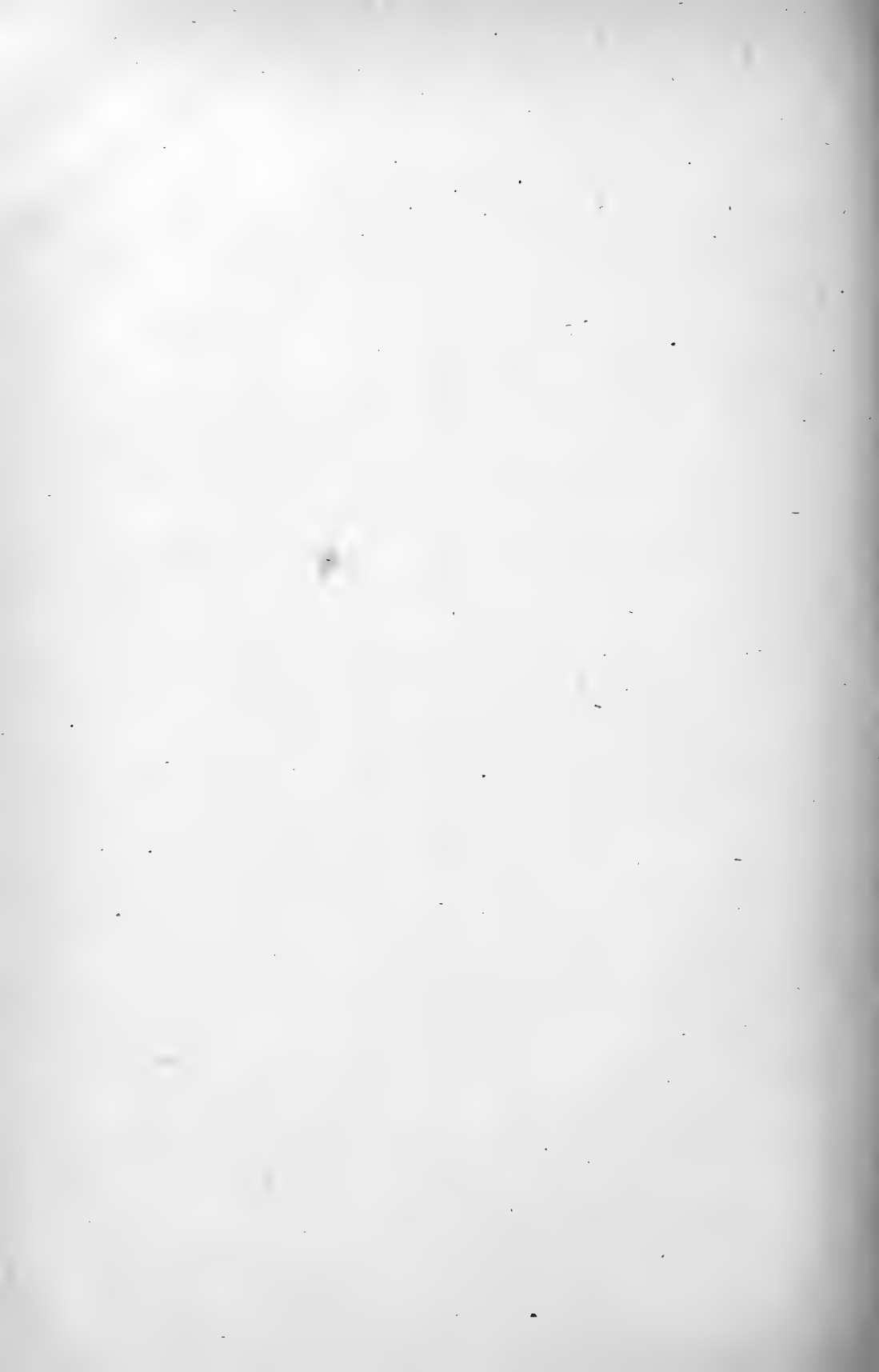
6. No data were obtained as to the age when the various species spawn for the first time. Spawning is probably at the end of the third summer, and, if so, the six-ounce regulation protects the two species, *L. artedi* and *L. prognathus* in respect to being allowed to spawn once, but does not protect *L. eriensis* since it attains a weight of six ounces in its third summer.

7. The girth measurements were taken around the body just anterior to the dorsal fin, that is where the greatest girth occurs. The results show that the three inch gill net regulation is quite satisfactory for the species *L. artedi* and *L. prognathus* since they do not attain a girth of six inches until the sixth summer, but barely protects *L. eriensis* since this species attains a girth of six inches in three years.

8. In any undertaking for the artificial propagation of ciscoes in Lake Erie, at least for the region west of Long Point, particular attention should be given to *L. eriensis*, because of its rapid growth and its excellent qualities as a food fish.

### CONCLUSION

This study has proved to be merely preliminary. The ciscoes of Lake Erie form a complex association and it has been impossible in this investigation to determine their inter-relations or to study the physical factors in relation to the various forms. Solution of the many difficult problems must await a thorough study of the physical conditions of existence in the various parts of the lake, such as distribution of temperatures, oxygen, carbon dioxide, currents, etc., and the relation of these factors to spawning, growth, movements of the fish, as well as to the production and distribution of their food organisms.



No. V

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THE FOOD OF CISCOES (*Leucichthys*) IN LAKE ERIE

BY

WILBERT A. CLEMENS

AND

N. K. BIGELOW

*University of Toronto*



# The Food of Ciscoes (*Leucichthys*) in Lake Erie.

BY WILBERT A. CLEMENS,

AND

N. K. BIGELOW,  
*University of Toronto.*

The results of the examination of the contents of the digestive tracts of 211 ciscoes (fresh-water herring) are presented herein. The bulk of the material was obtained early in June, 1919, and from July to November in 1920, from Lake Erie at various points along the north shore. The species examined were *Leucichthys eriensis*, the jumbo cisco; *L. artedi*, the Lake Erie cisco; *L. sisco huronius*, the Lake Huron cisco; and *L. prognathus*, the Lake Ontario deep water cisco (longjaw). These were taken at Merlin, Rondeau, Port Dover, Nanticoke, McKillop's fishery (near Port Maitland), and Dunnville. In addition 19 individuals of *L. harengus*, the Georgian Bay cisco, from Warton, Georgian Bay, and 7 individuals of *L. ontariensis*, the Lake Ontario cisco, from Port Credit, Lake Ontario, have been examined for comparative purposes. The material from Merlin, Rondeau, Nanticoke and McKillop's was obtained in pound nets while the material from all the other points was obtained in gill nets.

The results are given in the following tables. In the table "Unidentified species" are placed those fish whose identity was not determined. The figures indicate the relative abundance, namely: (1) that only a few individuals were noted; (2) that the organisms occurred rather abundantly; (3) very abundantly.

## SUMMARY:

1. An examination of the tables shows that the ciscoes are pre-eminently plankton feeders. The study practically covers the fishing season, and during that time at least, the free swimming crustacea form the bulk of the food of these fish. Of Canadian waters, Lake Erie produces more ciscoes than all the other Great Lakes combined. For example, in 1919 Lake Erie produced 7,425,713 lbs., while the remainder of the Great Lakes produced 4,022,711 lbs. It is not improbable that the production of ciscoes is directly dependent upon the amount of plankton Crustacea produced. The numbers of these Crustacea which must abound in Lake Erie in order to support the millions of ciscoes, as well as the great numbers of white fish and young of many other species, is almost beyond the imagination. Comparative quantitative plankton studies in the Great Lakes would, no doubt, afford considerable information as to the fish productive capacities of these lakes.

2. It is doubtful if the various species of ciscoes show any preference among the entomostraca as food material. They doubtless take whatever forms occur in the waters they happen to inhabit.

3. In the great majority of alimentary tracts examined, *Daphnia* formed the great bulk of the contents, while other forms were represented by scattered individuals. In many cases *Daphnia* alone were present. This was particularly true of the jumbo and the Lake Ontario ciscoes. It appears, therefore, that *Daphnia* are very much the most important of the entomostraca as food organisms. *Daphnia longispina* occurred in all the material examined, as variety *hyalina galeata*. *Daphnia ephippia* were abundant in October in Lake Ontario and in November in Lake Erie. Occasional ephippia with three eggs were noted.

4. Of the Copepods *Diaptomus sicilis* and *Limnocalanus macrurus* were perhaps the most abundant forms occurring in the digestive tracts, although *Epischura lacustris* occurred frequently and occasionally in considerable numbers. Very often the oil globules of these forms gave the contents a bright red colour.

5. In the eastern end of Lake Erie one of the most important food organisms was *Mysis relicta*. As far as we are aware this is the first record of the occurrence of this form in Lake Erie. Its presence indicates at least an approach of conditions in the eastern end of this lake to conditions in the other Great Lakes.

6. Three individuals were found to have eaten small fish. In each case digestion had proceeded too far to allow of identification. All three ciscoes were taken in the eastern end of the lake, two were longjaws (*L. prognathus*) and the third, while not definitely identified, was probably also a longjaw. A fisherman near Point Pelee has stated that one winter he found that some ciscoes which he took through the ice, had eaten "minnows."

7. As is shown in the table for the longjaws (*L. prognathus*) these fish in June, 1919, had fed practically entirely upon *Ephemeridae* (*Ephemera simulans*), both adults and subimagos. The importance of these insects as fish food is thus further demonstrated. Moreover, there is no doubt that the transformation of the nymphs to the subimaginal stage takes place at the surface of the water, as occurs in the closely related genus *Hexagenia* (Needham, 1920).\* This means that the subimagos, as well as the imagos, were taken at the surface of the water by the ciscoes. The projecting lower jaw of these forms is well suited to such surface feeding.

8. The following table, compiled from the food tables, shows the distribution of the food organisms in the lake.

The outstanding points in the table are:

(a) The absence of *Mysis relicta* from the western portion and the absence of *Daphnia pulex* and *D. retrocurva* from the eastern portion. Further investigation, however, may show the presence of these species throughout the lake.

(b) Although only 43 gill net fish were examined, and the list of forms is, therefore, incomplete, yet the results are an indication of what would be expected in any large body of water, namely, that the shore waters contain a greater number of species of food organisms than the more open waters. The gill net

\*Needham, James G. 1920. Burrowing Mayflies of our Larger Lakes and Streams. Bull. U.S. Bur. Fish., Vol. XXXVI, 1917-18.



	WESTERN PORTION	EASTERN PORTION	
	87 pound net fish from Merlin and Rondeau	55 pound net fish from McKillop's and Nanticoke	43 gill net fish from Port Dover and Dunnville
<i>Epischura lacustris</i> .....	+	+	+
<i>Diaptomus sicilis</i> .....	+	+	+
<i>Limnocalanus macrurus</i> .....	+	+	+
<i>Cyclops</i> sp.....	+	+	
<i>Sida crystallina</i> .....	+	+	
<i>Diaphanosoma brachyurum</i> .....	+		
<i>Holopedium gibberum</i> .....	+		
<i>Daphnia pulex</i> .....	+		
" <i>retrocurva</i> .....	+		
" <i>longispina</i> .....	+	+	+
<i>Bosmina longirostris</i> .....	+		+
<i>Eurycerus lamellatus</i> .....	+		
<i>Chydorus</i> sp.....	+		
<i>Leptodora kindtii</i> .....	+	+	
<i>Mysis relicta</i> .....		+	+
<i>Hyallolela knickerbockerii</i> .....	+		
<i>Ephemeridae</i> .....	+	+	+
Small fish.....		+	

fish were taken over 5 miles from shore while the pound net fish were taken within 2 miles of shore.

(c) A comparison of the first two columns shows the possibility of there being a greater number of species in the western part of the lake than in the eastern end. There is a possibility also that quantitative differences exist in these regions as well as qualitative:

The results of this study serve to emphasize anew the importance of the plankton fauna of our inland waters, and the necessity for a thorough quantitative, qualitative and distributional investigation of these organisms, including particularly their relations to the production, distribution and movements of fish.

L. ERIENSIS—JUMBO CISCO IN LAKE ERIE.

Collection Number.	Date.	Locality.	Length in cms.	Weight in ozs.	Age.	<i>Epirischura lacustris</i> .	<i>Diafionus sicilis</i> .	<i>Limnocalanus macrurus</i> .	<i>Cyclops</i> sp.	<i>Sida crystallina</i> .	<i>Daphnia pulex</i> .	<i>Daphnia retrocurva</i> .	<i>Daphnia longispina</i> .	<i>Daphnia</i> sp.?	<i>Bosmina longirostris</i> .	<i>Leptodora kindtii</i> .	<i>Mysis relicta</i> .	Miscellaneous.
118	June 1/19	Rondeau	25.8	13	5	1		1	1	1	3	3						Insect fragments 1.
101	"	"	27.0	14½	4				1		3	1						
129	"	"	31.0	21	5						3							<i>Ephemera</i> 2; <i>Chironomidae</i> 1; <i>Amphipoda</i> 1.
127	"	"	35.5	31	6						3							<i>Ephemera</i> 1.
229	July 6/20	Merlin	23.5	8	4				1	2			3					
15 indiv.	"	"	24.5	10		1	1		1	1			1			3		
15 "	"	"	24.5	10		1	1		1	1			2			3		
15 "	July 8/20	"	22.5	6½		1	1		1	2	3		2			1		<i>Diaphanosoma brachyurum</i> 1; <i>Holopedium gibberum</i> 1.
12 "	July 10/20	"	22.5	6½		1	1						1			3		
299	Aug. 2/20	"	26.4	16	4					1			1			3		<i>Diaphanosoma brachyurum</i> 1.

1,206	Nov. 12/20	Rondeau	21.3 7	1	1					3									
1,201	"	"	21.6 6½		1					3									
1,210	"	"	21.8 7		1					3									1
																			<i>Encercus lamellatus</i> 1; Crustacean debris 1; <i>Volvox</i> 1.
1,213	"	"	22.2 7½							3									
1,208	"	"	22.3 8							3									
1,214	"	"	23.7 10							3									
1,211	"	"	24.3 11							3									
1,204	"	"	27.7 17½							3									
1,203	"	"	33.3 31							3									
	Nov. 24/20	Merlin	24.5		1					3									
	"	"	26.5	1	2					3									

L. ARTEDI—LAKE ERIE CISCO OR GRAYBACK IN LAKE ERIE

Collection Number.	Date.	Locality.	Length in cms.	Weight in ozs.	Age.	<i>Epirichthys lacustris</i> .	<i>Diplomnus scitis</i> .	<i>Limnocalanus macrurus</i> .	<i>Cyclops</i> sp.	<i>Sida crystallina</i> .	<i>Daphnia pulex</i> .	<i>Daphnia retrocurva</i> .	<i>Daphnia longispina</i> .	<i>Daphnia</i> sp.?	<i>Bosmina longirostris</i> .	<i>Leptodora kindtii</i> .	<i>Mysis relicta</i> .	Miscellaneous.	
104	June 1/19	Rondeau	21.4	5 $\frac{3}{4}$	4	2	1		1		2	2							
807	Nov. 10/20	"	21.6	7 $\frac{1}{2}$			3	2						1					<i>Hyallela knickerbockerii</i> I.
1,027	"	McKillop's	19.6	4 $\frac{1}{2}$	4		2	2						2					Crustacean debris 2.
1,046	"	"	20.2	5				3					2						
1,045	"	"	20.5	5	5			3					2						
1,043	"	"	20.9	6	5			3						2			1		
666	" 24/20	Merlin	23.5	9	6		1				3								

L. SISCO IIURONIUS—LAKE HURON CISCO IN LAKE ERIE

Collection Number.	Date.	Locality	Length in cms.	Weight in ozs.	Age.	<i>Epiplatys lacustris.</i>	<i>Diaptomus sicilis.</i>	<i>Limnocalanus macrurus.</i>	<i>Cyclops</i> sp.	<i>Sida crystallina.</i>	<i>Daphnia pulex.</i>	<i>Daphnia retrocurva.</i>	<i>Daphnia longispina.</i>	<i>Daphnia</i> sp.?	<i>Bosmina longirostris.</i>	<i>Leptodora kindtii.</i>	<i>Mysis relicta.</i>	Miscellaneous.	
371	Nov. 24/20	Merlin	26.1	11½							3								
1,200	" 12/20	Rondeau	26.3	9							3								

L. PROGNAATHUS—LAKE ONTARIO DEEP WATER CISCO IN LAKE ERIE

Collection Number.	Date.	Locality.	Length in cms.	Weight in ozs.	Age.	<i>Epirischura lacustris.</i>	<i>Diaptomus setilis.</i>	<i>Limnocalanus macrurus.</i>	<i>Cyclops</i> sp.	<i>Sida crystallina.</i>	<i>Daphnia pulex.</i>	<i>Daphnia retrocurva.</i>	<i>Daphnia longispina.</i>	<i>Daphnia</i> sp.?	<i>Bosmina longirostris.</i>	<i>Leptodora kindtii.</i>	<i>Myxis relicta.</i>	Miscellaneous.
17	June 1/19	Nanticoke	17.83	4		1								1				<i>Ephemera simulans</i> subimagos 3; Chironomid adults 1
8	"	"	18.53½	4					1									<i>Ephemera simulans</i> subimagos 3.
7	"	"	19.33½	4		1	1		1									" " 3.
10	"	"	19.54	5		1												" " 3; Dipterous adult 1.
42	"	"	20.86	4		1	1		1									<i>Ephemera simulans</i> subimagos 3; Dipterous adult 1.
1	"	"	20.95	5					1									<i>Ephemera simulans</i> subimagos 3; Dipterous adult 1.
16	"	"	20.94½	5					1									<i>Ephemera simulans</i> subimagos 3.
30	"	"	21.05	4			1		1									" " 3.
2	"	"	21.35	5		1	1		1					1				" " 3.



L. PROGNAATHUS LAKE ONTARIO DEEP WATER CISCO IN LAKE ERIE—Cont.

Collection Number.	Date.	Locality.	Length in cms.	Weight in os.	Age.	<i>Epirichthys lacustris.</i>	<i>Diplomus stictis.</i>	<i>Limnocalanus macrurus.</i>	<i>Cyclops sp.</i>	<i>Sida crystallina.</i>	<i>Daphnia pulex.</i>	<i>Daphnia retrocurva.</i>	<i>Daphnia longispina.</i>	<i>Daphnia sp.?</i>	<i>Bosmina longirostris.</i>	<i>Leptodora kindtii.</i>	<i>Mysis relicta.</i>	Miscellaneous.
829	Nov. 10/20	Nanticoke	23.07		4													Small fish fragments
816	"	"	23.07½		6			1									3	
826	"	"	23.26½		5			2						1			1	Small fish fragments.
808	"	"	25.49½		6		1						2				2	
1,051	Nov. 10/20	McKillop's	21.45½		5		1										3	
1,044	"	"	21.55		5		1	1					2				3	
1,039	"	"	22.05½		5												3	
1,032	"	"	22.35½		5												3	



L. HARENGUS—GEORGIAN BAY CISCO IN GEORGIAN BAY.

Collection Number.	Date.	Locality.	Length in cms.	Weight in ozs.	Age.	<i>Epirschura lacustris.</i>	<i>Diplomus sicilis.</i>	<i>Limnocalanus macrurus.</i>	<i>Cyclops sp.</i>	<i>Sida crystallina.</i>	<i>Daphnia pulex.</i>	<i>Daphnia retrocurva.</i>	<i>Daphnia longispina.</i>	<i>Daphnia sp.?</i>	<i>Bosmina longirostris.</i>	<i>Leptodora kindtii.</i>	<i>Mysis relicta.</i>	Miscellaneous.	
23	Nov. 24/20	Wiarton	19.1	3½	4		3	2					2						
25	"	"	22.4	6	5	1	2	2					2						
21	"	"	22.7	5½	6		2	2						2	1				Ostracods 1.
27	"	"	23.4	7	6	1	2	2					1				1		
15 indiv.	"	"	similar	similar		1	2	2	1				1		1				

L. ONTARIENSIS—LAKE ONTARIO CISCO IN LAKE ONTARIO

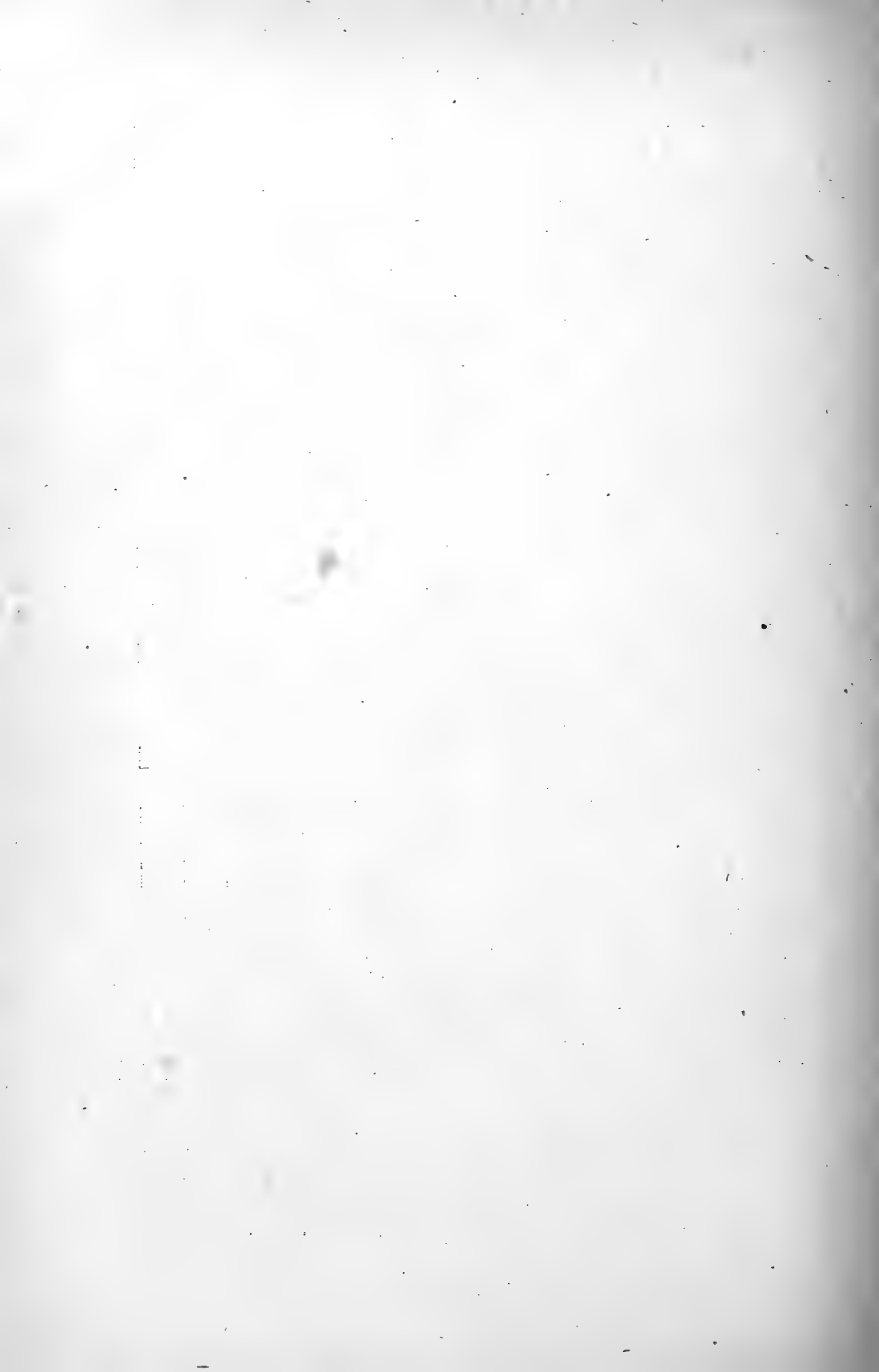
Collection Number.	Date.	Locality.	Length in cms.	Weight in oz.	Age.	<i>Epischura lacustris</i> .	<i>Diplomus sictis</i> .	<i>Limnocalanus macrurus</i> .	<i>Cyclops</i> sp.	<i>Sida crystallina</i> .	<i>Daphnia pulex</i> .	<i>Daphnia retrocurva</i> .	<i>Daphnia longispina</i> .	<i>Daphnia</i> sp.?	<i>Bosmina longirostris</i> .	<i>Leptodora kindtii</i> .	<i>Mysis relicta</i> .	Miscellaneous.	
2	Oct. 21/20	Port Credit	22.0	7½	3								3						
7	" "	"	22.7	8	3		1						3						
6	" "	"	23.9	9½	3								3						
1	" "	"	24.5	9½	4								3						
5	" "	"	25.9	10½	4								3						

L. PROGNAATHUS?—LAKE ONTARIO LONGJAW IN LAKE ONTARIO

11	Nov. 25/20	Port Credit	22.6	8	3						3								
9	" "	"	26.4	12½	4														3

## UNIDENTIFIED SPECIES FROM LAKE ERIE.

123	June 1/19	Rondeau	19.9	4 $\frac{1}{4}$	4					1	3	3							Hydrachnid 1.
107	"	"	23.8	8	4	2	1		1		3	3							Insect fragments (Chironomidae, Trichoptera Ephemeridae) 3.
15 indiv.	Aug. 5/20	Nanticoke				2	"	2	1	1			2						Ephemeridae (Ephemera, Heptagenia, imagoes and sub-imagoes) 3.
1	"	9/20 McKillop's																	Insect fragments 1.
12	"	Nov. 3/20 Port Dover																	Insect fragments 1.
809	"	10/20 Nanticoke	21.1	6	4														3
830	"	"	22.9	7	5									1					3
810	"	"	23.2	11	7			2											2
824	"	"	21.0	6	5			1	1										Small fish.
812	"	"	23.5	9 $\frac{1}{2}$	6	2	3	2						1					Crustacean debris 3.
819	"	"	23.6	11	4			1											3
1,048	"	McKillop's	24.3	11										1					3
1,212	Nov. 12/20	Rondeau	23.5	11															Chydorus sp.? 1.
1,207	"	"	26.2	11 $\frac{1}{2}$				1											3



No. VI

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THE PACIFIC HERRING.

BY

C. MCLEAN FRASER

*Marine Biological Station, Nanaimo, B.C.*



## The Pacific Herring

BY C. McLEAN FRASER.

*Marine Biological Station, Nanaimo, B.C.*

Of the numerous species of fish found in the waters of the Pacific Ocean, adjacent to the coast of North America, none plays a more important rôle in general marine economy than a species that is rather despised from a commercial point of view, the Pacific herring. The salmon, the halibut and the cod receive almost all the consideration when North Pacific fish are mentioned, but the herring, if it is included at all, comes as an afterthought. This is not because of any lack of food value or any lack of supply, but rather because of a lack of appreciation of the truly wonderful possibilities of development in the value of the herring industry.

While in the case of the halibut and the salmon there are strong indications that human interference is more or less rapidly decreasing the numbers, in the case of the herring the human factor has been too insignificant to make any material impression.

As a species the herring has a more extensive distribution than any other food fish of the coast, with the possible exception of the spring salmon, as apparently there is an abundance all the way from San Francisco, or farther south, to the Arctic Ocean. In all the wide range there is little difference in general appearance and habits, as far as I have been able to ascertain, except that in Bering Sea there appears to be a race in which the individuals grow much larger than at other points along the coast. As I have been unable to get any of these for examination I have no opinion to offer as to the cause of such difference.

For several years I have made use of opportunities for observing the habits of the herring and for collecting data on the life history, and while much of the material remains to be worked up and many of the data are still to be correlated, since specimens have been obtained at all times of the year and at all ages a somewhat connected idea of the life history has been obtained.

Most of the observations have been made in the vicinity of the Biological Station, Nanaimo, B.C., and in general the statements made in this paper will have special reference to these.

In the herring the gregarious habit is carried to the extreme. To attempt to describe the size of, or the numbers in, a herring school to one who has never seen anything of that nature is but to court the destruction of one's reputation for veracity. To watch them as they feed near the surface of the water, or as they are rounded up in a seine, one is struck with the wonderful degree of uniformity in size of all the individuals of the school. Careful measurements of a large number bear out this fact. In the case of those caught in the purse seines, where none has a chance to escape, the average length is about 20 cm. or 8 inches, the caudal fin rays not included, and the average weight 100 grams or 3.6 oz.

The migrations of the herring have been considered among the wonders of the deep. Little speculation has been reported about the Pacific species, but its habits are much like those of the Atlantic species, about which so many theories have been propounded. There is nothing to indicate that the movements of the Pacific herring are any more mysterious than those of any other active fish, but since they move about in such large schools their presence or absence in any one location is much more readily observed. I cannot find any reason for thinking that any herring that are found in the strait of Georgia have ever been away from the strait or the various channels adjoining, and it may readily be that the radius of activity is limited to comparatively few miles. Their movements seem to be due largely to the necessity of following up the food supply. The main basis of that supply is provided by copepods. Among hundreds of stomachs examined I do not remember finding a single one in which the contents were recognizable where there were not copepods, as eggs, larvæ or adults, no matter what else was found. The necessity for a supply of these copepods is, therefore, constant. I have never counted the number present in the stomach of a mature herring, but in a young herring 6.6 cm. long, over 3,000 copepods were present. As digestion takes place very rapidly that would probably by no means represent the number taken in a whole day. When this is true for a herring six months old, how many must be needed for a mature fish, and then how many for a school of fish having several million individuals? When it is impossible to conceive of such a number is it any wonder that there is often a sudden migration of the fish to catch up with the food supply? Even if the copepods are numerous they do not remain indefinitely in any one locality. They are affected by temperature, intensity of light, by currents and probably by the degree of salinity and many other conditions, and in the case of some at least of these conditions, the change will affect the copepods in mass. In these wanderings the herrings must follow. A school of herring can be observed only when these herring are feeding near the surface of the water. They have not far to go from the shallow water near shore to get into water deep enough to cover up all evidence of their presence.

It is true that by going back to the copepods the matter of migration is simply removed one step further. Another step is made by passing on from copepods to diatoms on which they feed. This places a limit as far as organisms are concerned, unless bacteria have something to do with preparing the food for the diatoms. The processes preceding must be left to the physiologist, the chemist and the physicist. This is not all that is to be said in the matter however. In February and March, when copepods and diatoms are scarcer than usual in the surface waters of the strait, the herring find it necessary to supplement the copepod diet. They come into shallow water at times and feed on the nauplius and cypris larvæ of the barnacles and for days at a time they remain in the barnacle zone. This is most noticeable about spawning time, hence, although it is usually stated that they come into the shallow water to spawn, it is possible that the reason of their presence is entirely or largely due to the food supply, the spawning in shallow water being merely incidental. Mollusc eggs, decapod and other crustacean larvæ, ascidian larvæ and rotifers are also eaten, but in



no case have I found them to be the main portion of the diet. After the spawn has been deposited it appears to be a common thing for them to gorge themselves with it. On one occasion out of 94 herring examined 76 of them were so gorged. Later, when the eggs are hatched out, many of the young fry meet with the same fate. During all this time the large schools spend the greater portion of the time in shallow water, since the nature of the food at that time makes this a necessity.

Since the spawning season has been mentioned some consideration of this season here may be in place. As far as the Nanaimo district is concerned there is nothing perplexing about the spawning season of the herring as there is in the case of the North Sea herring, since there is a single quite definite season, the last days of February, through March and early April. All the evidence, and it is quite conclusive, goes to show that no spawning takes place at other times.

Herring are caught throughout the year. For some time after spawning the gonads are empty, very little evidence of renewal showing before the end of the third month. At the end of four months the eggs are still very small, each gonad weighing less than a gram. From that time on the growth is noticeable. Much variation in the size of the egg and the weight of the gonad is to be expected as the young fish spawning for the first time produces fewer and smaller eggs than older fish. At the end of six months the weight of the gonad varies from 2 to 5 grams, and this difference becomes more marked as the spawning season approaches. Young herring may have mature gonads with each gonad weighing less than 5 grams, while for a female the greatest weight observed was 18.6 grams and for a male 28 grams. The increase in the size of the egg will give some idea of the increase in the size of the gonad. On October 10 the average diameter was .7 mm.; on November 9, .85 to .9; on December 12, 1.0 to 1.05; on January 28, 1.1 to 1.2; on February 8, 1.25 to 1.30; on February 22, 1.35 to 1.40; and on February 28 (spawned), 1.4 to 1.6.

For several days before the spawning begins the herring appear in the shallow water near shore, actively feeding on the barnacle larvæ as well as any copepods that may be obtained. The fishermen say they come in to look for suitable grounds for spawning, but why should they do so such a length of time ahead when they have been in and out of the shallow water several times in the preceding months, and even when they are farthest from shore they could come in in a few hours at most? In any case spawning does take place in shallow water, so shallow at times that individuals perish by being left high and dry on account of a flip out of the water near shore. There must be a large supply of eel grass or seaweed of the pliable kind present, such stiff material as kelp being seldom made use of. Against the seaweed the female rubs as the spawn is liberated and, as the spawn is very adhesive, all of it remains attached. One fish may rub against many pieces of weed or grass before the spawn is all liberated, but as the fish are so close together and may spawn over the same area several days in succession, every particle of a weed may become coated several layers thick. Immediately after the female liberates the spawn the male follows, rubbing against the seaweed in the same way. The milt in mass adheres for a short time,

but it soon separates and permeates the water to such extent that the water becomes opaque. When the spawning of a large number takes place at the same time the opaque area may reach for miles, so dense that the herring darting through the water, even when only a few inches from the surface of the water, appear but as shadows and if they are down a couple of feet they will not be seen at all.

As the herring spawn somewhere in the vicinity of the Biological Station every year there has been plenty of opportunity for observation, and during several seasons a careful watch was kept over certain of these spawning areas. The herring do not spawn in the same place season after season as some other fish apparently do. A thorough survey of the spawning grounds of one year may be of no assistance in finding the spawning grounds of the next year. While the areas of one year may overlap the areas of another year I have never known them to correspond exactly in two succeeding years.

In a previous paper<sup>1</sup> some description of the spawning areas was given, but further observation has shown that the matter is not so simple as at first it seemed. The spawning dates for different areas were quite correct, but it was not realized that at times spawning takes place day after day for a considerable period; it may take place for a number of days in succession, cease for a short time and then begin again, or it may take place over a short period only, even for a single day. The longest period, day after day, recorded, extended from March 19 to April 5, 1916. This was around Horswell rock, at the northern entrance to Departure Bay.

Where spawning takes place in the same area day after day the spawning is by no means continuous. It seldom occurred outside of the period between 12 noon and 5 p.m. The height of the tide evidently had nothing to do with it as the spawning was at its height at different times of the tide each day. On this account, since the spawn is always deposited in shallow water, usually less than 6 feet, much of that which is deposited at high tide is left exposed for some hours at low tide, particularly at spring tide. These exposures seem to do no harm, unless there is too much bright sun during the exposure. As the majority of really low tides come at night during that season such a thing seldom happens.

It is not for lack of seaweed areas at greater depths that the shallow water is used, as it often happens that the bottom at a little greater depth is much more densely covered than the bottom near shore.

After spawning is over the herring are in no hurry to leave the shallow water. They have been seen in Departure Bay in intervals during April and May, and this year a small school stayed around continuously until the end of June.

The dangers of the deep water must be great if they are much greater than the dangers of the shore and shallow water. While the herring are spawning they are naturally not so active as at ordinary times and hence they fall a prey to their enemies the more readily. As they are so near the surface the gulls can see them and reach them readily. Since there are myriads of these they must cause the disappearance of innumerable herring just at the time when protection is most needed. The dogfish, doubtless their enemies at all times,

<sup>1</sup> On *Clupea pallasii* Cuvier and Valenciennes. Trans. Royal Can. Inst., 1916, p. 97-108.

are able to take their toll with greater ease and in consequence it is nothing out of the way to find one with five or six herring in its stomach. The spring salmon and many others of the larger fishes at times, at least, find herring a satisfactory diet.

The danger to the fish is not the only danger, however, as the spawn exposed at low tide is in position to suffer extensively. The effect of the weather has already been mentioned, but much greater destruction is caused by the animals that use spawn for food. In the Nanaimo district the various species of ducks, especially the surf scoter, take predominance in this regard. These may be seen by hundreds of thousands, and as each must get rid of millions of eggs per day, it would be hard indeed to estimate the damage done in a season in this way. I should have no hesitation in saying that I have seen sufficient numbers of ducks feeding within a radius of five miles to destroy more fish—in the embryo of course—in one day, than all the fishermen on the coast catch in a year. Many fish, including the herring itself, as well as shore species among the invertebrates, feed on this spawn, but all of these taken together must make a small showing when compared with that taken by the ducks. It is well that the embryonic life is short. If it were as long as that of the salmon, for instance, it would seem as though none of the eggs would ever get a chance to hatch.

Nor is the danger ended with the hatching out of the eggs. When the fry are still young, in the alevin stage, they are rather helpless since they are usually found carried into large masses by the currents in such a way that they can readily be seen and seized, more particularly by the many species of fish that enjoy very young herring for breakfast. Here again the mature herring is one of the many offenders.

The eggs when ripe are 1.4 to 1.6 mm. in diameter and in weight they run from 900 to 1,200 to a gram weight of ovary, and the number of eggs varies much with the age of the fish. Those spawning for the first time produce about 12,000 eggs, while the oldest or largest fish produce about 35,000. The development of the embryo until the time of hatching has been described in the paper to which reference has been made. After the yolk is absorbed the activity is immediately increased. The individuals become more separated, but still remain in large schools, and growth takes place quite rapidly.

The young herring just liberated from the shell membrane is 7 mm. long. When the yolk is all absorbed it is about 1 mm. longer. At this time the pectoral fins are present in the form of small flaps and the caudal fin is present, but the anal fin is not separated from it. These are not supported by fin rays. None of the other fins are distinct. At a length of 12 mm. the dorsal fin appears as a slight elevation; at 14 mm. the dorsal fin rays begin to appear. At 18 mm. the end of the vertebral column, which up to this time has been straight, begins to turn up to form the urostyle. At 20 mm. the urostyle is completely turned upward, the dorsal and anal fin rays begin to show; the dorsal fin has 16 rays. At 22 mm. a slight protuberance indicates the beginning of the pelvic fins; at 26 mm. these take definite shape; at 29 mm. the pelvic fin rays begin to appear. At 35 mm. definite pectoral fin rays appear.

Until now the young fish looks little like the older herring, but about this

time, 35 to 40 mm., the metamorphosis takes place, at which time the scales begin to grow. This occurs about the end of June or the beginning of July. In six months the fish are about 6 cm. long and in a year 9 to 10 cm. During all of this period they live in immense schools along the shore and more particularly around the wharves and floats, where they mix freely with sticklebacks, various species of young perch, sand launces and other small fish. Their staple diet, as in the case of the older fish, consists largely of copepods. These may make up the entire food supply and only occasionally does anything else predominate. Here also the diet may be varied by the nauplius and cypris larvæ of barnacles, other crustacean larvæ, molluscan larvæ and eggs, ascidian larvæ, rotifers and peridinia.

At much the same time as the mature herring leaves the shallow water for the deep, the yearlings do also. Nothing has been observed to indicate that they go out in the same schools. During the summer they are caught with hand lines in swiftly running water in some of the main passes between the islands, and in such cases they are not in very deep water. In the seine hauls made from September to March there are seldom any young fish. It might be supposed that they are small enough to pass through the meshes of the net leaving only the larger ones in the net, but this can scarcely be correct as there are exceptions to the general rule. One instance will illustrate. In November, 1914, the fishermen were working off Cowichan Gap (Porlier Pass) and all the catches lacked the usual uniformity. The fish were smaller than usual and consisted of fish of many different sizes. On November 27 Mr. H. McIndoo, Fisheries Overseer at Nanaimo, brought me in a pailful, taken without sorting, from one of the catches. The 79 fish brought in were of 50 different lengths, differing from 8.8 to 22.0 cm. One was in the first year, 6 in the second, 47 in the third, 15 in the fourth, 8 in the fifth and 2 in the sixth. From this it would seem that if the small fish were with the large ones on ordinary occasions they would be caught as they were in this case. Furthermore, on different occasions, I have watched a school of herring in continuous procession for hours pass a point and often for shorter periods without seeing any small fish among them.

In their third year some of the herring spawn and these appear with the schools of older fish, but comparatively few, even at this age, are found in the seines. Probably much greater numbers spawn for the first time in their fourth year. If the immature fish keep separate from the mature fish it will be a difficult matter to find the time of the year at which the segregation takes place or what determines the segregation. The North Sea investigators have concluded that there is a time for such segregation among the Norwegian herring, hence further work along that line may establish some important facts concerning this mixing.

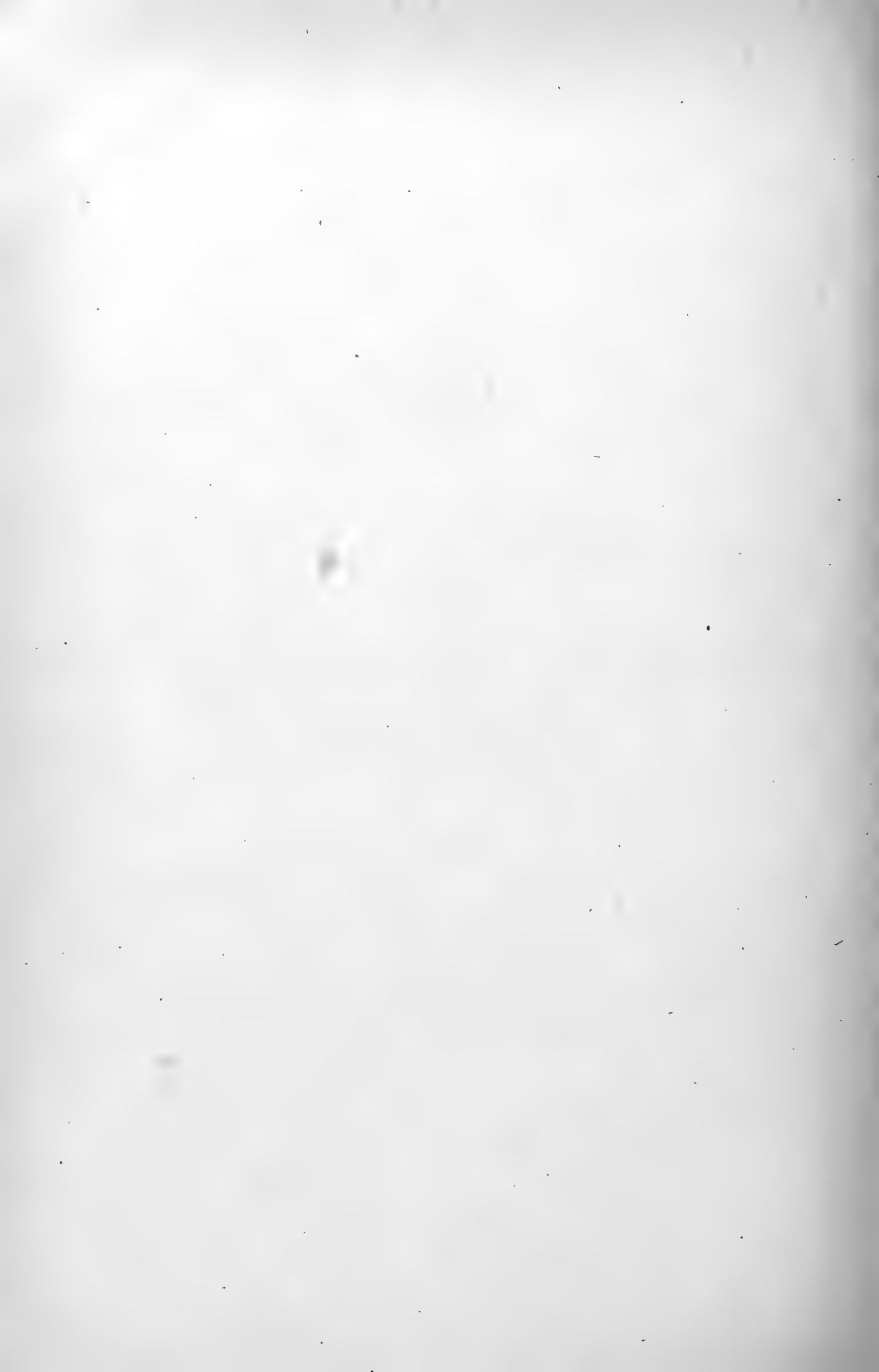
Doubtless the immature fish wander in towards shore and out again as the mature fish do, but as they are small they are not observed readily. Whether the individual school retains its main components, making additions from year to year from the young fish to take the place of those that disappear or whether there is promiscuous mixing of schools may not be determined readily, although here again this seems to have been fairly well determined for the North Sea

herring. If the schools wander far there might easily be much mixing. If their wanderings are restricted to a comparatively small area such mixing would not so likely take place to any extent. Coast conditions along the British Columbia coast are not readily comparable to those of the Norwegian coast and with regard to two distinct species one may do nothing more than surmise that the same habits would prevail.

In any case, after a fish has once spawned there is every indication that the process is an annual one for the remainder of its life. It is probable that after the first spawning the individual remains with the same school throughout the rest of its life, although this would be a difficult matter to prove.

Extensive observations over a long period would be necessary to demonstrate the racial differences in the different schools, but there is little doubt that such differences exist; even though, in the main, their habits, times of migration, etc., may be very similar.

The majority of the fish caught in the purse seines are from 4 to 7 years old and none have been found of a greater age than 10 years.



No. VII

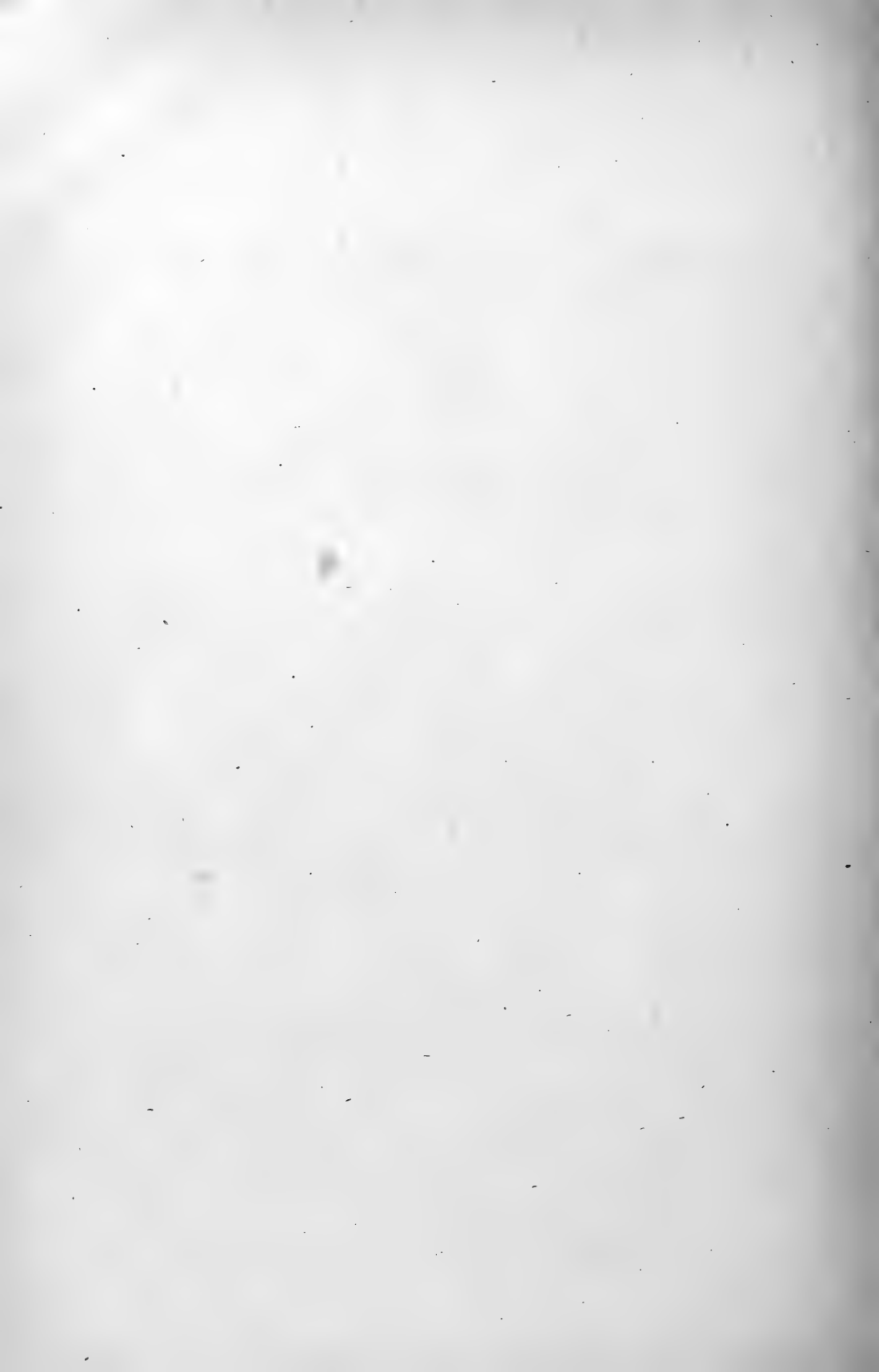
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ON THE DEVELOPMENT OF THE ANGLER (*Lophius piscatorius*, L.)

BY

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## INTRODUCTION.

During the summer of 1918 the writer made a study of the distribution, etc., of the Angler in Canadian waters and gave a general account of the life-history of this fish in Bulletin No. 3, issued by the Biological Board of Canada. The detailed results of observations made during that season are contained in the following paper.

While carrying on another investigation at the Biological Station, St. Andrews, N.B., during the summer months of 1919 and 1921, additional observations were made on the early stages in the development of the Angler, and these are also included in this paper.

I wish here to cordially thank Dr. A. G. Huntsman, Curator of the Biological Station, for his kind assistance and many valuable suggestions while making this investigation.

## OVA OF THE ANGLER.

The period of spawning of the Angler, *Lophius piscatorius*, in Canadian waters extends from about June to August. The eggs are embedded as a single layer in a mucous band about thirty or forty feet in length, and this gelatinous mass floats near the surface of the water. Fulton (1898, p. 118) has shown that the mucoid substance is secreted by a specially modified epithelium. He has further described the development of the ovarian eggs of *Lophius* from the earliest stages to their maturation and has shown that the increase in volume of the eggs during maturation is due to the imbibition of a watery fluid. The specific gravity of the mature ovum, according to Milroy, is 1.034, while the specific gravity of the mucous band, together with its mature ova, is 1.005. The floating properties of the egg are due to the mucous substance. They are pyriform when embedded in the mucous substance, but when free they assume a more spherical form, though they still retain the flattened surfaces due to the pressure of adjacent eggs. There are many small oil globules in the immature egg, which fuse in the ripe egg to form one large oil globule.

## DEVELOPMENT.

Agassiz described the young embryo just before hatching and also the early larval stages. Prince described and figured embryos at the stage just before hatching and also the early larval and post-larval stages for the European form,

but found no stage similar to the remarkable post-larval specimen figured by Agassiz. His specimen resembled rather the post-larval stage obtained by MacIntosh. Williamson made a further study of the larval Angler, showing some minor points of difference, but with results agreeing essentially with those of Prince. In all cases where the eggs have been found floating in the sea or thrown up on the shore they contained embryos at well advanced stages or about to hatch. So far as the writer can ascertain none of the earlier stages following fertilization have been hitherto observed.

On June 24th, 1910, eggs of *Lophius* were found by the Indians at Pleasant Point at the entrance of Passamaquoddy Bay. It was noted at the time that the oil-globules in the eggs gave the entire mass a pink shade. A portion of the mucous band containing the eggs was preserved in formalin at the Biological Station, St. Andrews, N.B., and later transferred to alcohol. These eggs I examined and found that they were in a very early stage of development; they must have been taken shortly after fertilization. On account of the manner of preservation, however, the eggs had undergone a considerable shrinkage. They were all approximately in the same stage of development, and showed the blastodisc divided into numerous cells or blastomeres at one pole of the egg and a large oil-globule at the other. The greatest diameter of the egg measured 1.7 mm. The oil-globule measured 0.37 mm. in diameter. The egg capsule showed distinct criss-cross markings, and a very thin layer of protoplasm which surrounded the yolk ball after the blastodisc was formed, appeared shrunken but was held fixed to the periphery by the blastodisc at one pole and by the oil-globule at the opposite pole.

Further material was available during the summer of 1919 and on examination proved to contain embryos in very early stages of development. Portions of a band of mucus containing eggs were picked up at Deer Point, Campobello, on August 9th, 1916, and preserved in formalin. The mucous substance is quite transparent and its presence in the preserving fluid is inferred from the fixed positions which eggs maintain with respect to one another. Of the large number of eggs examined all were in process of development. A large number of the eggs, however, were quite opaque and difficult to examine. In these the blastoderm had covered less than half of the yolk, and on being placed in formalin suffered considerable shrinkage and distortion. The embryonic shield, with its early differentiation of the embryonic axis rising from the embryonic ring, was visible and at its anterior portion the head end appeared as a slight expansion while posteriorly the caudal portion of the embryo projected downward for a slight distance. Worthy of note is the very early pigmentation. The embryonic shield and the lateral portions of the embryo were covered with black pigment spots, circular in outline, but the neural region of the embryo remained free of pigment, except for one or two patches in the head region. The pigmented area apparently extends over the embryonic shield, though it was not possible to determine accurately the limits of the shield which gradually merges into the rest of the blastoderm.

In a large percentage of the eggs the blastoderm covered more than half of the yolk, and in these no distortion occurred. The eggs were transparent

and the structure of the embryo quite clear. Figure 1 shows a stage in which the blastoderm covers about five sixths of the surface of the yolk. The embryonic ring is very narrow but distinctly marked. The embryo extends over approximately one-half the circumference of the yolk, the perpendicular distance from head to caudal extremity being 1.2 mm. The pigment spots are now much larger and branch frequently, connecting with each other. They cover the larger portion of the blastoderm, only that portion opposite the embryo being free of pigment. At this stage the optic sacs are beginning to be differentiated and just posterior to them, the pigment spots extend across the median dorsal region. A large oil-globule has its position opposite the caudal end of the embryo. Sometimes a second oil-globule near the large one is present at this stage. In some eggs that portion of the blastoderm covering the oil-globule

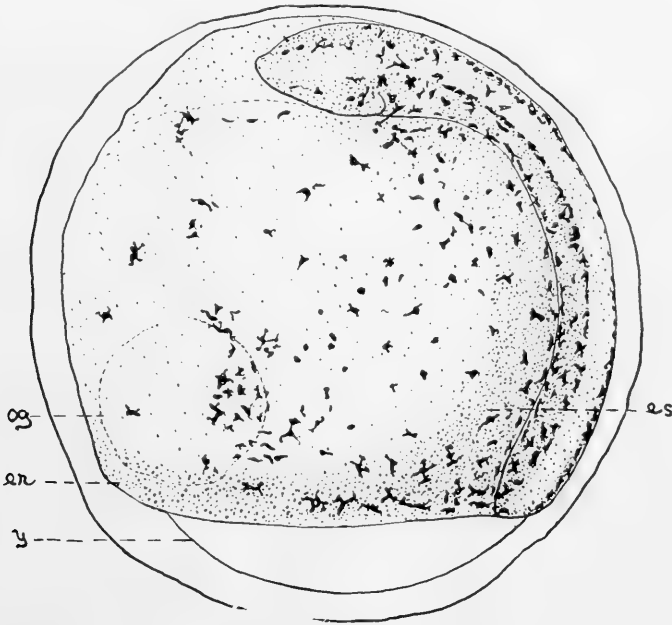


Fig. 1. Egg showing embryo at more advanced stage. *es*, embryonic shield; *og*, oil-globule; *er*, embryonic ring; *y*, yolk.

becomes more densely pigmented than elsewhere, with the exception of the lateral parts of the embryo, but in others the oil-globule is yet quite free of pigmentation. There is no indication at this stage of the formation of somites. In a few eggs the blastoderm has almost surrounded the yolk, the blastopore having now a width about equal to the diameter of the oil-globule. There is no further differentiation of the embryo shown at the slightly older stage except that the head is more distinctly marked off.

In the summer of 1921 three specimens in early larval stages were observed among material collected at Brazil Rock, off Barrington Passage, Shelburne County, N.S. These specimens were taken with a young fish trawl on the 9th of August at a depth of 25 to 30 metres. They are but 8 to 9 mm. in length, measured from the tip of the lower jaw to the extremity of the tail. In the 8 mm.

specimen there are four dorsal spines, the most anterior in position being 3 mm. long and the fourth 0.5 mm., the other two, intermediate in position, being also intermediate in size. The ventral fins possess two rays, the outer or the longer ray being 4 mm. long and the inner about 3 mm. The bud of a third ray is just beginning to appear. The rays bear dense patches of black pigment, especially towards their extremities. The pectoral fins are pad-like structures in which the rays are beginning to be differentiated. The other specimens, 8.5 mm. and 9 mm. in length, do not differ materially from the first, showing merely a corresponding increase in the size of the parts. The second ray of the ventral fin in the 9 mm. specimen has lengthened considerably and the third ray is now 0.5 mm. long. In all three specimens a continuous median fin surrounds the trunk and caudal region. Two large patches of black dendriform pigment are present on each side of the trunk and a third is present near the caudal extremity. The dorsal portion and the region of the body covered by the pectoral fins are also heavily pigmented. The lower jaw protrudes beyond the upper and bears a single row of conical teeth. A few small teeth were also visible on the upper jaw.

On the same date that these specimens in the larval stage were taken Capt. Arthur Calder, of the Biological boat *Prince*, captured with a dip-net a young *Lophius*, which was swimming on the surface at Brazil Rock. This specimen is in the post-larval stage and approximates very closely the 30 mm. post-larval stage described and figured by Agassiz. As some doubt apparently exists concerning this stage, so grotesque in appearance, a few details will be given in confirmation of Agassiz's observations. The specimen, however, is apparently abnormal in that the frontal surface of the head forms almost a right angle with the axis of the trunk. It is true that this angle decreases with growth, but there is only 4 mm. difference in length between this specimen and Agassiz's, which is hardly sufficient to account for so great a change. Moreover, the younger larval stage 9 mm. in length does not show so great a cephalic angle, which indicates that the Brazil Rock specimen is, in this respect, abnormal.

The Brazil Rock specimen has a total length of 26 mm. measured from tip of lower jaw to extremity of tail. The greatest breadth of head is 7 mm.; greatest height, 9 mm.; distance between eyes, 3.5 mm.; diameter of eye, 1.5 mm. The median fins are all differentiated, though connected with one another by a median fold at the base, and have well-developed fin rays. The anterior dorsal spines, representing together the anterior dorsal fin, are six in number. The first three are isolated from one another. The most anterior of these situated 2 mm. behind tip of jaw, though longest in adult stage, is in this stage the shortest, as figured by Agassiz. The first dorsal spine is 4 mm. long with a curved and flattened tip; the second 7.5 mm. and the third 8 mm. long. Then follow three dorsal spines connected by a membrane and forming the dorsal finlet, the first and longest ray being 6.5 mm. in length. Posterior to these six spines, forming together the anterior dorsal fin, is the second or posterior dorsal, having a length measured at the base of 8 mm. and a breadth expanded of 10 mm. The caudal fin is 7 mm. long. The pectoral fins are fan-shaped structures held erect and having a greatest breadth expanded of 14 mm. and a depth of 9 mm.

The rays of the ventral fins were damaged following the capture of the specimen so that exact lengths could not be determined. They are 3 mm. wide at the base. The median and shortest of the three rays reached slightly beyond the extremity of the caudal fin. At its base and medial to it the bud of a fourth ray was visible and lateral to the outer or longest ray the bud of a fifth ray. The entire body, except the ventral surface between the anal fin and the origin of the ventral fins, is mottled with dark brownish dendriform pigment spots. The caudal fin is only slightly pigmented along its rays. On the upper surface of the head three post-orbital spines were already visible.

#### RATE OF GROWTH.

While the structure of the young embryo at the time of hatching and the following larval stages have been studied by various authors little is known concerning the post-larval conditions and the rate of growth of the Angler. A description of a post-larval stage rarely met with has already been given. After reaching the advanced post-larval stage it must seek greater depths, or seek protection among algae-covered rocks, for specimens up to four or five inches have rarely been observed either in American or European waters. According to Fulton (1903, p. 187) one of the smallest European specimens found was 127 mm. or five inches long.

To determine the rate of growth it is, of course, necessary to begin with the time of spawning. The period of spawning extends, as already mentioned, from June to August; eggs in early stages of development were found in both months in the same waters, namely Passamaquoddy Bay. Moreover, larval stages 8 to 9 mm. in length, and a post-larval stage 26 mm. in length, were taken August 9th at Brazil Rock, near the mouth of the Bay of Fundy.



Fig. 2. Photograph of Angler about three inches long, captured in Halifax Harbour, N.S.

One of the youngest specimens found in Canadian waters and indeed one of the smallest on record was caught in Halifax Harbour in 1870 and is preserved in the Provincial Museum. It was identified by Dr. Theodore Gill, and a detailed description of it is given by J. M. Jones in a report of the *Nova Scotian Institute of Science* (Vol. III, p. 103, 1871). Unfortunately, it is not now in a good state

of preservation. It has a total length of about  $2\frac{1}{2}$  inches or 5.94 cm. The exact date of its capture is not recorded, but it was taken "A few weeks" before Mr. Jones read his paper in November, so that it was evidently spawned the same year and is only a few months old. The second Halifax specimen has an extreme length of 7.6 centimeters or about three inches (Fig. 2). It weighs 5.2 grams or about  $\frac{1}{5}$  of an ounce. There is likewise no exact date of capture recorded for this specimen, but like the last it was obviously spawned the same year. The largest of the three young specimens caught in Halifax Harbour, and at present in the Provincial Museum, measures 13.3 centimeters or about  $5\frac{1}{4}$  inches. It weighs  $34\frac{1}{2}$  grams or  $1\frac{1}{2}$  ounces. This specimen belongs at least to the previous year.

A specimen of the Angler caught on August 12th, 1910, at Campobello Island, Bay of Fundy, and preserved in formalin, had an extreme length, measured from the tip of the lower jaw to the extremity of the tail, of 11.2 centimeters or about  $4\frac{1}{2}$  inches and weighed 15.7 grams or about half an ounce (Fig. 3).

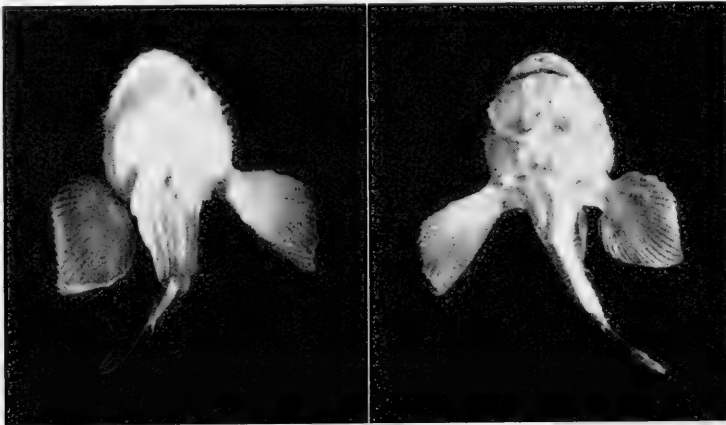


Fig. 3. Photograph of Angler four and a half inches long; dorsal and ventral view.

Though slightly shorter than the Halifax specimen there is a considerable difference in development. The pectoral fins are membranous, wing-like structures and comparatively wide, being 3 centimeters or about  $1\frac{3}{16}$  inches when expanded, while in the latter specimen the pectorals have become thick, flipper-like structures apparently more adapted for crawling than swimming. The ventral fins of the Campobello specimen are long and narrow, and lie parallel to the long axis of the body, while in the Halifax specimen they are broader with strongly developed rays. They are now directed backwards and outwards, crossing over the axils of the pectorals. The head in both specimens is about one-third the length of the body. The Campobello specimen also belongs at least to the previous year.

#### OTOLITHS AND THE RATE OF GROWTH.

In determining the age and growth of fishes the scale method has been employed in recent years with much success. As the Angler is without scales

we must adopt another method to determine its growth. The otoliths, or earstones, also show zones of growth and the rate of growth of some fishes has been determined from them. Reibisch was the first to apply this method in determining the rate of growth. The method, however, presents some difficulties and is not so commonly used as the scale method.

The labyrinths, with their contained otoliths, are situated at the base of the skull on either side of the brain. They can be exposed to view by making a transverse cut in the skull on the line connecting the anterior margins of the pectoral fins, cutting forward along the median axis of the skull, and then raising the two sections of the top of the skull thus formed on either side of the median axis. The lagena, or primitive cochlea, contains minute granules of calcareous matter and where the two semi-circular canals join the sac there is a very small otolith, but for determining the age of fishes only the large otolith, the so-called sagitta, situated in the sacculus, is used.

The otoliths consist of calcareous matter and show a remarkable variety of form in different fishes. They have all, however, essentially the same structure. In the centre is an opaque kernel, oval or circular in outline, and around this kernel or nucleus are concentric lines marking off the successive zones of growth. During the rapid growth of summer a broad zone, which appears light under the microscope by transmitted light, is formed and this zone is separated from the zone of the following summer by a dark ring which represents the slow growth of winter.



Fig. 4. Otolith one-twenty-fifth of an inch in diameter from Angler shown in figure 4.

In the young Angler fish represented in Figure 3 the otolith is quite small (1 mm. or about  $1/25$  of an inch longest diameter), and is so thin that its structure can easily be made out. In the centre is an opaque oval kernel (Fig. 4) and around this there is a broad zone which, under higher magnification, is seen to have fine concentric laminae. Taking into consideration the time of spawning

and the period of larval development it is probable that only the kernel could be formed during the first summer, and the line which limits it represents the check in growth of the first winter. The broad zone around the kernel represents the growth of the following summer so that this specimen is at least one year old. A dark line divides the area outside the kernel into an inner broad opaque zone and an outer narrow transparent zone. There is a possibility that this line represents a check in the growth caused by a second winter and that the outer marginal zone represents the growth of the following summer up to August 12th, when the fish was caught. The outer zone is comparatively narrow to represent an additional year, though it should be remembered that in the waters of the Bay of Fundy the temperature is higher in the late than in early summer, and consequently more rapid growth would take place in late summer.

In many fishes the otoliths of mature fish are so transparent that the zones of growth are easily distinguished. In the specimen of the young Angler they are also quite distinct, but in the adult they are opaque and irregular, so that it is difficult, even when the otolith is ground down to a thin flake, to recognize distinctly the annual rings of growth.

The otoliths of the Angler lie on either side of the brain with their long axis slightly converging posteriorly towards the median axis of the body. They lie somewhat tilted towards the brain. For descriptive purposes we may, with Fryd, distinguish between a dorsal and a ventral margin, an outer and an inner surface, an anterior and a posterior end. The lower or ventral margin is slightly curved. The upper or dorsal margin is arched and notched. The outer surface is concave and the inner somewhat convex. A little below the centre of the inner surface there is a horizontal groove which stands in close relationship with the *macula acustica*. Radial lines run along the surface from the central portion to the upper margin and end in the notches.

The otoliths of the Angler are small for the size of the fish; their diameter in a specimen 11.2 cm. long was, as we have seen, one mm. Below the measurements of otoliths from Anglers of various sizes are given.

FISH	OTOLITH		
	Length	Width	Weight
95 cm.	9 mm.	6.5 mm.	0.12 grams
79.2 cm.	9 "	6 "	0.07 "
74 "	8 "	5 "	0.05 "
46.5 "	6.9 "	5 "	0.03 "
79.2 "	9 "	7 "	0.07 "
103.4 "	9.5 "	6 "	0.15 "
99 "	10.5 "	6.5 "	0.13 "

Apart from the typical features described above there is a great variety of form in the otoliths of the Angler. Frequently the notches are quite deep, forming prominent lobes, and in some cases the otolith is deeply cleft by a groove dividing it into two main sections. In the other cases the notches are barely perceptible. This is generally true of the otoliths of the young specimens.



Again the posterior end, though usually truncated, has often a conical protuberance directed backwards. Smaller papilla-like masses are frequently present on other parts of the surface. There is thus a great variety in outline and general appearance of the otoliths of the Angler of different ages and even of those of approximately the same age. As Immerman has pointed out, it would be an interesting problem to determine how variety of life conditions cause this variation in the sculpture of otoliths having otherwise essentially a constant structure.

#### VERTEBRAE AND THE RATE OF GROWTH.

The vertebrae also show annual rings and can likewise be used to determine the age. Taking into consideration the structure and size of the vertebrae at the end of the first year one can approximately determine the age by the broad and whitish rings laid down in successive years. In an Angler having a total length of 46.5 cm., or about 18 inches, there were four distinct annual rings indicating that the fish was four years old.

In larger specimens it is more difficult to make out the rings, but I have estimated the ages as follows: length 46.5 cm. or 31 inches, 9 years; 95 cm. or 37 inches, 10 years; and 100 cm. or about 40 inches, 12 years. The average yearly increment of growth is about  $4\frac{1}{2}$  inches during the early years, and gradually decreases in the older Angler. This is a slower growth than that calculated by Fulton (1903, p. 194), who estimates that an Angler four years old measures approximately twenty-seven inches. The slower growth could be accounted for by the lower temperature in the Bay of Fundy.

The age at which maturity is reached was not determined definitely as a sufficient number of specimens of different ages was not obtained. The specimen, with a total length of 18 inches, was, however, not yet mature, while all specimens over 30 inches in length were mature.

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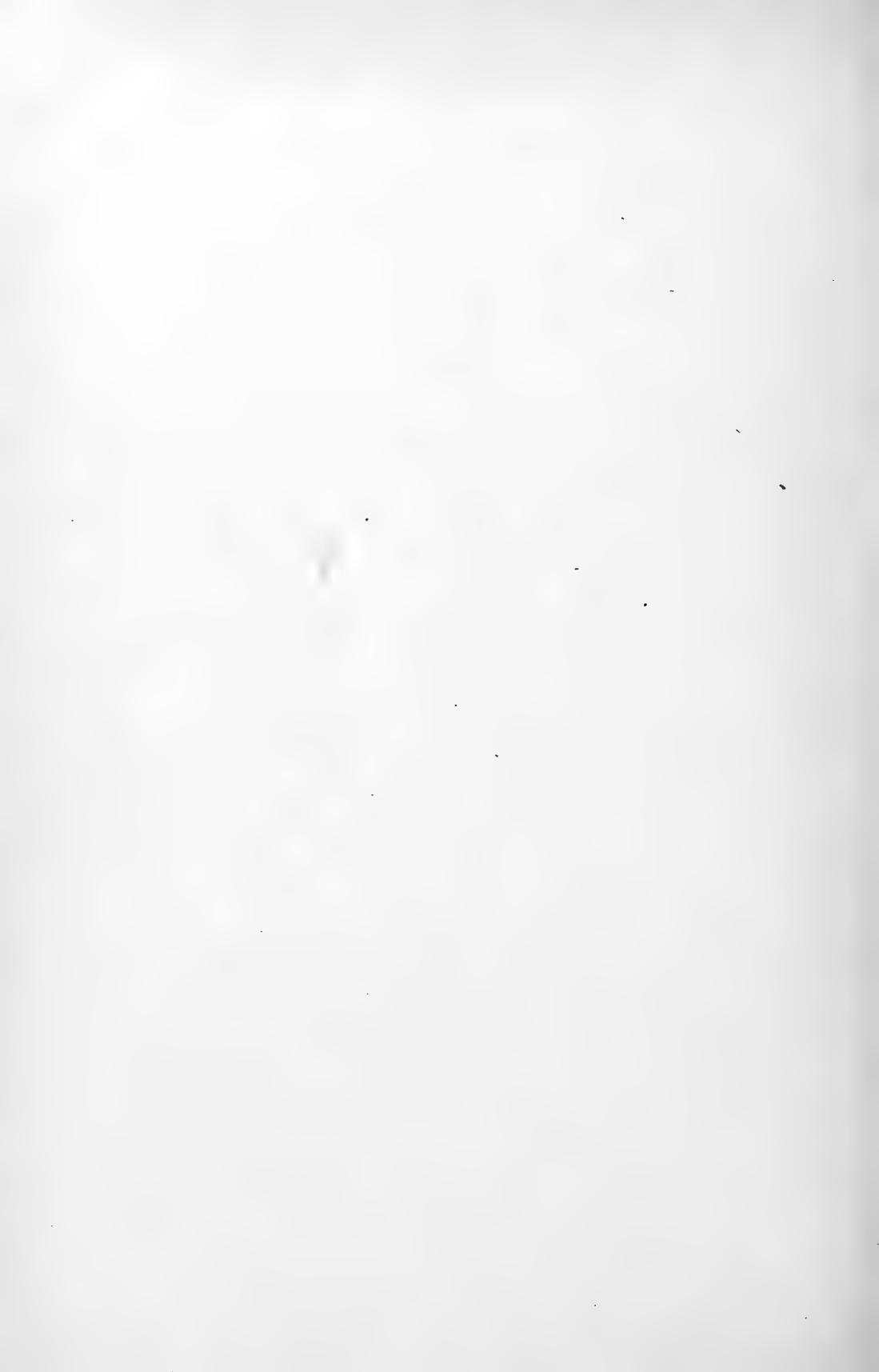
No VIII

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THE COMPOSITION OF LOBSTER MUSCLE

BY

SADIE N. BOYD, M.A.  
*University of Toronto*



# The Composition of Lobster Muscle

BY SADIE N. BOYD, M.A.

*University of Toronto.*

This examination of lobster muscle was made because up to this time little work had been done in this connection. Miss O. G. Patterson (1) has made determinations of the coagulation points of the proteins of lobster muscle. These are noted later. Dr. A. B. Macallum (2) analyzed the blood serum of the lobster in order to determine whether there was any connection between its composition and the composition of the sea-water in which it lived.

In the following analysis a (3) qualitative study of the lobster muscle was made to determine the elements present, and it was found to contain sodium, potassium, a small amount of calcium, and only a trace of magnesium and iron. These elements were present as phosphates, sulphates, carbonates, and chiefly as chlorides.

The material used for the quantitative analysis was fresh lobster muscle. A determination was made of the "total solids" present in each sample of muscle for analysis. This was done in order that all results might be calculated as per cent. of the dry material.

An estimation of the total salts present in lobster muscle was made in the usual way of charring, extracting with hot water and ashing.

Dr. A. B. Macallum's methods were used for separating calcium, magnesium and iron, and determining the weight of each and also for the determination of the weights of potassium and sodium. The usual methods (4) were used to separate the chlorides and sulphates. They were precipitated as silver chloride and barium sulphate respectively.

The following results were obtained in the complete quantitative analysis. All results are calculated as per cent. of the dry material.

The total solids as ascertained in two determinations were averaged in one case 21.39 per cent. and in the other 19.59 per cent. The fact that the muscle which was used for the second determination was obtained at a different time from that which was used for the first may probably account for the difference in the results:

The total salts in the lobster muscle were found to average 8.3117 per cent.

The following are the results obtained for the weight of iron, calculated as per cent. of the dry muscle.

Weight of dry muscle (gms.)	Weight of oxide (gms.)	% of iron in oxide	Weight of Fe PO <sub>4</sub> (gms.)	% of iron in Fe PO <sub>4</sub>	Total iron (per cent.)
1. I. 5.6738	0.0012	0.0074	0.0002	0.0013	0.0087
II. 10.0038	0.0012	0.0040	0.0004	0.0014	0.0054
2. I. 10.9674	0.0016	0.0052	0.0002	0.0007	0.0059
II. 16.5412	0.0026	0.0057	0.0008	0.0017	0.0074
3. I. 7.9851	0.0006	0.0027	0.0010	0.0046	0.0073
II. 12.9772	0.0014	0.0037	0.0016	0.0045	0.0082
4. I. 8.5964	0.0012	0.0049	0.0002	0.0008	0.0057
II. 14.1552	0.0018	0.0044	0.0006	0.0014	0.0058

The following table shows the weights obtained for the calcium and magnesium.

Weight of dry muscle	Weight of calcium oxide	% of calcium oxide	% of calcium	Weight of magnesium pyrophosphates	% of Mg <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub>	% of Magnesium.
1. I. 5.6738	0.0208	0.3665	0.2655	0.0025	0.0440	0.0040
II. 10.0038	0.0360	0.3598	0.2554	0.0033	0.0329	0.0030
2. I. 10.9674	0.0433	0.3948	0.2822	0.0149	0.0446	0.0040
II. 16.5412	0.0629	0.3802	0.2717	0.0339	0.0779	0.0072

The analysis of the ash gave the following results for the weights of sodium and potassium.

Wt. of muscle	Wt. of platinum	Wt. of K.	Wt. of KCl	Wt. of NaCl & KCl	Wt. of NaCl	% of NaCl & KCl	Wt. of Na	% of Na	% of K
1. 4.0430	0.0616	0.0248	0.0472	0.2730	0.2258	6.75	0.0888	2.1963	0.7691
2. 3.1148	0.0576	0.0232	0.0442	0.2064	0.1622	6.63	0.0638	2.0482	0.7450
3. 3.2028	0.0563	0.0226	0.0484	0.2272	0.1788	7.09	0.0703	2.1949	0.7056
4. 4.3020	0.0551	0.0222	0.0476	0.2848	0.2372	6.62	0.0933	2.1687	0.5160

The following table shows the weights obtained for chlorides.

Weight of muscle	Weight of AgCl	% of AgCl	% of Chlorides
3.3741	0.3394	10.0592	2.4884
4.1321	0.4140	10.0190	2.4785
3.7882	0.3870	10.2159	2.5272
1.6229	0.1632	10.0560	2.4876
1.8149	0.1822	10.0391	2.4835
1.6229	0.1622	9.9944	2.4724

The weights obtained for the sulphates are shown in the following table.

Weight of muscle	Weight of Ba SO <sub>4</sub> gms.	% of Ba SO <sub>4</sub>	% of SO <sub>3</sub>
2.4475	0.0073	0.2982	0.1022
3.3456	0.0093	0.2780	0.0954
2.5564	0.0077	0.3012	0.1033
2.9470	0.0092	0.3121	0.1070

An investigation of the mineral constituents of the muscle of various animals by (5) Julius Katz led to a variety of results, which are quoted below as per cent. of the dry material.

	K	Na	Fe	Ca	Mg	Cl	S
Pig.....	0.9363	0.5752	0.0218	0.0298	0.1042	0.1787	0.7536
Beef.....	1.5200	0.2695	0.1019	0.0088	0.1006	0.2342	0.7719
Deer.....	1.3586	0.2848	0.0423	0.0388	0.1175	0.1637	0.8517
Dog.....	1.4178	0.4000	0.0193	0.0291	0.1005	0.3415	0.9643
Fowl.....	1.4700	0.3008	0.0295	0.0333	0.1174	0.1904	0.9234
Codfish.....	1.7281	0.5118	0.0300	0.1138	0.0863	1.2447	1.1514
Eel.....	0.6519	0.0812	0.0148	0.1061	0.0483	0.0935	0.3657
Pike.....	2.0176	0.1426	0.0209	0.1929	0.1505	0.1548	1.0576

Katz found the total solids in the codfish muscle to average 19.36 per cent. and in the pike 20.62 per cent.

The following is a summary of the analysis of the lobster muscle which may be compared with the table containing Katz's results:

	K	Na	Fe	Ca	Mg	Cl	S
Lobster.....	0.7399%	2.1520%	0.0068%	0.2687%	0.0045%	2.4876%	0.1020%
Total solids...	21.39%	19.59%					

Very few, if any, general conclusions may be drawn from a comparison of the results quoted above. Each particular muscle is distinct in containing a definite proportion of each of the mineral constituents. There are, however, several outstanding facts which may be noted. In every kind of muscle, except that of the cod-fish, pike and eel the calcium is less than the magnesium.

According to the results obtained in the analysis of the lobster muscle the calcium is greater than the magnesium. From these results it seems that this may probably be a characteristic of marine forms. Examination of Katz's results shows that the amount of chlorides contained by any one form is highest in the cod-fish. The lobster muscle contains an even higher percentage of chlorides. The fact that the cod-fish and lobster are both salt water forms doubtless accounts for this. The sodium content of the cod-fish is higher than that of the eel or pike, but highest of all in the lobster. With the potassium the conditions seem to be reversed. The total solids in the lobster compare very closely with the solids in the cod-fish and pike. On the whole the analysis of the lobster muscle resembles most that of the cod-fish when considered in conjunction with the other forms analysed by Katz, and as far as the figures show, the features which seem to be common to marine forms are, similarity in the amount of total solids, high percentage of chlorides, and low percentage of magnesium, which is even less than the calcium.

The proteins in the lobster muscle were separated by fractional coagulation (6) and (7).

Miss O. G. Patterson obtained coagulations in a distilled water extract of the lobster muscle at the following temperatures: 39°, 47°, 52°, 62° and 70-71°C. These results were verified in the following investigation.

A distilled water extract and a dilute salt solution extract of the muscle were heated gradually and the coagulation filtered off whenever it formed. The temperature was kept constant the necessary length of time.

From the results obtained it was seen that the muscle salts which were present in the distilled water extract were sufficient in themselves to dissolve out the proteins.

The following coagulation temperatures were obtained: 39°, 46°, 53°, 62° and 72°. There are, therefore, probably five proteins present. This coincides with Miss O. G. Patterson's results.

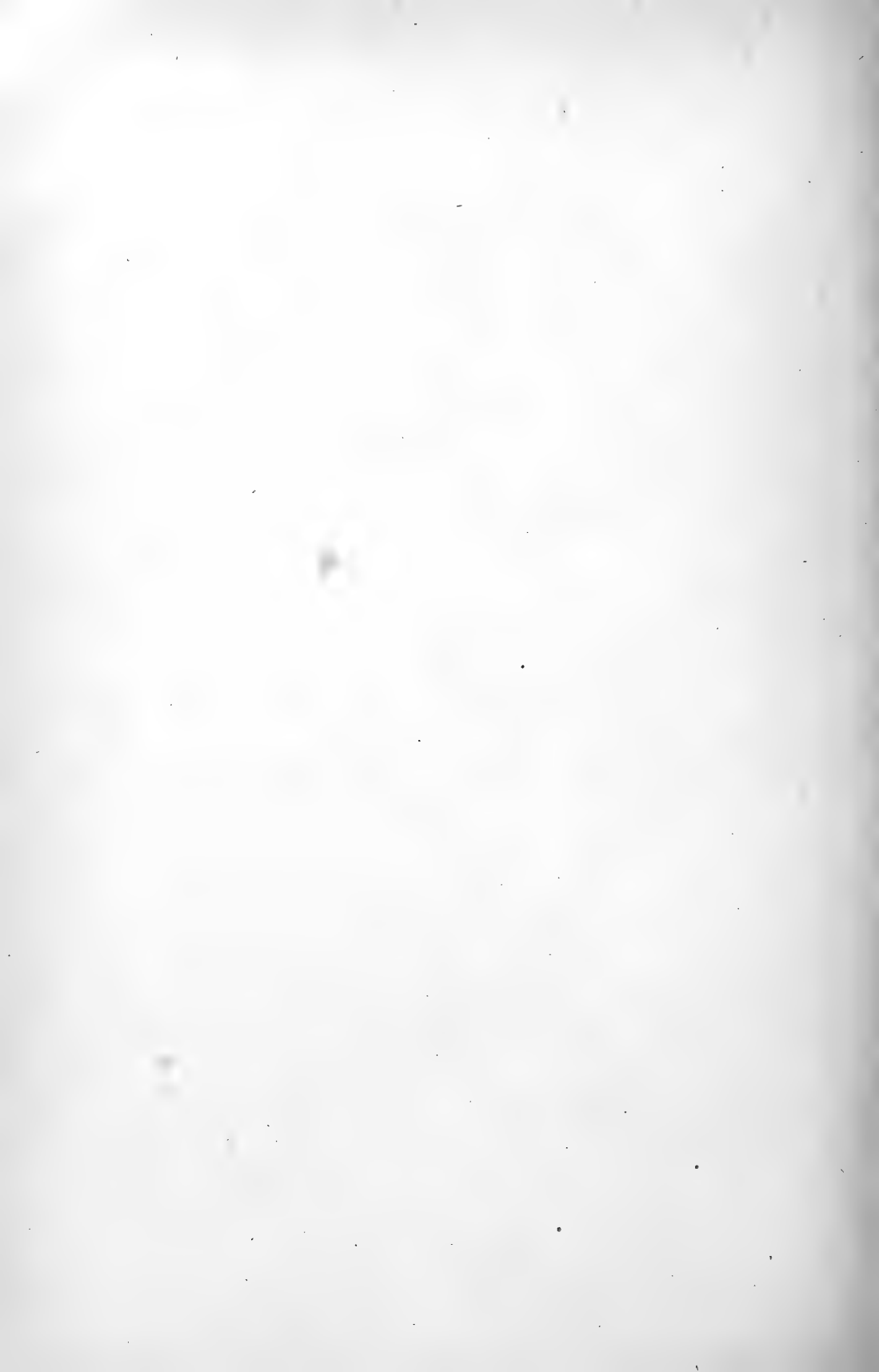
The following table is a summary of the results which were obtained. The figures given are the average results in each case.

Total Solids 21.39%—19.59%	Chlorides.....2.4876%
Total Salts.....8.3117%	Sulphates.....0.1020%
Iron.....0.0068%	Sodium.....2.1520%
Calcium.....0.2687%	Potassium.....0.7399%
Magnesium.....0.0045%	



## LITERATURE.

- (1) O. G. PATTERSON: Unpublished results.
- (2) A. B. MACALLUM: The Inorganic Composition of the Blood in Vertebrates and Invertebrates and its Origin. From *Proceedings of Roy. Soc. B.*, Vol. 82, 1910.
- (3) Plimmer's *Physiological Chemistry*.
- (4) A. B. MACALLUM: p. 608. Same article as before stated. Also FRESSENIUS, p. 284. Instruction in Quantitative Chemical Analysis.
- (5) JULIUS KATZ. *Pflüger's Archiv.*, Vol. 63,
- (6) O. G. PATTERSON, *Loc. cit.*
- (7) W. D. HALIBURTON, *Journal of Physiology*, Vol. 5, p. 152; Vol. 13, p. 806.



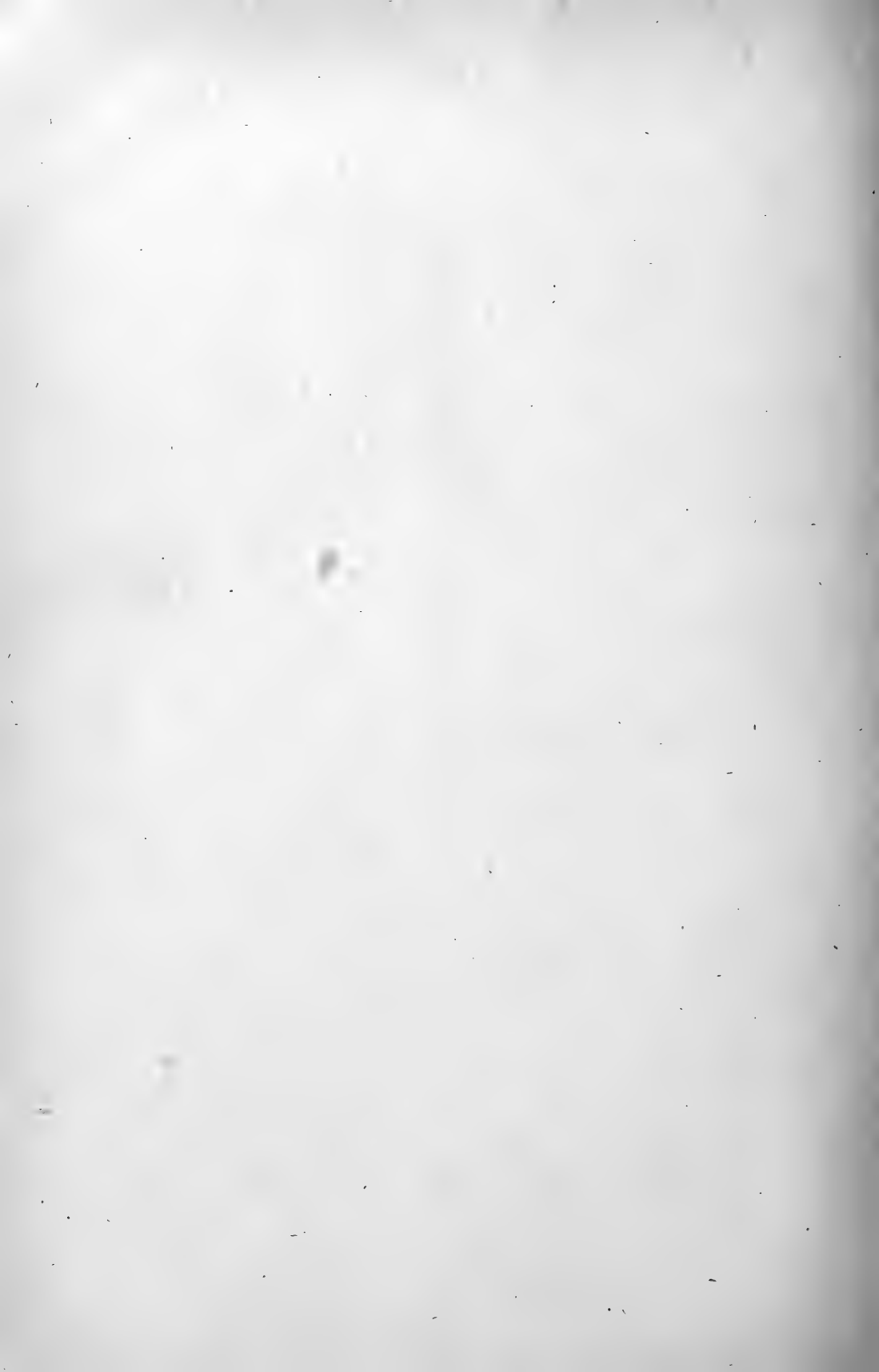
No. IX.

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RESULTS OF THE HUDSON BAY EXPEDITION, 1920.  
I. THE FORAMINIFERA

BY

JOSEPH A. CUSHMAN



# Results of the Hudson Bay Expedition, 1920

## I. The Foraminifera.

BY JOSEPH A. CUSHMAN.

The few bottom samples collected by Mr. Frits Johansen in Hudson Bay and James Bay, 1920, were sent to me to examine for foraminifera. While the number of species obtained is not large, they form a very interesting collection from the standpoint of distribution. No foraminifera have previously been known from this region. In all more than thirty species were obtained. These are mostly species which are characteristic of Arctic conditions. A comparison of these with the fauna known from other parts of the Arctic may be interesting.

One of the most interesting things is the lack of certain species which are common elsewhere in the Arctic. Such, for example, is *Hyperammina subnodosa*, which is abundant in the Canadian Arctic Expedition collection, 1913-18, and also north of Newfoundland. It may be noted, however, that Kiaer did not record this species in his paper on the American Arctic. Other species which were abundant in the Canadian Arctic collection are missing in the Hudson Bay collection or are replaced by other species.

A comparison of the Hudson Bay collection with the fauna recorded by Brady from off Nova Zembla, and by Parker and Jones from Baffins Bay and Davis Strait shows that these faunas are both very similar. It is evident, from a comparison of these faunas, that the foraminifera of Hudson Bay are more closely allied to regions to the east than to the regions to the west of this longitude. It is also very evident from a study of both of these collections that there are developed in the Arctic regions very definite species, which are distinct from the warmer water forms often assigned to the same species.

### STATIONS FROM WHICH MATERIAL WAS EXAMINED WITH SPECIES OF FORAMINIFERA AT EACH STATION.

(1) Bay at (N. of) S.E. point of South Twin Island, James Bay, 4-5 fathoms. Sand, gravel, and stones. July 27, 1920.

*Trochammina rotaliformis*, *Verneuilina advena*, *Discorbis wrightii*, *Polystomella striato-punctata*, var. *incerta*, *Quinqueloculina seminulum*.

(2) Bay on south side of Grey Goose Island, east side of James Bay (lat. 54°N.), 10 fathoms. Sandy mud and algae. July 30, 31, 1920.

*Ammobaculites cassis*, *Trochammina rotaliformis*, *Patellina corrugata*, *Pulvinulina frigida*, *Polystomella striato-punctata*, var. *incerta*, *Quinqueloculina seminulum*, *Quinqueloculina subrotundà*.

(3) Richmond Gulf (about 3 miles from entrance), east coast of Hudson Bay, 15-20 fathoms. Stones, sand, and *Delesseria*-algae. August 23, 1920.

*Sorosphaera confusa*, *Psammatodendron arborescens*, *Haplophragmoides canariensis*, *Verneuilina advena*, *Lagena globosa*, *Polymorphina lactea*, *Discorbis wrightii*, *Truncatulina lobatula*, *Pulvinulina frigida*, *Nonionina stelligera*, *Polystomella striato-punctata*, var. *incerta*, *Cornuspira foliacea*, *Quinqueloculina seminulum*, *Quinqueloculina subrotunda*.

(4) Bay inside Boat opening, Manitouk Sound, east coast of Hudson Bay, 5-7 fathoms. Clay with sand and stones. August 27, 1920.

*Pelosina variabilis*, *Pelosina cylindrica*, *Pelosina rotundata*, *Webbinella hemisphaerica*, *Tholosina bulla*, *Reophax curtus*, *Ammobaculites cassis*, *Trochammina rotaliformis*, *Verneuilina advena*, *Polymorphina lactea*?

(5) Bay between Black Whale and Olaska Harbours, E. coast of Hudson Bay (about lat. 55 N.), 10 fathoms. Sandy mud with many loose algae. August 28, 1920.

*Psammospaera fusca*, *Reophax curtus*?, *Ammobaculites cassis*, *Trochammina rotaliformis*, *Verneuilina advena*, *Nodosaria calomorpha*, *Polymorphina lactea*, *Polymorphina lanceolata*, *Polymorphina ovata*, *Polymorphina oblonga*, *Discorbis wrightii*, *Pulvinulina frigida*, *Nonionina orbicularis*, *Nonionina scapha*, *Polystomella striato-punctata*, var. *incerta*, *Polystomella arctica*, *Cornuspira foliacea*, *Quinqueloculina seminulum*, *Quinqueloculina subrotunda*, *Triloculina oblonga*, *Quinqueloculina sp.*

(6) Sound between Paint Hills Islands, east coast of James Bay, 10 fathoms. Sept. 10, 1920. Sandy mud with stones.

*Trochammina rotaliformis*, *Nonionina orbicularis*, *Polystomella striato-punctata*, var. *incerta*, *Quinqueloculina sp.*

## FAMILY ASTRORHIZIDAE.

GENUS PSAMMOSPHAERA F. E. SCHULZE, 1875.

*Psammospaera fusca* F. E. Schulze.

*Psammospaera fusca* F. E. Schulze, II. Jahr. Comm. Wiss. Unt. deutsch. Meer in Kiel, 1875, p. 113, pl. 2, figs. 8 a-f.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 249, pl. 18, figs. 1, 5-8 (not 2-4).

Rare specimens occur only at station 5. They are composed of small, angular quartz grains, with a whitish cement, and no visible apertures. The species is recorded from a very wide range, but there are entirely different forms which should be carefully studied. I have recorded a large form from the western Atlantic (Bull. 104, U.S. Nat. Mus., pt. 1, 1918, pl. 13, fig. 6; pl. 14, figs. 1-3) which may not be this species. It is certainly not like this northern form which seems to be typical. The type station is Houguesund, Norway, 120 fathoms.

GENUS SOROSPHERA H. B. BRADY, 1879.

*Sorosphaera confusa* H. B. Brady?

*Sorosphaera confusa* H. B. Brady, Quart. Journ. Micr. Sci., vol. 19, 1879, p. 28, pl. 4, figs. 18, 19; Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 251, pl. 18, figs. 9, 10.

There are a very few specimens from station 3 which may be referred to this species with some doubt. They are composed of fine white amorphous material for the most part, of several chambers irregularly arranged, but with definite apertures. In one of the specimens these are irregularly grouped near where the chambers intersect, in another they are remote from one another. In the usual form of the species the apertures are not apparent, according to the description, but the figures in the *Challenger* Report show rather definite areas which appear to be apertures closed by amorphous material. Most of the other records are from deep water.

GENUS PELOSINA H. B. BRADY, 1879.

*Pelosina variabilis* H. B. Brady.

*Pelosina variabilis* H. B. Brady, Quart. Journ. Micr. Sci., vol. 19, 1879, p. 30, pl. 3, figs. 1-3; Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 235, pl. 26, figs. 7-9—Flint, Rep. U.S. Nat. Mus., 1897 (1899), p. 266, pl. 4, fig. 1.—Rhumbler, Arch. Prot., vol. 3, 1903, p. 239, fig. 74 (in text).—Chapman, Trans. New Zealand Inst., vol. 38, 1905, p. 83.—Cushman, Bull. 71, U.S. Nat. Mus., pt. 1, 1910, p. 47, fig. 52 (in text).—Heron-Allen and Earland, Trans. Linn. Soc. London, vol. 11, pt. 13, 1916, p. 218.—Cushman, Bull. 104, U.S. Nat. Mus., pt. 1, 1918, p. 53, pl. 22, figs. 1-4.

At station 4 this and the two following species occur. One of the specimens of *P. variabilis* has a double aperture. The test is composed of fine-grained, light-coloured, amorphous material. Most of the records for the species are in cold or deep water.

*Pelosina cylindrica* H. B. Brady.

*Pelosina cylindrica* H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 236, pl. 26, figs. 1-6.—Egger, Abh. bay. Akad. Wiss. München, vol. 18, 1893, p. 253, pl. 4, figs. 1, 2.—Rhumbler, Arch. Prot., vol. 3, 1903, p. 239, fig. 72 (in text).—Chapman, Trans. New Zealand Inst., vol. 38, 1905, p. 83.—Cushman, Bull. 71, U.S. Nat. Mus., pt. 1, 1910, p. 46, figs. 50, 51 (in text).—Pearcey, Trans. Roy. Soc. Edinburgh, vol. 49, 1914, p. 1002.—Cushman, Bull. 104, U.S. Nat. Mus., pt. 1, 1918, p. 54, pl. 22, fig. 5.

*Rhizammima indivisa* Goës (part), Bull. Mus. Comp. Zoöl., vol. 29, 1896, p. 20.

Like the preceding, this species is known mostly from deep, cold waters. It is recorded from the Antarctic as well as from northern regions. The Hudson Bay specimens are tubular with thick walls of amorphous material which carry sand grains imbedded in the surface.

*Pelosina rotundata* H. B. Brady.

*Pelosina rotundata* H. B. Brady, Quart. Journ. Micr. Sci., vol. 19, 1879, p. 31, pl. 3, figs. 4, 5; Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 236, pl. 25, figs. 18-20.—Egger, Abh. bay. Akad. Wiss. München, vol. 18, 1893, p. 254, pl. 11, fig. 60.—Rhumbler, Arch. Prot., vol. 3, 1903, p. 239, fig. 71 (in text).

Chapman, Trans. New Zealand Inst., vol. 38, 1905, p. 83.—Cushman, Bull. 71, U.S. Nat. Mus., pt. 1, 1910, p. 45, figs. 47-49 (in text); Bull. 104, U.S. Nat. Mus., pt. 1, 1918, p. 55, pl. 21, figs. 4-6.

A few specimens were found which seemed to belong to this genus. They had apertures, but were without necks. Later a single specimen with the tapering tubular neck was found, showing that the whole are probably *P. rotundata*. Records for typical specimens are rare and much scattered.

#### GENUS WEBBINELLA RHUMBLER, 1903.

*Webbinella hemisphaerica* (Jones, Parker and H. B. Brady).

*Webbina hemisphaerica* Jones, Parker and H. B. Brady, Pal. Soc. Mon., 1865, p. 27, pl. 4, fig. 5.—Robertson, Rep. Brit. Ass., 1875, p. 189.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 350, pl. 41, fig. 11.—Egger, Abh. bay. Akad. Wiss. München, vol. 18, 1893, p. 266, pl. 14, figs. 1-3. Cushman, Proc. Boston Soc. Nat. Hist., vol. 34, 1908, p. 24.—Heron-Allen and Earland, Proc. Roy. Irish Acad., vol. 31, pt. 64, 1913, p. 53.

*Webbinella hemisphaerica* Rhumbler, Arch. Prot., vol. 3, 1903, p. 228, fig. 54 (in text).—Cushman, Bull. 71, U.S. Nat. Mus., pt. 1, 1910, p. 51, figs. 56*a*, *b* (in text).—Pearcey, Trans. Roy. Soc. Edinburgh, vol. 49, 1914, p. 1003. Cushman, Bull. 104, U.S. Nat. Mus., pt. 1, 1918, p. 62, pl. 25, figs. 1-3.

At station 4. this species is evidently common as numerous small stones sent me had numerous specimens on their surfaces. The specimens are not as high as that of the *Challenger* Report figure, nor are they of the same texture or shape. The same is true of a comparison of those I have figured from off the Carolinas, and there is a considerable difference from either of the others.

The specimens which are common in Hudson Bay give the appearance of being the result of selection in position of the material. If it may be supposed that the original animal was free and able to ingest various sorts of material, it is easy to see how the test might be formed. The whole is somewhat convex in the central portion, with a thinning toward the periphery which is in general circular, but often somewhat irregular. The central cavity in broken specimens is comparatively small. It is bordered with the largest sand grains of the whole test, and the outside gradually becoming finer, until the final outer coating is very fine and smooth. There is no apparent aperture. All the specimens examined are very uniform in structure and in appearance. This would lead one to the belief that in this region there is a definite species, probably not the same as that described by Jones, Parker and H. B. Brady, nor the same as that figured in the *Challenger* Report, nor the same as that I have figured and referred to above.

#### GENUS THOLOSINA RHUMBLER, 1895.

*Tholosina bulla* (H. B. Brady)?

This species which was so abundant in the Canadian Arctic Expedition collection seems to be almost wanting in Hudson Bay, unless a single detached



specimen represents it. The specimen is of the usual convex form and white colour, and shows the central cavity. *T. vesicularis* was also entirely lacking in the collection.

#### GENUS PSAMMATODENDRON NORMAN, 1881.

##### *Psammatodendron arborescens* Norman.

*Psammatodendron arborescens* Norman, MSS. in H. B. Brady, Denkschr. k. Akad. Wiss. Wien, vol. 43, 1881, p. 98; Ann. Mag. Nat. Hist., ser. 5, vol. 8, 1881, p. 404.—Eimer and Fickert, Zeitschr. Wiss. Zool., vol. 65, 1899, p. 670.—Cushman, Bull. 104, U.S. Nat. Mus., pt. 1, 1918, p. 79, pl. 30, figs. 1, 2.

*Hyperammia arborescens* H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 262, pl. 28, figs. 12, 13.—Wright, Proc. Belfast Nat. Field Club, 1884-85, App. IX., 1886, p. 319, pl. 26, fig. 1.—Goës, Köngl. Svensk. Vet. Akad. Handl., vol. 25, No. 9, 1884, p. 18, pl. 4, figs. 63, 64.—Schaudinn, Bergens Mus. Aarbok, 1894-95, No. 9, p. 5.—Rhumbler, Arch. Prot., vol. 3, 1903, p. 260, fig. 102 (in text).—Awerinzew, Mem. Acad. Imp. Sci. St. Petersburg, ser. 8, vol. 29, No. 3, 1911, p. 11.—Heron-Allen and Earland, Trans. Linn. Soc. London, vol. 11, pt. 13, 1916, p. 220.—Cushman, Bull. 104, U.S. Nat. Mus., pt. 1, 1918, p. 79, pl. 30, figs. 1, 2.

This species seems to be characteristic of the colder regions of the North Atlantic and Arctic Oceans. It is recorded by Awerinzew from the Siberian Arctic. In the North Atlantic it is known from off the coast of Norway and Great Britain as well as further north off Greenland, Iceland, Nova Zembla, and Franz Joseph Land.

Only small branching portions were found in the Hudson Bay collection at station 3.

#### FAMILY LITUOLIDAE.

##### GENUS REOPHAX MONTFORT, 1808.

##### *Reophax curtus* Cushman.

*Reophax scorpiurus* Goës (part) (not *R. scorpiurus* Montfort), Köngl. Svensk. Vet. Akad. Handl., vol. 25, No. 9, 1894, p. 24, pl. 5, figs. 160-163.

*Reophax curtus* Cushman, Bull. 104, U. S. Nat. Mus., pt. 2, 1920, p. 8, pl. 2, figs. 2, 3.

Test short and thick, composed typically of three chambers, increasing rapidly in size as added, last-formed chamber making up a large proportion of the test, fusiform or elliptic, axis of the test straight or more often slightly curved; wall composed of angular quartz sand grains, with a considerable amount of grey cement between; apertural end slightly tapering, without a definite neck, the aperture being an opening between three or more sand grains at the end of the chamber.

Length up to 2 mm.

The type station for this species is *Albatross* D2458 in 89 fathoms, north of the Grand Banks, in very cold water (29.5°F.). Fine, large, typical specimens

are common at station 4, and a single specimen from station 5 may be referred here. The species occurs off Greenland and off the north coast of Europe in cold water.

The species is shorter, thicker, and fewer-chambered than *R. scorpiurus*, the chambers fewer and longer than in *R. pilulifer*, and different in the material of the wall and in the number and shape of the chambers from *R. bilocularis*.

It seems to be a species of cold waters and moderate depths.

Goës figures this species under the name of *R. scorpiurus* in the reference noted above. The specimens were from the Greenland Sea in 35-215 meters, and from the Skagerack in 250 meters.

#### GENUS HAPLOPHRAGMOIDES CUSHMAN, 1910.

*Haplophragmoides canariensis* (d'Orbigny).

A single specimen only from station 3 gives the only record for this species in the collection. It has been already recorded from the Canadian Arctic Expedition and from other Arctic areas, as well as in temperate regions. It is evidently not the same as that found in shallow, tropical waters.

#### GENUS AMMOBACULITES CUSHMAN, 1910.

*Ammobaculites cassis* (Parker).

*Lituola cassis* Parker, in Dawson, *Canad. Nat.*, vol. 5, 1870, pp. 117, 180, fig. 3. *Haplophragmium cassis* H. B. Brady, *Rep. Voy. Challenger*, *Zoology*, vol. 9, 1884, p. 304, pl. 33, figs. 17-19.—Goës, *Köngl. Svensk. Vet. Akad. Handl.*, vol. 25, No. 9, 1894, p. 24, pl. 5, figs. 152-157.—Flint, *Rep. U.S. Nat. Mus.*, 1897 (1899), p. 275, pl. 19, fig. 4.—Awerinzew, *Mem. Acad. Imp. Sci. St. Petersburg*, ser. 8, vol. 29, No. 3, 1911, p. 20.

*Ammobaculites cassis* Cushman, *Rep. Canadian Arctic Exped.*, vol. 9, pt. M, 1920, p. 6m, pl. 1, fig. 3; *Bull.* 104, *U.S. Nat. Mus.*, pt. 2, 1920, p. 63, pl. 12, fig. 5.

At one station (4), specimens were fairly common. The specimens are mostly fairly broad, but some more slender ones also occur, but as a rule, these seem to be young. There are a few specimens also from stations 2 and 5.

*A. cassis* is one of the species characteristic of cold waters. It ranges southward as far as Cape Cod on the Atlantic coast, thence northward along the New England coast, into the mouth of the St. Lawrence, Gaspé Bay, thence westward into Hudson Bay, and is known from off Greenland, Spitzbergen, Nova Zembla, the Siberian Arctic, and from the Canadian Arctic. It also apparently is in cold waters in the North Pacific. The records are all in comparatively shallow waters.

#### GENUS TROCHAMMINA PARKER AND JONES, 1860.

*Trochammina rotaliformis* J. Wright.

*Trochammina inflata* (Montagu), var., Balkwill and Wright, *Trans. Roy. Irish Acad.*, vol. 28 (Science), 1885, p. 331, pl. 13, figs. 11, 12.

*Trochammina rotaliformis* J. Wright, in Heron-Allen and Earland, Journ. Roy. Micr. Soc., 1911, p. 309.—Heron-Allen and Earland, Proc. Roy. Irish Acad., vol. 31, pt. 64, 1913, p. 52, pl. 3, figs. 11-13.—Cushman, Bull. 104, U.S. Nat. Mus., pt. 2, 1920, p. 77, pl. 16, figs. 1, 2.

This is one of the commonest species in the collection. It occurs at all but one of the stations, and at station 5 in great numbers. The specimens are very similar to the original figures given by Balkwill and Wright, much more so than those given by Heron-Allen and Earland from the Clare Island region.

It has not previously been recorded from the western Atlantic and I failed to find it in the *Albatross* dredgings from Newfoundland southward. It may be a species of shallow water. Its occurrence in Hudson Bay is an interesting one.

## FAMILY TEXTULARIIDAE

GENUS VERNEUILINA D'ORBIGNY, 1840.

*Verneuilina advena* Cushman, new species.

Test minute, elongate, triserial, tapering, broadest near the apertural end, composed of as many as twenty-five chambers, inflated; sutures distinct and depressed; wall arenaceous, but very smoothly finished on the exterior, the amount of cement and fine material being proportionately large; aperture in a deep depression at the junction of the last of the three series of chambers; colour reddish-brown, the last-formed chamber often white.

Length usually not over 0.3 mm.

At four of the stations this minute species has occurred, and at station 3 in some considerable numbers. It is known from the Canadian Arctic Expedition where I recorded it as *V. polystropha* (Rep. Canadian Arctic Exped., vol. 9, pt. M, 1920, p. 8m, pl. 1, fig. 5). I have also found it off our eastern Atlantic coast, and it is known from other regions to the north. It is probably recorded under *V. polystropha* from various localities. *Verneuilina scabra* (Williamson) (*V. polystropha* in part) does not so far as I have seen, occur in the western Atlantic.

Heron-Allen and Earland have recently published a paper (Proc. Roy. Irish Acad., vol. 35, No. 8, 1920) in which they note and figure this species, referring it to *V. polystropha*, and speaking of it as a dwarf form as a result of "nanism." Inasmuch as the larger typical form does not seem to occur on the American coast, and this smaller species is widely distributed here, it would seem that the two are distinct. Beside the difference in distribution there are very definite characters in the size, and especially the characters of the wall which distinguish the two.

## FAMILY LAGENIDAE.

GENUS LAGENA WALKER AND BOYS, 1784.

*Lagena globosa* (Montagu).

"*Serpula* (*Lagena*) *laevis globosa*" Walker and Boys, Test. Min., 1784, p. 3, pl. 1, fig. 8.

*Vermiculum globosum* Montagu, Test. Brit., 1803, p. 523.

*Lagena globosa* Brown, Illus. Rec. Conch. Great Britain and Ireland, ed. 1, 1827, pl. 1, fig. 37.—Cushman, Bull. 71, U.S. Nat. Mus., pt. 3, 1913, p. 3, pl. 4, fig. 2.

At station 3 there were taken several specimens that evidently belong to this species as usually known. They are of the elongate form figured by Brady in the *Challenger* Report (pl. 56, fig. 1). It is recorded from Baffins Bay by Parker and Jones, and there are other records from various parts of the Arctic.

#### GENUS NODOSARIA LAMARCK, 1812.

##### *Nodosaria calomorpha* Reuss.

*Nodosaria calomorpha* Reuss, Denkschr. Akad. Wiss. Wien, vol. 25, 1865, p. 129, pl. 1, figs. 15-19.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 497, pl. 61, figs. 23-27.—Cushman, Bull. 71, U.S. Nat. Mus., pt. 3, 1913, p. 48, pl. 25, fig. 6.

A single, two-chambered specimen was found in the bottom material from station 5. It is similar to the specimens figured by Brady, the test translucent and thin-walled.

Awerinzew records this species from the Siberian Arctic.

#### GENUS POLYMORPHINA D'ORBIGNY, 1826.

##### *Polymorphina lactea* (Walker and Jacob).

"*Serpula tenuis ovalis laevis*" Walker and Boys, Test. Min., 1784, p. 2, pl. 1, fig. 5.

"*Polymorphina Subcordiformia vel Oviformia*" Soldani, Testaceographia, vol. 1, pt. 2, 1791, p. 114, pl. 112, figs. 11, nn, etc.

*Serpula lactea* Walker and Jacob, Adams' Essays, ed. 2, 1798, p. 634, pl. 24, fig. 4.

*Polymorphina lactea* Magillivray, Moll. Aberd., 1843, p. 320.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 559, pl. 71, fig. 11.—Cushman, Bull. 71, U.S. Nat. Mus., pt. 3, 1913, p. 84, pl. 34, fig. 8.

A few specimens, somewhat compressed, resemble the figures given of this species. The specimens are translucent and thin-walled. They occurred at stations 3, 4, and 5. The species of *Polymorphina*, as recorded in the literature of this genus, are in a state of great confusion. From studies I have made of tropical material and that from cooler regions it seems that careful discrimination will result in definite distributions of a considerable number of species.

##### *Polymorphina lanceolata* Reuss.

*Polymorphina lanceolata* Reuss, Zeitschr. Deutsch. Geol. Gesell., vol. 3, 1851, p. 83, pl. 6, fig. 50.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 492, pl. 61, fig. 32.—Cushman, Rep. Canadian Arctic Exped., vol. 9, pt. M, 1920, p. 9m.

Forms referred to this species, as figured by Brady, are rare at station 5. The surface is smooth and polished and the sutures hardly depressed.

*Polymorphina ovata* d'Orbigny.

*Polymorphina ovata* d'Orbigny, For. Foss. Vienne, 1846, p. 233, pl. 13, figs. 1-3.  
—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 564, pl. 72, figs. 7, 8.—Cushman, Bull. 71, U.S. Nat. Mus., pt. 3, 1913, p. 87, pl. 30, fig. 2.

Rare specimens which show an alternating of chambers somewhat similar to those figured by Brady occur at station 5.

*Polymorphina oblonga* d'Orbigny.

*Polymorphina oblonga* d'Orbigny, For. Foss. Vienne, 1846, p. 232, pl. 12, figs. 29-31.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 569, pl. 73, figs. 2-4.—Cushman, Bull. 71, U.S. Nat. Mus., pt. 3, 1913, p. 88, pl. 37, fig. 6.

Specimens very similar to the figures given by Brady occur at station 5. The sutures are depressed and the chambers stand out from the general surface.

FAMILY ROTALIIDAE.

GENUS PATELLINA WILLIAMSON, 1858.

*Patellina corrugata* Williamson.

*Patellina corrugata* Williamson, Rec. Foram. Great Britain, 1858, p. 46, pl. 3, figs. 86-89.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 634, pl. 86, figs. 1-7.—Cushman, Bull. 71, U.S. Nat. Mus., pt. 5, 1915, p. 9, pl. 7, fig. 1.

A single specimen of this interesting species was obtained in the material from station 3. It is typical of the cold water form of this species. Records of its distribution range as far north as 83°19'N., at a depth of 72 fathoms. It is also known from off Nova Zembla and the coasts of Europe. I have recorded it on the Atlantic coast from the Woods Hole region. This is probably different from the species so common in shallow water of the South Pacific which has been assigned to this of Williamson.

GENUS DISCORBIS LAMARCK, 1804.

*Discordis wrightii* (H. B. Brady).

*Discorbina parisiensis* J. Wright (in part) (not d'Orbigny), Proc. Belfast Nat. Field Club, 1876-1877 (1877), Appendix, p. 105, pl. 4, figs. 2 *a-c*.

*Discorbina wrightii* H. B. Brady, Denkschr. Akad. Wiss. Wien, vol. 43, pt. 2, 1881, p. 104, pl. 2, figs. 6*a, b*.—Earland, Journ. Quekett Micr. Club, ser. 2, vol. 9, 1905, p. 223.—Heron-Allen and Earland, Proc. Roy. Irish Acad., vol. 31, pt. 64, 1913, p. 131, pl. 12, fig. 4.

A small specimen very similar to Brady's original figure with the beading of the ventral side extending about half way from the periphery to the umbilicus occurred at station 3. From station 5 there is a better developed specimen which has become somewhat flatter on the ventral side, and has the beading

extending to the periphery. From station 1 is a specimen, or rather two specimens in a plastogamic condition, which are evidently this same species.

Brady's original specimens were from off Nova Zembla and the species has been recorded by Heron-Allen and Earland from the coasts of the British Isles.

GENUS TRUNCATULINA D'ORBIGNY, 1826.

*Truncatulina lobatula* (Walker and Jacob).

*Truncatulina lobatula* Cushman, Rep. Canadian Arctic Exped., vol. 9, pt. M, 1920, p. 9m.

This species, which has already been recorded in the Canadian Arctic Expedition occurs at station 3 in Hudson Bay. It is not as common, however, as might be expected.

GENUS PULVINULINA PARKER AND JONES, 1862.

*Pulvinulina frigida* Cushman, new species.

*Pulvinulina karsteni* H. B. Brady (not Reuss), Trans. Linn. Soc. London, vol. 29, 1864, p. 470.

*Pulvinulina repanda* (Fichtel and Moll), var. *karsteni* Parker and Jones, Phil. Trans., vol. 155, 1865, p. 396, pl. 14, figs. 14, 15, 17.

Test small, biconvex, rotaaliform, composed of about two and one-half coils; chambers distinct, usually six in the last-formed coil; sutures distinct but not depressed on the dorsal side, on the ventral side slightly depressed and filled with an amorphous material radiating out from the umbilical region; wall clear and translucent on the dorsal side, usually showing all the chambers back to the proloculum distinctly, on the ventral side less clear.

Diameter up to 0.4 mm.

This Arctic, or at least cold water species, was obtained at stations 2, 3, and 5. It is not the same as *P. karsteni* Reuss, as a reference to the original figures will show, especially the ventral side. The figures given by Parker and Jones of Arctic specimens are very excellent for this species as it occurs in Hudson Bay. There is little or no trace of any carina on the ventral side except that the material filling the sutural depressions sometimes becomes confluent along the periphery. The species was referred by Brady to *P. karsteni* in 1864, and he has been followed since. Brady's notes in 1864 are interesting in this connection.

"Three or four small starved specimens of this species have been pointed out amongst my mountings by Mr. Parker. . . . As I have never met with mature specimens, I can only refer to Professor Reuss's memoir on the Chalk of Mecklenburg (Zeitsch. Deutsch. Geol. Gesellsch., vol. vii., p. 273, pl. 9, fig. 6), and in this instance I have preferred copying his figures of the shell to drawing direct from immature specimens."

The following quotation is from Parker and Jones in 1865:

"This is a neat, many-chambered, moderately conical variety of *P. repanda*, with some degree of limbation bordering the chambers, especially beneath, where a wheel-like system of exogenous shell-matter characterizes the shell."

They also note differences between the Arctic and North Atlantic specimens referred to this species and also that Reuss's figure is not exactly like either.

*P. frigida* is evidently an Arctic species of definite distribution and definitely characterized.

#### FAMILY NUMMULITIDAE.

##### GENUS NONIONINA D'ORBIGNY, 1826.

*Nonionina orbicularis* H. B. Brady.

*Nonionina orbicularis* H. B. Brady, Denkschr. Akad. Wiss. Wien, vol., 43, 1881, p. 105, pl. 2, figs. 5a, b; Ann. Mag. Nat. Hist., ser. 5, vol. 8, 1881, p. 415, pl. 21, figs. 5a, b; Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 727, pl. 109, figs. 20, 21.—Heron-Allen and Earland, Trans. Linn. Soc. London, Zoology, ser. 2, vol. 11, 1916, p. 280.

In the Hudson Bay collection this species is fairly common, especially at station 5, with fewer specimens at station 6. They are very similar in all respects to the specimen figured by Brady from off Nova Zembla. The species is evidently an Arctic one of wide distribution in cold waters. The figures of specimens from warm waters referred to this species are evidently not identical with it. In general form, and especially in the condition of the umbilicus and sutures, the specimens are exactly like the Nova Zembla specimens.

*Nonionina stelligera* d'Orbigny.

This species I have already recorded from the collection of the Canadian Arctic Expedition. It is known from many Arctic and Subarctic localities. The only specimen from Hudson Bay was from station 3.

D'Orbigny's original specimens were from shore sands from the Canaries at Teneriffe, and it would be interesting to obtain specimens of this from this locality to see if in reality it is the same as this widely distributed Arctic species

*Nonionina scapha* (Fichtel and Moll).

*Nautilus scapha* Fichtel and Moll, Test. Micr., 1803, p. 105, pl. 19, figs. *d-f*.

*Nonionina scapha* Parker and Jones, Ann. Mag. Nat. Hist., ser. 3, vol. 5, 1860, p. 102, No. 4.

*Polystomella crispa* Linné, var. (*Nonionina*) *scapha* Parker and Jones, Phil. Trans., vol. 155, 1865, p. 404, pl. 14, figs. 37, 38; pl. 17, figs. 55, 56.

A very few specimens were obtained from station 5. They are of the very broad, triangular form, in apertural view similar to the Arctic and North Atlantic specimens figured by Parker and Jones in the above reference. This form is very striking and different from many of the figures assigned to this species from other regions by many authors.

##### GENUS POLYSTOMELLA LAMARCK, 1822.

*Polystomella striato-punctata* (Fichtel and Moll), var. *incerta* (Williamson).

This variety I have already recorded from the collection of the Canadian Arctic Expedition. It has occurred in the Hudson Bay collection at all but one

station, 1, 2, 3, 5, and 6. From the records it seems to be widely distributed in the Arctic and Subarctic regions.

*Polystomella arctica* Parker and Jones.

This circumpolar species occurs in the collection from Hudson Bay from station 5. I have already recorded it from the Canadian Arctic Expedition. There are numerous other specimens which have a form similar to this but have a single row of openings, but with a broad band of exogenous shell material above each suture.

FAMILY MILIOLIDAE.

GENUS CORNUSPIRA SCHULTZE, 1854.

*Cornuspira foliacea* (Philippi).

In the Report of the Canadian Arctic Expedition I have given notes on this species. It has again been found in very similar form in these collections from Hudson Bay, occurring at stations 3 and 5.

GENUS QUINQUELOCULINA D'ORBIGNY, 1826.

*Quinqueloculina seminulum* (Linné)?

This species was recorded from the collection of the Canadian Arctic Expedition. It is recorded in most of the Arctic collections. Our specimens, however, are all of a stout, squarish shape, with a very highly polished, smooth surface. They were from stations 1, 2, 3, and 5, not common at any of the stations.

In shape these specimens are nearest to the figure given by Parker and Jones (Phil. Trans., vol. 155, 1865, pl. 15, fig. 34) as *Miliolina* (*Quinqueloculina*) *oblonga* (Montagu) from the Arctic.

*Quinqueloculina subrotunda* (Montagu).

Most of the lists from the Arctic include this species. It has occurred in the Hudson Bay collection at stations 2, 3, and 5. It was previously found in the collection of the Canadian Arctic Expedition.

*Quinqueloculina* sp.

There is a single specimen of an arenaceous *Quinqueloculina* from station 5. It is dark red in colour and of different form from *Q. agglutinans* d'Orbigny. Parker and Jones record this arenaceous reddish form from the Arctic.

*Quinqueloculina* sp.

From station 6 there is a single large specimen very similar to that figured by Parker and Jones (Phil. Trans., vol. 155, 1865, pl. 15, figs. 36 *a-c*), and referred by them to *Quinqueloculina ferussacii* d'Orbigny. It is not the same as d'Orbigny's species and may possibly represent a distinct Arctic form.



## GENUS TRILOCULINA D'ORBIGNY, 1826.

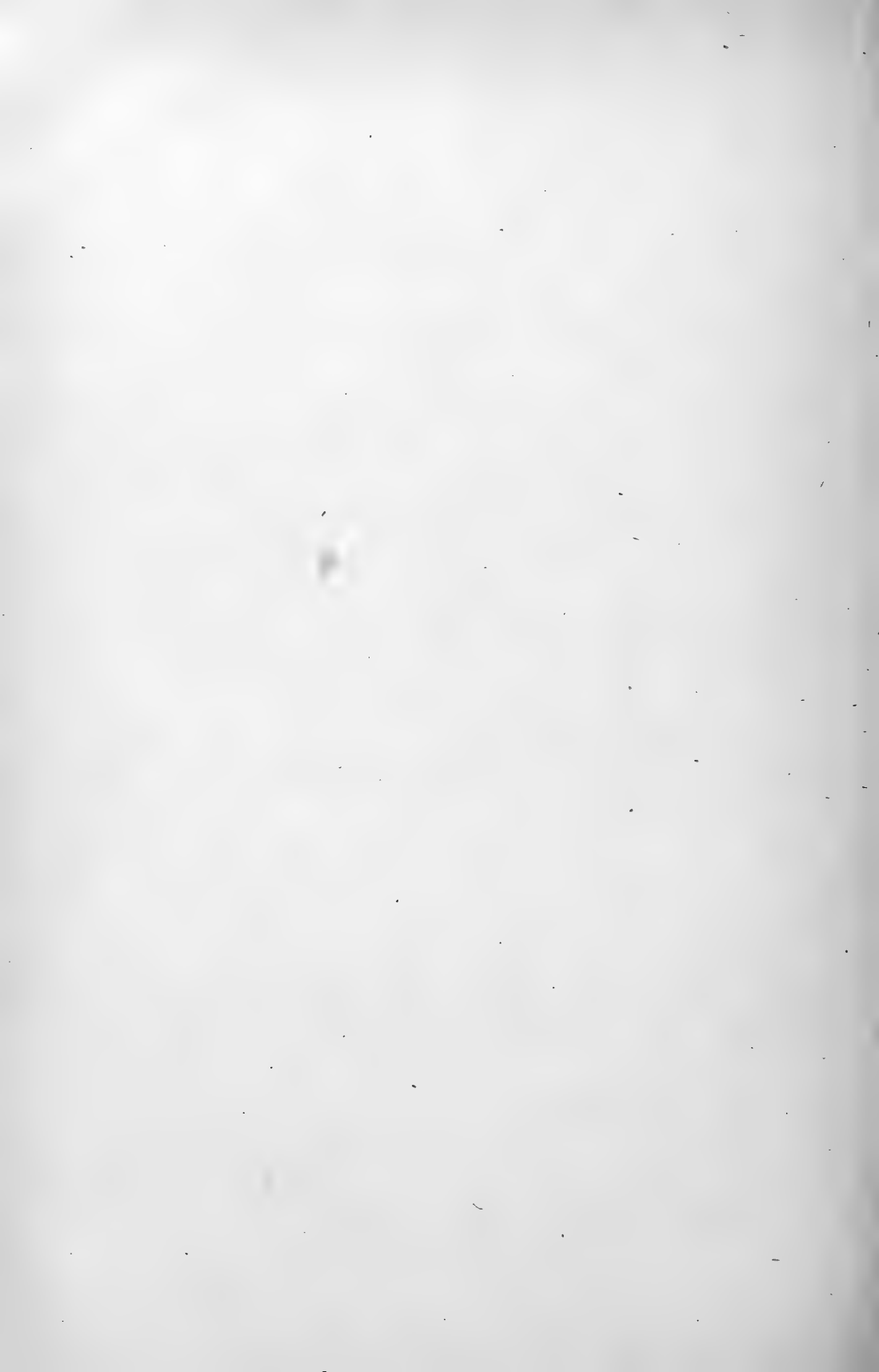
*Triloculina-oblonga* (Montagu).

*Vermiculum oblongum* Montagu, Test. Brit., 1903, p. 522, pl. 14, fig. 9.

*Triloculina oblonga* d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 300, No. 16; Modèles, No. 95; in De la Sagra, Hist. Fis. Pol. Nat. Cuba, 1839, "Foraminifères," p. 155, pl. 10, figs. 3-5.—Cushman, Bull. 71, U.S. Nat. Mus., pt. 6, 1917, p. 69, pl. 26, fig. 3; figs. 35, 36 (in text).

*Miliolina oblonga* H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 160, pl. 5, figs. 4a, b.

There are numerous specimens from station 5 which may be referred to this species. They are not as elongate as tropical specimens such as are usually assigned to *T. oblonga*. The surface of the test is smooth and polished.



No. X

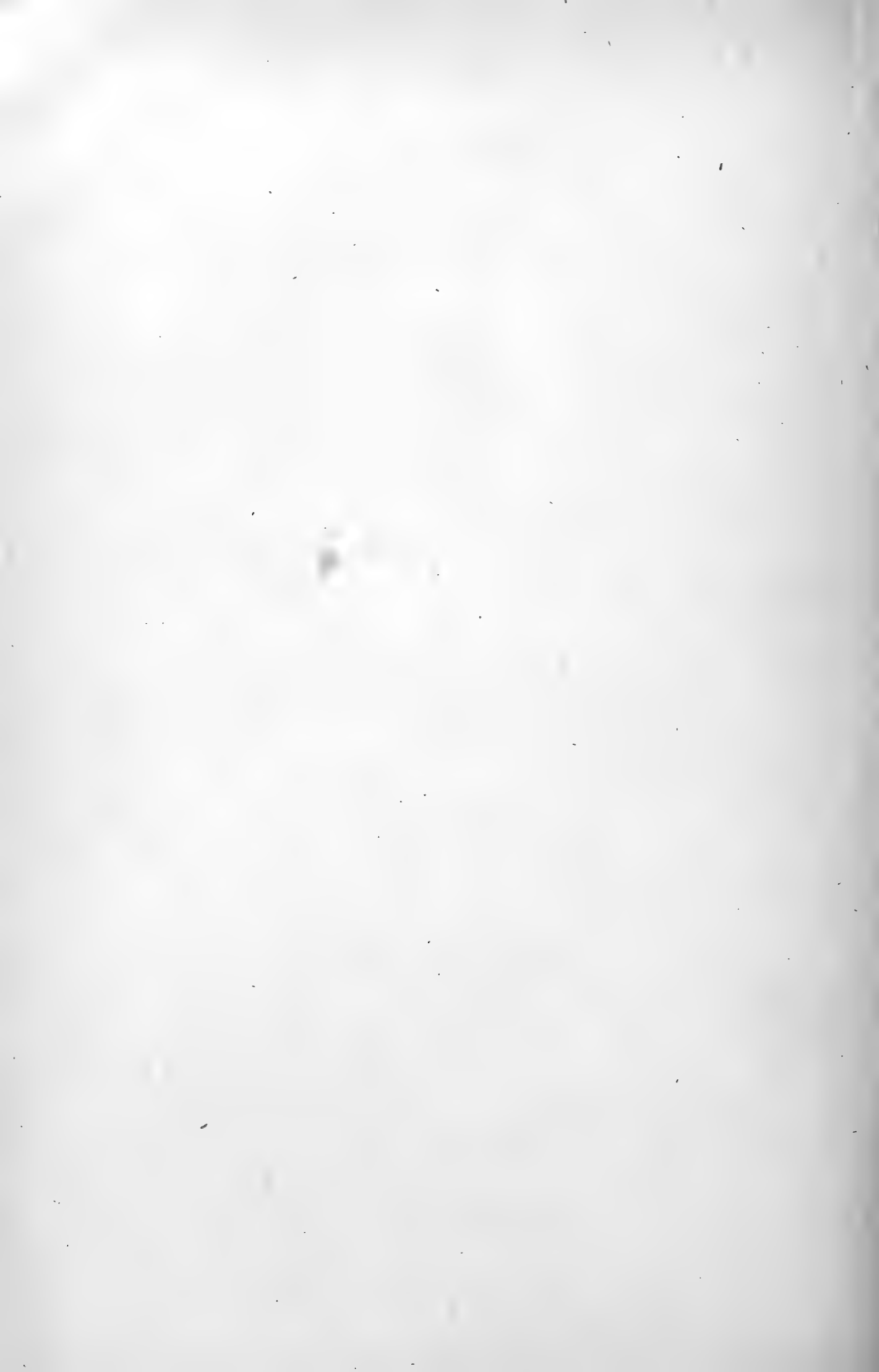
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RESULTS OF THE HUDSON BAY EXPEDITION, 1920

II. THE GASTEROSTEIDÆ

BY

PHILIP COX, PH.D.



# Results of the Hudson Bay Expedition, 1920

## II. The Gasterosteidæ.

BY PHILIP COX, PH.D.

In the winter of 1920-21, I received a collection of sticklebacks from Mr. Frits Johansen, which he had made in James and Hudson Bay and the tributary waters at the instance of the Biological Board of Canada. It is of special interest as being the largest collection of such material ever made in those regions, about whose fish fauna so little is definitely known. It consists of nearly 200 specimens, which are in a good state of preservation.

Our knowledge of the sticklebacks of Hudson Bay is merely fragmentary and very incomplete. To illustrate this, it is only necessary to state that in "Fishes of North and Middle America," Jordan and Evermann, 1896-1900, Hudson Bay is mentioned only once and that in a footnote. The Atlantic and Pacific coast forms, as well as those of the interior, are well known through the writings of Richardson, Reinhardt, Storer, DeKay, Girard, Eigenmann, Kendall, and others; but little is known of the species of Hudson Bay. Information from that remote and hitherto inaccessible region leaked out slowly. It is gratifying, however, to learn that the Biological Board of Canada is making successful progress in unlocking the hidden treasures of the north, and making them known to the scientific public.

Sticklebacks were taken at 15 stations, which, for convenience of reference, I have numbered, giving also the dates.

- July 3. Stn. No. 1.—Ponds in swamp on beach, and at low tide, south coast of James Bay, 30 miles west of Moose River.
- " 8. Stn. No. 2.—Pools in swamp at Fort Albany, James Bay.
- " 14-15. Stn. No. 3.—Pond at Moose Factory.
- " 16. Stn. No. 4.—Pools at beach, east side of Charlton Island, James Bay.
- " 18. Stn. No. 5.—Trout pond on south side of Charlton Island.
- " 27. Stn. No. 6.—East side of South Twin Island, James Bay.
- Aug. 6 & 7. Stn. No. 7.—Creek-mouth, east side of Hudson Bay, about 15 miles north of Great Whale River.
- " 8-11. Stn. No. 8.—East coast of Hudson Bay, lat. 56° N.
- " 12. Stn. No. 9.—Ponds on river flats, second river south of Little Whale River, east side of Hudson Bay.
- Sept. 2. Stn. No. 10.—Sea surface between Cape Jones and Long Island, east coast of Hudson Bay, 1 mile off mainland.
- Sept. 10. Stn. No. 11.—East coast, James Bay, lat. 53° N.
- " 11. Stn. No. 12.—Moar Bay, east coast of James Bay, about lat. 53° N.

- Sept. 14. Stn. No. 13.—Brackish land-locked pool (creek outlet) at beach of Cape Hope Islands, east side of James Bay, lat. 52° 30' N.
- “ 22. Stn. No. 14.—In pools in creek, interior of Charlton Island, James Bay.
- Oct. (middle) Stn. No. 15.—In pools at Abitibi River, and between New Post and Moose River.

*Eucalia inconstans* (KIRTLAND).

BROOK STICKLEBACK.

The writer is not aware of any previous record of this species from the Hudson Bay country, nor is there any from Newfoundland or Labrador. Its alleged occurrence at Sukkertoppen, Greenland (Proc. Ac. Nat. Sci. Phila., 1865, p. 81), by E. D. Cope, would seem to need verification.

Mr. Johansen found this species at stations 2, 3, 5, 13, 14 and 15, but seemingly not in abundance; or, perhaps, the facilities for making large hauls were not at hand. A new character, however, has been added to the distribution; namely, its occurrence in saltish water, for he collected it at station 13 in a “brackish land-locked pool.” It has always been regarded as a strictly fresh-water species, and its occurrence there may have been accidental; but, in high latitudes, the severe cold, long winters, and deep freezing of coastwise streams and ponds may induce, or rather force, a migration to brackish water. In this way the species may have become more tolerant of such a medium. Whitefish, too, in the far north, are known to descend to the sea, or at least into brackish estuaries.

The fish are fairly typical of the species as met with in the United States and southern and western Canada. It is observed, however, that the gill membrane is freer from the isthmus, the depth less in proportion to the length, the pelvic spines shorter, and the thoracic processes less divergent; but minor differences such as these are specifically unimportant, and are apt to be seen among all species when representatives from widely separated localities are compared.

*Pygosteus pungitius* (LINNAEUS).

NINE-SPINED STICKLEBACK.

It was to be expected that this species would be met with, for it is the most widely distributed of all the sticklebacks and probably extends its range farther into the boreal regions of North America than any other. It had been recorded from Greenland, Labrador, the Arctic islands, and the Hudson Bay country.

Mr. Johansen collected it at stations 1, 4, 6, 9, 10, and 13, and generally in quantity. At station 1, 69 specimens were secured; at station 7, lat. 56°, the most northern point visited, only 4 were taken.

The majority is composed of under-sized and young fish. One specimen, the largest, is 63 mm. long. The dorsal spines are 9; a very few have 10; one has 8. No example with 7 is seen. This is about the status of the species elsewhere. In colour and colour pattern they are similar to those of the Bay of Fundy, though somewhat duller.

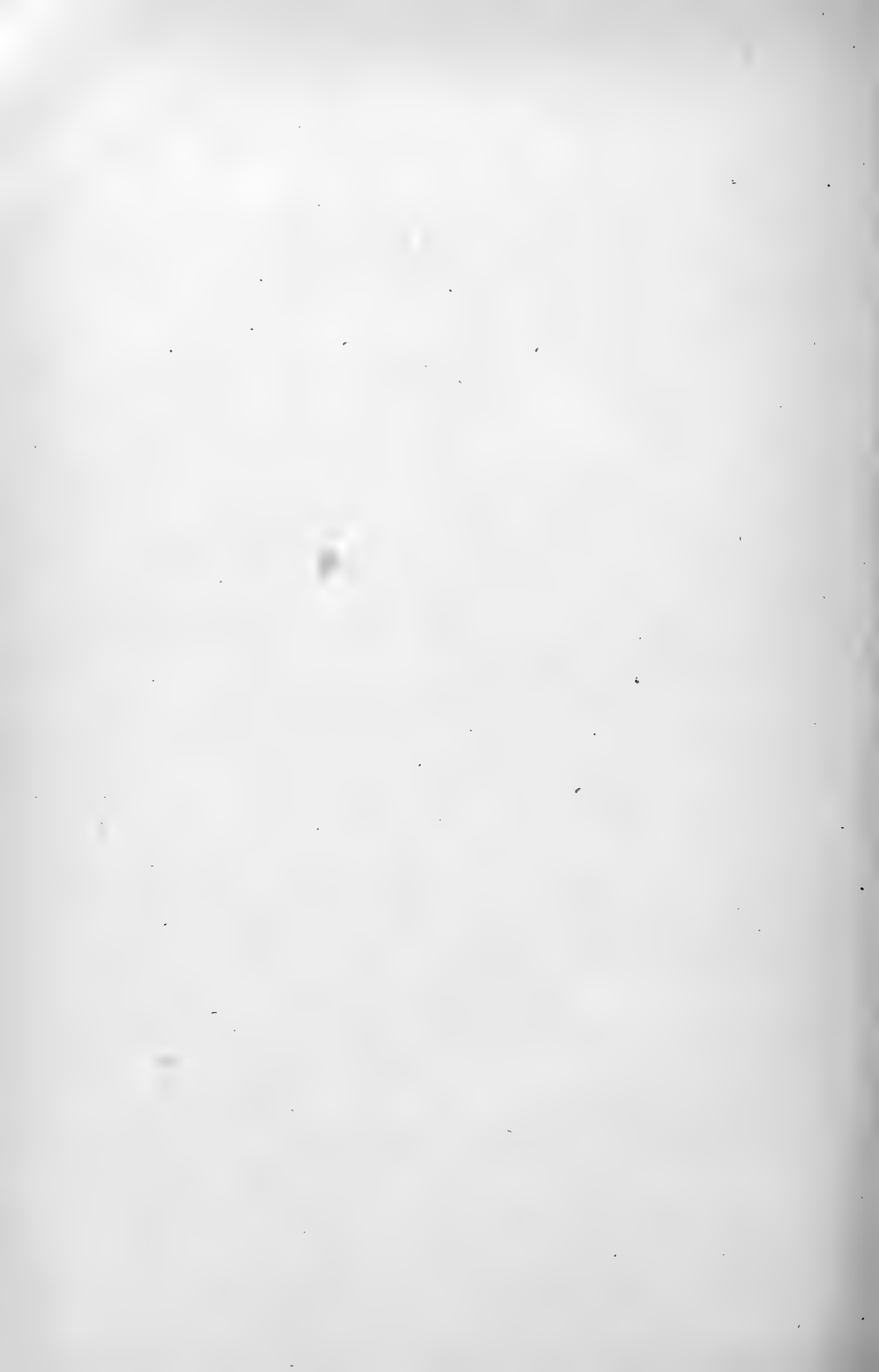
*Gasterosteus cuvieri* (GIRARD).

This partly naked stickleback is the only *Gasterosteus* in the collection. By some authors it is classed as a variety or subspecies of the fully armoured *G. bispinosus*, but the reason is not apparent. Its characters are very uniform over a wide range, including Hudson Bay, and intermediate forms, linking it with the alleged parent species, are not met within this range. These are the essentials of a good species, and entitle it to full recognition as such.

It was found to be common. At stations 1, 3, 8, 10, 11, 12 and 13 collections were made. It does not seem to be limited to tidal pools, creeks, estuaries, and shore waters, but occurs at considerable distances from the coast, as for instance at station 10.

The fish are, on the average, small, the largest being 54 mm. in length, or a little over half the greatest length of *G. bispinosus* in the Gulf of St. Lawrence and Atlantic shore waters of Nova Scotia. The lateral scales are typically 4-4, occasionally 4-5, rarely 5-5; nothing beyond this is seen. They are counted from behind the one under the first dorsal spine backwards.

*G. bispinosus* does not appear in the collection; it is doubtful if it occurs in Hudson Bay at all. In the United States National Museum there is one small collection of *Gasterosteus* from Hudson Bay, but it consists entirely of *cuvieri*; neither is any other found in the collection made there by Rev'd. W. G. Walton in 1919 and examined by the writer.





No. XI

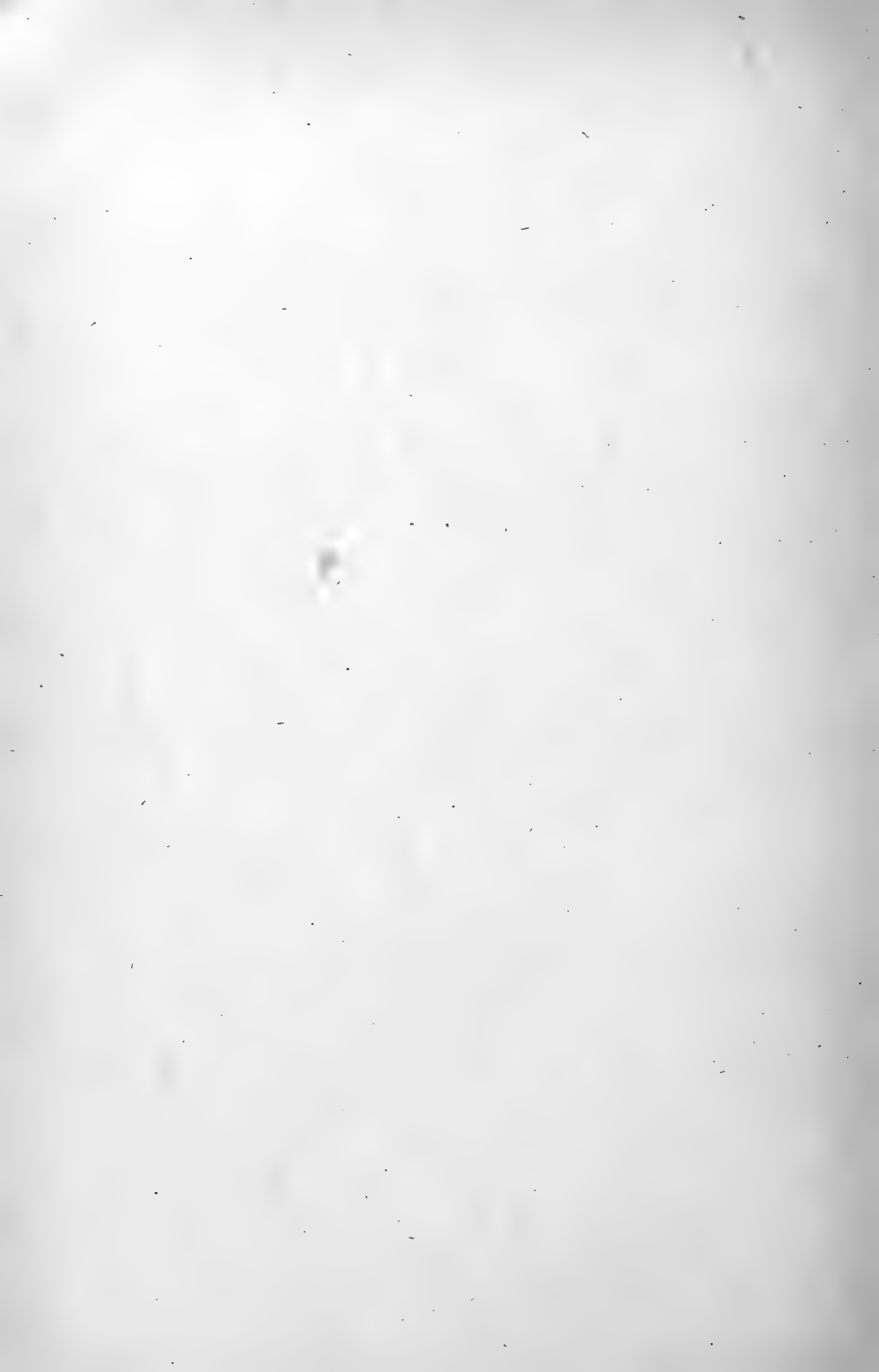
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DIATOMS FROM THE QUILL LAKES, SASKATCHEWAN, AND FROM  
AIRDRIE, ALBERTA

BY

L. W. BAILEY, PH.D., LL.D.

*Fredericton, N.B.*



# Diatoms from the Quill Lakes, Saskatchewan, and from Airdrie, Alberta

BY L. W. BAILEY, PH.D., LL.D.  
*Fredericton, N.B.*

The collections of Diatoms from the two localities named above are of exceptional interest, first from the fact that the lakes referred to are *saline* lakes and contain a number of species of *marine* types not previously found at points remote from the sea, and secondly, as showing that certain forms, previously referred to distinct genera, are in reality different aspects of a single genus and a single species.

## I.

### DIATOMS FROM QUILL LAKES.

The lakes are two in number, viz., Big Quill Lake and Little Quill Lake, and are not widely separated from each other, being situated on the line of the Canadian Pacific Railway, near Kandahar, in the Province of Saskatchewan. Both are saline, receiving fresh water only from local drainage and having no outlet. The salinity in the larger lake is about one half that of sea water or 1.65%, the bases present in the salt being, as in sea water, in order of relative abundance, sodium, magnesium, calcium and potassium. The salinity of the smaller lake is considerably less, and the amount of calcium is also much less. The larger lake is deeper than the other, with drainage from a smaller area coming into it, and in Spring remains frozen for a much longer period. Both lakes occupy simple depressions of the surface, without any distinct evidence of glacial origin. The collections were made by Dr. A. G. Huntsman, of Toronto University in 1920, and to him I am indebted for the foregoing particulars of the locality.

Besides Diatoms, the waters of the Quill Lakes contain very large numbers of Copepods and other Crustacea, as well as Infusoria and fresh water Algae.

The Diatoms are very numerous, as indicated by the lists which follow, these being based mainly upon observations made by the writer and Dr. A. H. MacKay of Halifax, N.S., but supplemented by a few afforded by Mr. H. C. Wheeler of Montreal, Mr. Oliver Kendall, Jr., of Providence, R.I., and Mr. Chas. S. Boyer of Philadelphia. For the measurements of species I am wholly indebted to the labour of Dr. MacKay.

The most interesting feature connected with these collections is that, though found so far inland, they contain not less than six genera or species which are usually regarded as wholly *marine*. These are the following:

*Amphiprora ornata*—Bail.

*Chaetoceras*.

*Pleurosigma elongatum*.

*Thalassiothrix nitzschioides*.

*Cocconeis scutellum?*

*Surirella striatula*, or a closely related species, *S. Baileyana*.

*S. ovalis*, Breb. with its varieties, *ovata* and *Brightwellii*.

It is difficult to account for the presence of these marine forms, none of which, with a single exception, has been previously found in the inland lakes of Canada or elsewhere. The exception is in the case of the genus *Chaetoceras*, a species of which has been found by Mr. Boyer of Philadelphia in the waters of the Devil's Lake of Nevada, also a saline lake, and which has been described and figured by him under the name of *Chaetoceras Elmorei*. It closely resembles, but is apparently not identical with that of the Quill Lakes, and is more fully described below.

It has been suggested that the occurrence of these marine types at a point so remote from the sea and wholly disconnected with the latter may be due to the agency of migratory birds, which are known to sometimes carry organisms of different kinds to long distances, but in this instance we have to consider not a few isolated individuals but large communities, the forms of *Chaetoceras* being present by the thousand, as are the *Surirellas*, which constitute the most abundant as they are the most conspicuous of the species present, while the others, though less numerous, are by no means rare. It is evident that the Quill Lakes are their natural home, as further indicated by the fact that they include reproductive as well as vegetative specimens. If the agency of birds in transportation be accepted as the explanation of their presence it will follow that these brought only a few individuals as the original stock, and these, being active, continued to multiply under the favourable conditions afforded by the salinity of the lakes. The only other supposition would seem to be that they are survivals of a time when the sea actually covered the region in which they are found, possibly in some one of the inter-glacial periods. In the case of the Devil's Lake in Utah, which contains a similar *Chaetoceras*, this is known to be of glacial origin, but that the same is the case with the Quill Lakes has not yet been ascertained.

Another feature of interest in connection with the Quill Lake gatherings is that of the species present at least two, and perhaps three, are believed to be either entirely new or new varieties of species already known. These are the following:

*Surirella Baileyana* MACKAY OR *S. striatula* VAR. *Baileyana* MCK,

(Plate I, Figs. 3 to 5).

Valve broadly ovate, in length from 100 to 185 microns and in breadth varying from 30 to 65  $\mu$ . Often twisted, the twist sometimes confined to the narrower end but often involving the entire frustule as in *S. spiralis* Kutz, or *S. torquata* Pant. Canaliculi distant, 7 to 13 on each side, large and conspicuous, also more or less twisted from a branching symmetry, rectangular to the axis in central portion of the valve, but curving outward toward either extremity. Marginal area strongly lobed. Striation fine, showing lines from 15 to 20 in ten microns, with a marginal row of small points more distant along the outer margin of each lobe. Zonal view showing strong transverse ribs, alternating with small dots.

Localities: Big and Little Quill Lakes, Saskatchewan. Very abundant.

The above species is the most characteristic one in the Quill Lake gatherings. It bears a close resemblance in general aspect and dimensions to *Surirella striatula* Turpen, of which it may be only a variety; but as indicated in the above diagnosis, it differs in important particulars. It also nearly resembles Pantocsek's *S. torquata*, from the marine fossil deposits of Karand, Hungary, the latter exhibiting similar sizes of costae, striae and marginal points, being also similarly twisted. *S. striatula* is a marine species, and besides occurring in the modern ocean is found in the same fossil deposits as *S. torquata*. There can be but little doubt that the form now under consideration is of marine origin. *S. striatula* also occurs in the salt water of the Great Salt Lake in Utah, where varieties like *ovata* and *Brightwellii* of Brebisson's *S. ovalis* are found. These marine forms are found in the Quill Lakes, if not also a variety *Quillensis*, as distinct as Grunow's variety *S. ovata* K. var. *Utahensis*, which is nearly identical with *S. ovalis* Breb. var. *Brightwellii* Sm.

*Cyclotella Quillensis*, L. W. BAIL.

(Plate I., Fig. 1).

Valves circular, in the form of low vaulted domes, of which the surface is sometimes slightly undulated. The size varies from 50 to 70 microns. Striae radiant as in *Cyclotella compta*, but arranged in three or four concentric circles, of which the outer has the character of ribs rather than striae, being strong and more or less distinctly pearly, while the second is much fainter and the third visible only with high powers. Even a fourth circle can sometimes be made out, approaching the apex of the low zone. The number of marginal ribs is about 6 in 10 microns, and from these, in many cases, spring spines from one to two microns long, thus bearing a close resemblance to *Stephanodiscus*. Minute nodules are sometimes visible at the inner end of the second, third or fourth zone of radiating striae. The centre of the dome is usually smooth, but sometimes shows a number of dots irregularly arranged. The species is larger than *C. Kutzingiana* or *C. compta*, being more like *C. Meneghiniana*. The marginal radial ribs look as if they might have been developed from striae originating like those of *S. astrea* or *S. Niagarae*, while the fainter second circle is not continuous with these, but appears to spring from an inter-rib depression.

Localities: Big and Little Quill Lakes, Saskatchewan.

*Chaetoceras Quillensis*, L. W. BAIL.

(Plate I., Fig. 2).

Primary frustules quadrate, concatenate, in zonal view from 4 to 16  $\mu$ , in valval view 6 to 18  $\mu$ . Secondary valves unlike, the surface of one rising into a well marked dome, while the second, by a marked constriction becomes bottle-necked. Between one frustule and another extends in some instances a small tube, connecting dome with dome as in *Chaetoceras Elmorei*, Boyer. Setae 4 to each frustule, straight, 100 microns or more in length, crossing at joints and making angles of less than 60 degrees. Foramina narrowly linear.

Locality: Quill Lake, Saskatchewan.

Specimens of *Chaetoceras* are very abundant in some of the Quill Lake gatherings, though apparently wanting in others. They occur in both lakes and probably include more than one species. That described above closely resembles the form described and figured by C. S. Boyer under the name of *Chaetoceras Elmorei*, as found in the Devil's Lake, North Dacotah—which, like the Quill Lakes, is saline—but others appear to differ.

Excepting in the Devil's Lake locality no species of the genus *Chaetoceras* has heretofore been found in any inland waters, unless it be those of the Caspian Sea. It is also to be noticed, as bearing upon the theory of transportation by birds, that the species in question is wholly different from any other forms as yet observed upon either the Atlantic or Pacific sea boards of America or elsewhere.

LIST OF DIATOMS FROM LITTLE AND BIG QUILL LAKES, SASKATCHEWAN.\*

- Amphiprora lepidoptera* Greg. 85 (42:30:42) s20.  
*Amphora commutata* Grun. 56 (11) s10.  
 " *ovalis* K. 33 (15) s13.  
 " *salina* W. Sm. 26 (6) ?  
*Campylodiscus clypeus* E. 210 (210) s1; 110 (110) s2 and 12.  
*Chaetoceras Quillensis* (nov. sp.) z16 (15); z13 (12); z4 (15). Setae 100 plus, crossing at joints making angles of less than 60. Valval view 18 (10) 13 (6), 9, 6.  
*Cymbella ehrenbergii* K. 45 (10) s10.  
 " *tumida* Breb. 62 (5:15:5) s8.  
*Cyclotella compta* (E) K. 25 (9:7:9) s6 and 18.  
 " *compta* var. *affinis* Grun. 23 (6½:10:6½) s10.  
 " *Quillensis* (n. sp.) 50 (50) s6; 75 (75) s6.  
*Encyonema* ? 26 (7) s16.  
*Epithemia gibba* K. 130 (5:8:5) s6; 90 (7:10:7) s5.  
*Eunotia pectinalis* var. *undulata* Ralfs. 82 (7) s10.  
*Fragillaria virescens* Ralfs. 32 (45/11) s18.  
*Gomphonema capitatum* E. 70 (7:10:20:15) s8.  
*Mastogloia lanceolata* Thew. 58 (3:11:3) s0.  
 " *Smithii* Thew. 30 (10) s16.  
 " " var. *lacustria* Grun.  
*Melosira granulata* (E) Ralfs. z15 (12) s8; 29 (12) s12.  
 " *distans* K. z16 (40/5) s16.  
*Navicula acrospheria* var. *sandricensis* A. S. 94 (13:9:16:9:13) s10.  
 " *ammophila* Grun. (or *mollis* Sm.) 29 (7) s11. Doubtful  
*Navicula anglica* Ralfs. (Doubtful.) 35 (4:15:4) s13.  
 " *bacilliformis* Grun. 38 (9:9:9) s20.  
 " *crucicula* W. Sm. 48 (5:15:5) s17.  
 " *cryptocephala* K. 40 (3:10:3) s12.

\*For explanation of formulæ see last page.

- Navicula forcipata* Grev. 30 (11) s20. Too small (and marine) to be the sp. but has a resemblance. Only one specimen.
- “ *Grevillei* Ag. 55 (5:15:5) s10 and 20.
- “ *iridis* E. 75 (23).
- “ “ var. *producta*? 50 (3:12:3) s16.
- “ *major* K. 190 (25:28:25) s7.
- “ *mesolepta* E. 60 (8:12:9:12:9:12:8).
- “ *oblonga* K. 72 (9:11:9) s10. A small variety.
- “ *ovalis* Hilse, 56 (34) s8 and 12.
- “ *Quillensis* (nov. sp.) 110 (10:30:10) s13.
- “ *scutellum* O.M. (?) 33 (16) s14.
- “ *tenella* Bréb. 29 (2:6:2) s10.
- Nitzschia hungarica* Grun. 60 (. . 11:12:11. .) s16 and 8.
- “ *thermalis* (K) Grun. 48 (3:5:3) s16 and 0 (?).
- “ *tryblionella* Hantzsch. V. *calida* Grun.
- Pleurosigma attenuatum* W. Sm.
- “ *accuminatum* (K) Grun. 120 (4:14:4) s20. Sigmoid.
- “ *elongatum* W. Sm. 260 (5:25:5) s17.
- Rhoicosphenia curvata* Grun. 30 (5:10) s14.
- Stauroneis crucigera* Sm. 45 (5:14:5) s20 and *stauros*?
- “ *salina* W. Sm. 45 (13) s20 and St.
- Tabellaria fenestrata* K. 68 (6:3½:8:3½:6) s17.
- Swirella ovalis* Bréb. 95 (66) s3 and 18; 62 (33) s3 and 18.
- “ “ var. *ovata* K. 80 (60) s4 and 18; 50 (40) s3 and 18.
- “ “ “ *Brightwellii* Sm. 58 (51) s3 and 18; 40 (28) s3½ and 18.
- “ “ “ *Crumena* Breb. Nearly circular (?).
- “ “ “ *minuta* Breb. Like *Brightwellii*, but smaller (?) 25 (19).
- S. Baileyana* MacKay 155 (107) s1 and 5 and 18; 100 (80) s75 (53) s2 & 18.  
Very abundant and contorted or twisted.
- S. biseriata* Bréb. 160 (30:45:20) s2.
- S. limaris* Sm. var. *constricta* 55 (14:13:14) s3.
- Synedra acus* (K) Grun. 82 (3:5:3) s16; 100 (2:6:2) s16.
- “ *danica* (K) 110 (1½:1:4:1½) s12.
- “ *pulchella* (K) 72 (6) s16.
- “ *nitzschoides* Grun. 70 (3). (See *Thalassiothrix*.)
- “ *ulna* E. 83 (3:6:3); 72 (3:7:3) s17.
- Thalassiothrix nitzschoides* Grun. 70 (3); 45 (3) s13; 32 (4) s13.
- Vanheurckia vulgaris* Thw. 50 (5:9:5) s?; 40 (5:9:5) s?; 30 (5:9:5) s?; 23 (4:8:4) s?

## II.

## DIATOMS FROM AIRDRIE, ALBERTA

- The diatoms in the list following were found in a collection made by Mr. H. C. Wheeler from a ditch near the C.P.R. track at Airdrie in November, 1920.
- Amphora ovalis* K. 33 (9) s10.
- “ “ var. *affinis* K. 30 (6) s12.

- Cocconeis oblonga* K.B. (?) 18 (14), 18 (10).  
 " *pediculus* E. 20 (15) s20.
- Cyclotella Meneghiniana* K. (?) 22 (22) s8.  
*Cymbella lanceolata* E. 80 (7:20:7) s6-7. Frequent.
- Encyonema* ———(?) Small variety.
- Epithemia gibba* (E) K. 190 ( ) s7 and 14. Abundant.  
 " " var. *parallela* Grun. (?).  
 " " var. *ventricosa* Grun. 94 (8:7:11:7:8) s5.  
 " *Hyndmani* W. Sm. (?).  
 " *turgida* (E) K. 110 (7:15:7) s8. Very abundant.  
 " " var. *vertagus* Grun. (?).  
 " *Westermanni* (E) K. (?) 87 (8:18:8).  
 " *zebra* (E) K. 43 (4:10:4) s12. Abundant.
- Gomphonema acuminatum*, var. *elongatum* W. Sm. Common. 47 (3:5:4:8:5:9:4) s10.  
 " *intricatum* (?).  
 " *lanceolatum* (?).  
 " *turris* E. 58 (4:13:10:5) s6 to 9. Frequent.
- IIantzschia amphioxys* Grun. 55 (2:8:8:2) s19. Frequent.  
 " *amphioxys* Grun. var. *intermedia* Grun. 60 (3:10:3) s6 and 16; 71 (3:2:8:2:3) s6 and 15; 80 (3:15:3) s6 and 13. Frequent.  
 " *amphioxys* var. *major* Grun. 182 (5:14:5) s6 and 12. Frequent.  
 " *amphioxys* var. (?). 80 (3:2½:11:2½:3) s3 and 15. Approximating *H. virgata*.
- Melosira* (?) Rare.
- Navicula bipunctata* Grun. (?) 30 (6:6:6:6:6) 20s.  
 " *cuspidata* K. f. *radiata* 124 (4:26:4) s9 to 14.  
 " " f. *parallela* 103 (4:24:4) s14.  
 " " " (craticulated) 78 (3½:20:3½) s14, 80 (4:18:4) s14.  
 " " var. *ambigua* E. f. *radiata* 54 (4:3:13:3:4).  
 " " " f. *parallela* 75 (4:4:19:4:4) s14, 98 (5:21:5) s16. Craticulated.  
 " " var. *Kendalli*, f. *radiata*, 115 (9:26:9) s8 to 12, 120 (5:23:5) s6 to 12.  
 " " " f. *parallela*, 150 (11:31:11) s10, 165 (14:32:14) s12, 175 (12:33:12) s11, 180 (14:33:14) s12.  
 " " " " Craticulated, 142 (10:27:10), 155 (11:29:11), 163 (11:31:11), 184 (11:30:11).  
 " *lacunarum* Grun. 40 (8) s20. Rare.  
 " *oblonga* K. var. (?) 104 (13) s7. Rare.  
 " *parva* E. 65 (9:9:9) s8 to 10. Not rare.  
 " *pupula* K. 36 (7:7:8:7:7) s20.  
 " *viridis* K. 100 (19) s7. Common.



*Navicula* ———(?) , z35 (8:7:8) s10, v37 (8:7:8) s9. May be a new species not distant from *N. borealis*.

*Nitzschia amphibia* 17 (1:4:1) s8 and 16. Not rare.

“ *vermicularis* (K) Grun. 100 (4½) s8 and ?. Not common.

“ ———(?) 103 (10:15:13:15:10) s4½ and 13. Not rare. May be new.

“ ———(?) 32 (5) s7 and 15. Rare.

*Stauroneis phoenicenteron* E. Rare.

*Synedra ulna* E. Rare.

The most interesting feature of this collection is that it affords positive proof that two Diatoms previously referred not only to distinct species but also to two distinct genera are in reality but two different plates of a single species. The two forms thus regarded as being even generically different are *Navicula cuspidata* K. and *Surirella craticula*—both of similar shape and dimensions, but with the sculpture of the former consisting only of fine striae, closely approximated and rectangular to the raphe, while the second exhibits a surface which is strongly and irregularly craticulated. In the Airdrie collection both of these are found rather abundantly, but with them are others less abundant, in which the features thus referred to are both found in the same specimens, difference of focussing being all that is required to bring the one or the other into view, as may be desired. By the same focussing the craticular form of *Surirella craticula* is proved to be the inner plate of *Navicula cuspidata*.

Dr. MacKay, on the receipt of a mounted sample of this collection from Mr. O. Kendall of Providence, R.I., U.S.A., accompanied by photomicrographs herewith reproduced, maintains that a diatom of the *Navicula cuspidata* group, which abounds in a conspicuously fine craticulated form, is of co-ordinate specific or varietal value to *ambigua* E., *halophila* Grun. and its larger variety *major* Heribaud, and to *Perrotettii* Grun. of Senegal, which it most nearly approaches. (See Schmidt's Atlas, 221:33). Instead of adding to the number of species he takes at present the more conservative course of treating all these forms as varieties of the species *cuspidata*. On the other hand he is equally ready to allow them as species of the *N. cuspidata* group. *Ambigua*, in both the normal and craticulated form, is sharply distinguished from the others by its rostro-capitate ends, and the others by the rounding out of the rostrate ends of the type *cuspidata*.

These three other forms are of a similar type. Tapering from more or less narrow but rounded ends they swell more or less evenly to a maximum breadth at the centre, the exact dimensions of which can be comparatively shown in Dr. MacKay's notation as follows:\*

*N. halophila* Grun. 50 ( :10: ) s19 to 70 ( :12: ) s20.

*N. halophila* V. *major* Her. 110 (4:17:4) s16 to 136 (4:20:4).

*N. Perrotettii* Grun. 175 (16:41:16), Schmidt's Atlas, 211:33.

\* The numbers are microns—the length standing first, the breadths at the principal points of flexure along the margin of the valve being within the parenthesis separated by colons. The letter “S” following stands for “sculpture” and the number following for the number of lines or dot elements in the sculpture in the space of ten microns.

*N. Kendallii* (nov. sp.) 142 (10:27:10) Crat., 180 (14:33:14) s12 to 184 (11:30:11)  
s11 to 12.

*Halophila*, meaning "salt loving," is given in Paragallo's Marine Diatoms of France as found in brackish water in France, Belgium and England. *Perrotettii* and *Kendalli* may be the same possibly, the one from Senegal, the other from Alberta.

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## ADDENDUM

BY

A. H. MACKAY

The varieties and forms of *Navicula cuspidata* Ktz. from Airdrie were described before I had obtained Cleve's *Synopsis of the Naviculoid Diatoms, 1894*; the works of Héribaud and his collaborators on the diatoms of Auvergne, France (1893 to 1920); and the work of Pantocsek on the diatoms of Hungary, etc.

Cleve reduces all our forms to three species:

*halophila* Grun. (1881),  
*cuspidata* Ktz. with a few varieties, and  
*Perrotettii*.

In the Diatoms of Auvergne the following species are described:

*cuspidata* Ktz.  
*halophila* Grun.  
*ambigua* Ehr.  
*Héribaudi*, Peragallo  
*Aubertii*, Hérib.  
*Bouhardi*, Hérib. and

seven varieties of *N. halophila*, and three of *N. cuspidata*. Nearly all of these appear to be covered in our Airdrie list where the condensation is greater than Cleve's. This scheme appears also to include nearly all the varieties of Auvergne, except possibly the smaller varieties from the tertiary travertins.

Pantocsek's single specimen of *Craticula hungarica* from a tertiary marine deposit in Hungary is identical with our largest Airdrie specimen of *N. cuspidata* var. *Kendalli*. forma *parallela* (craticulated). His *N. protracta* Grun. var. *minor* Pant. is a small form of our var. *ambigua* f. *radiata*.

When the valve is cuspidate we have the original specific form. When the cusps become capitate we have the variety *ambigua*. When there are no cusps or capitate ends, and the valves taper evenly to rounded ends, we have the variety *Kendalli*, so called on account of the splendid photo-micrographs made of a number of specimens by Mr. Kendall, the best of which were received after the photogravures of the first were made. Each of these varieties has been found with the *parallel* striation and the central *radiate* striation, to the last of which *N. heribaudi* Peragallo is referable. The specimens so well photographed by O. Kendall, Jr., were collected by one of the most promising Canadian diatomists, E. C. Wheeler, of Montreal.

When these forms of the *N. cuspidata* group from over the world are ultimately compared, the precedence of nomenclature will undoubtedly be acknowledged if compatible with the scientifically ascertained relationship of the forms. Grunow's *N. halophila* is a very appropriate name for the salt-loving, even-tapering forms of the group, but the original is a very depauperate form of the Airdrie diatom from central Canada or of the marine *Craticula hungarica* Pant. from the tertiary deposits of central Europe.

Pantocsek's *Surirella torquata*, which is well figured, but too briefly and indefinitely described, approaches in some respects Boyer's *S. Baileyana*, and was found in a marine tertiary deposit in Hungary.

PLATE I.

- Fig. 1.—*Cyclotella Quillensis*, L. W. Bailey, n. sp.  
Fig. 2.—*Chaetoceras* n. sp.?  
Fig. 3.—*Surirella Baileyana*, flat form.  
Fig. 4.—*Surirella Baileyana*.  
Fig. 5.—*Surirella Baileyana*, doubled.  
Fig. 6.—*Surirella Baileyana*, partly twisted.

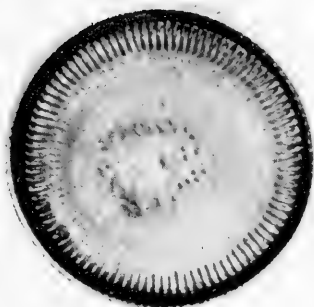
PLATE II.

- Fig. 1.—*Navicula cuspidata* K. var. *ambigua* E.  $\times 600$ . Measurements 88 (5:4:24:4:5).  
Fig. 2.—*Navicula cuspidata* K. var. *Kendalli* McK. (Showing the striated valve and craticular plate.)  $\times 457$ . Measurements 153 (13:33:13).  
Fig. 3.—*Navicula cuspidata* K. var. *Kendalli* McK. (craticulated).  $\times 455$ . Measurements 195 (13:39:13).  
Fig. 4.—*Navicula cuspidata* K. var. *Kendalli* McK., f. *parallela*.  $\times 452$ . Measurements 184 (12:38:12) s10 to 12 or 18.  
Fig. 5.—*Navicula cuspidata* K. var. *Kendalli* McK., f. *radiata*.  $\times 456$ . Measurements 177 (11:33:11) s7 to 12.

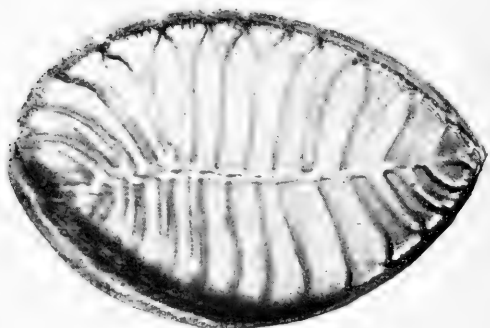
All the above examples of *N. cuspidata* were collected at Airdrie, Alberta, by H. C. Wheeler and photographed by O. Kendall.

Bailey. Diatoms from Quill Lakes and Airdrie.

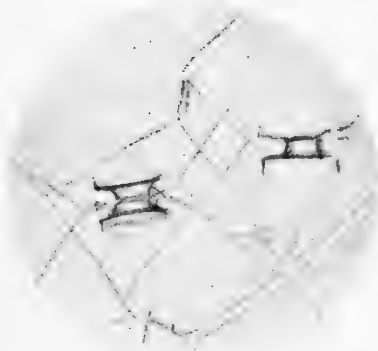
PLATE I



1



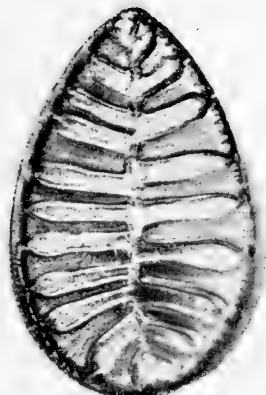
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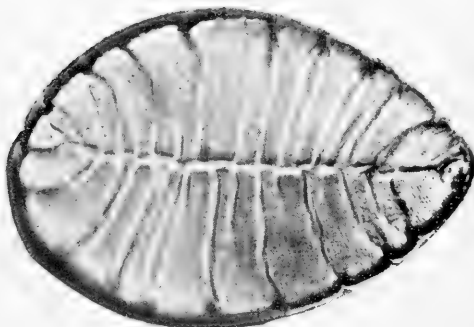
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5



3



6

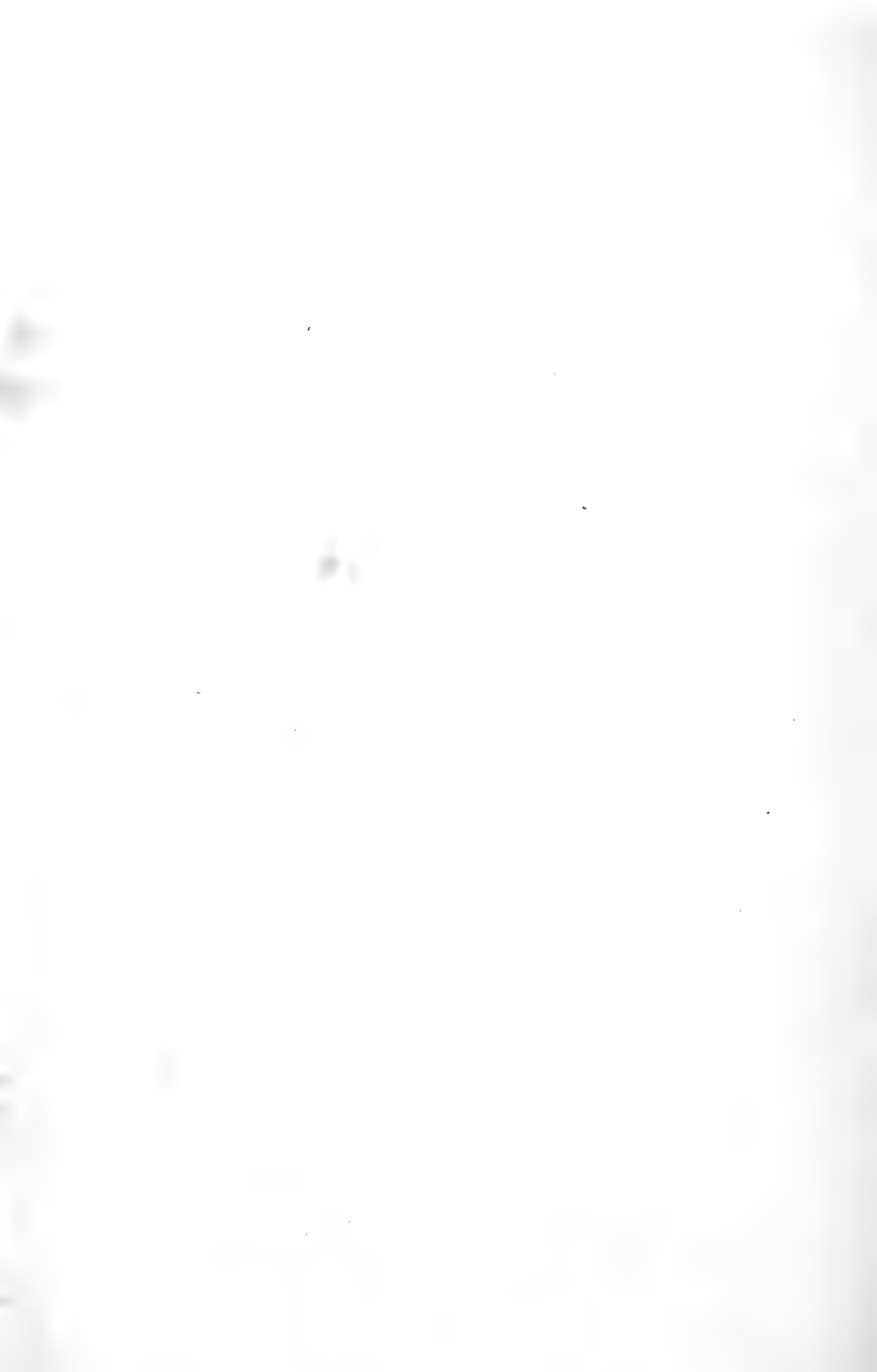
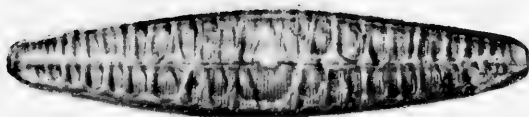


PLATE II.



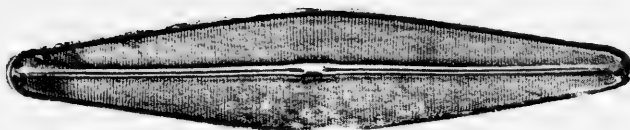
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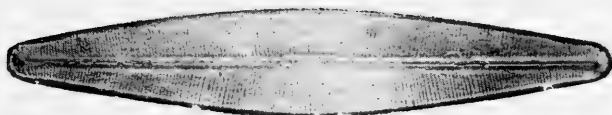
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4



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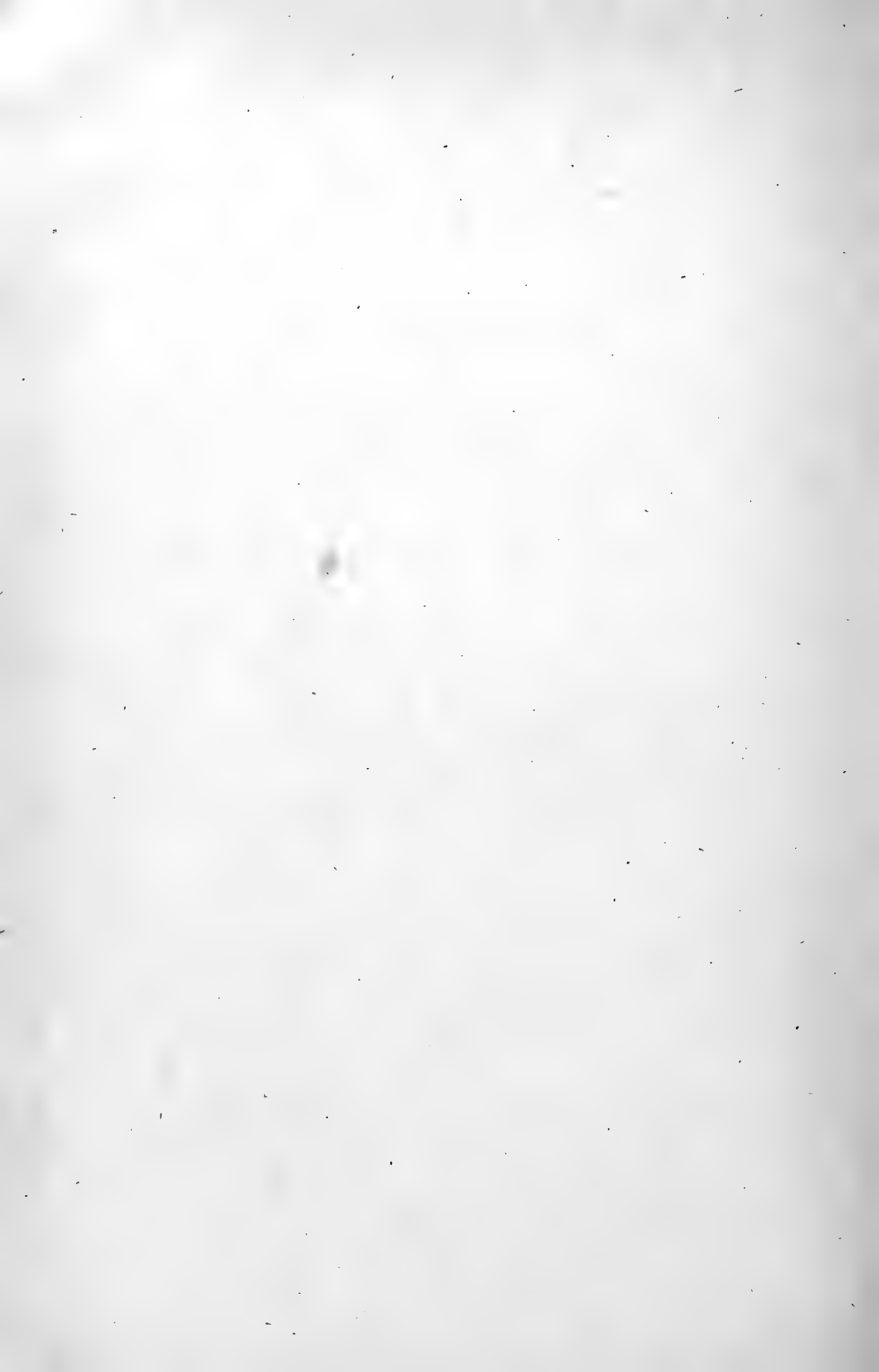
No. XII

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LIST OF PUBLICATIONS BASED ON RESULTS OBTAINED AT THE  
BIOLOGICAL STATIONS OF CANADA, 1901-1921.

COMPILED BY

A. G. HUNTSMAN AND C. M. FRASER



## List of Publications based on Results obtained at the Biological Stations of Canada, 1901-1921.

COMPILED BY A. G. HUNTSMAN AND C. M. FRASER

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