CONTRIBUTIONS

TO

CANADIAN BIOLOGY

BEING STUDIES FROM THE

BIOLOGICAL STATIONS OF CANADA

New Series. Volume I.

Nos. 1 to 25

THE BIOLOGICAL BOARD OF CANADA

Professor A. P. Knight, Department of Fisheries, Chairman.
Professor E. E. Prince, Commissioner of Fisheries, Secretary.
Professor J. P. McMurrich, University of Toronto, Editor.
Professor A. H. R. Buller, University of Manitoba.
Professor C. J. Connolly, St. Francis Xavier College.
Professor P. Cox, University of New Brunswick.
John Dybhavn, Esq., Prince Rupert.
Very Rev. Canon V. A. Huard, Laval University.
Professor W. T. MacClement, Queen's University.
Dr. A. H. MacKay, Dalhousie University.
Professor R. F. Ruttan, McGill University.
A. M. Whitman, Esq., Halifax.

UNIVERSITY OF TORONTO PRESS
1924

CONTENTS

(Published July 24th, 1922)

(Published February 24th, 1923)

(*Published March 24th, 1924*)

No. 1

A STUDY OF THE LUMPFISH (*CYCLOPTERUS LUMPUS* L.)

BY

PHILIP COX, PH.D.

AND

MARIAN ANDERSON, B.A.
University of New Brunswick

A Study of the Lumpfish (*Cyclopterus lumpus* L.)

By Philip Cox, Ph.D.,

and

Marian Anderson, B.A.,
University of New Brunswick

1. INTRODUCTION

The Biological Board of Canada sent an expedition to northern Cape Breton and the Magdalen Islands, in the summer of 1917, to study the general hydrographic conditions of the Gulf of St. Lawrence as they affect the fisheries of that region, as well as to investigate the life histories of the staple food fishes, and of the other fishes that have not heretofore been utilized in Canada. It was under the direction of Dr. A. G. Huntsman, Curator of the Atlantic Biological Station, St. Andrews, N.B., who had associated with him Mr. Frits Johansen, lately of the Stefansson Canadian Arctic Expedition, and Dr. Philip Cox, of the University of New Brunswick.

The study of the Lumpfish (*Cyclopterus lumpus* L.) was begun in June, continued for a time in September at St. Andrews on Passamaquoddy Bay, and finished during the ensuing winter. Besides giving as full an account as possible of its life history, by bringing together whatever was available in the literature of the species, and adding thereto the results of our observations, it aimed at investigating the claims of the fish to be regarded as of economic importance for food purposes and the possibility of introducing it to the Canadian consumer. This latter part has already been published in a separate article.

It is a pleasing duty to acknowledge our obligations to the late Jas. M. Macoun, of the Geological Survey of Canada, for specimens loaned for study, and to the members of the expedition for the valuable help they cheerfully gave on all occasions.

2. GENERAL CHARACTER AND SYSTEMATIC PLACE AMONG FISHES

The lumpfish owes its name to its short, swollen and tadpole-like body, a feature which it shares with the sculpins, or Cottidæ, of which it is a near relative and from which it is separated on grounds of scarcely more than generic value. It is made, however, the type of a special family, the Cyclopteridæ, and of the genus *Cyclopterus*. The ventral fins, generally reduced much below the normal in the sculpins, are here united into a sucking disk by means of which it attaches itself to the bottom or to floating objects. Another feature in which it diverges from the Cottoids is seen in the greatly reduced gill opening. The body is covered with small tubercles, as is the case with sculpins, and seven longitudinal rows of large ones occur—one in the median line dorsally, two laterally, and one ventrally on each side.

The anterior dorsal fin, consisting of weak spines, disappears early in life beneath the rising thick skin, which forms a hump, and renders the dorsal outline very convex. The head is short and decidedly blunt, and the pectorals and caudal are large, with wide bases—another cottoid character.

The skeleton is not well ossified, indeed it is best described as cartilaginous. The vertebral axis is very irregularly segmented, long and short vertebræ being mixed in the series. The pyloric cæca are numerous, and the body cavity extends well beyond the anus. The teeth are numerous and weak, and confined to the jaws. The form and structure suggest a fish of sluggish habits and circumscribed range, feeding on small, weak organisms.

3. GENERAL DISTRIBUTION

The lumpfish is found in the Atlantic littoral of North America, from Greenland to New Jersey, penetrating bays and channels, and even extending its range into the great Canadian inland sea of Hudson Bay. The most northern record is Isle Disko, lat. 70 N., and its most southern lat. 37 N. (Mouth of Chesapeake Bay, Gill, 1907, p. 182), hence its southward range is greater along the American coast than on the European side, where it is seldom found below 45°.

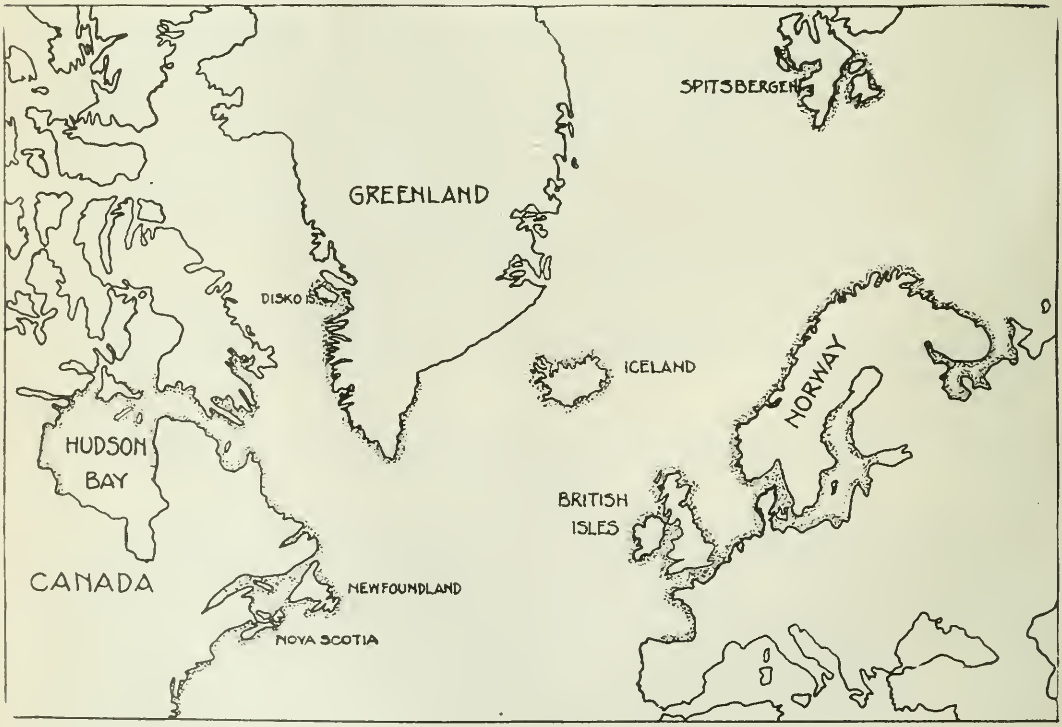


Fig. 1. Chart of the North Atlantic showing the distribution of the lumpfish in the dotted zone along the coast.

The vertical distribution is not well known. Ehrenbaum records captures in "150 to 200 fathoms," 1905, p. 116; Meek "in 150 fathoms on the coast of Norway," 1916, p. 359; and Smiley "on trawls off the coast of Iceland," 1885, p. 60. The crew of the motor boat "Prince" has failed to find any in more than a few fathoms, but collected great numbers among wrack and other drift material 15 miles from land in the Bay of Fundy, where the water was 112 fathoms or more in depth. This form of pelagic life is only an extension of that of the shallow shore waters, and may account for the European occurrences noted above.

The seasonal distribution is the result of two general movements, one shoreward in April and May, the other seaward in late autumn. Winter occurrences are very rare in our latitudes. The crew of the *Prince*, whose seining and net trawling operations have extended through several winters, has recorded only one occurrence, namely, 2 specimens, 41 and 45 mm. long, at Grand Manan, December 12, 1917. Fish of all ages and sizes participate in these migrations, at least in the Bay of Fundy.

4. DISTRIBUTION IN CANADIAN WATERS

In summer an abundance of lumpfish of all sizes occurs in Passamaquoddy Bay and about the islands of the western archipelago of the Bay of Fundy, living along the shore, and especially in the masses of seaweed, that are ever

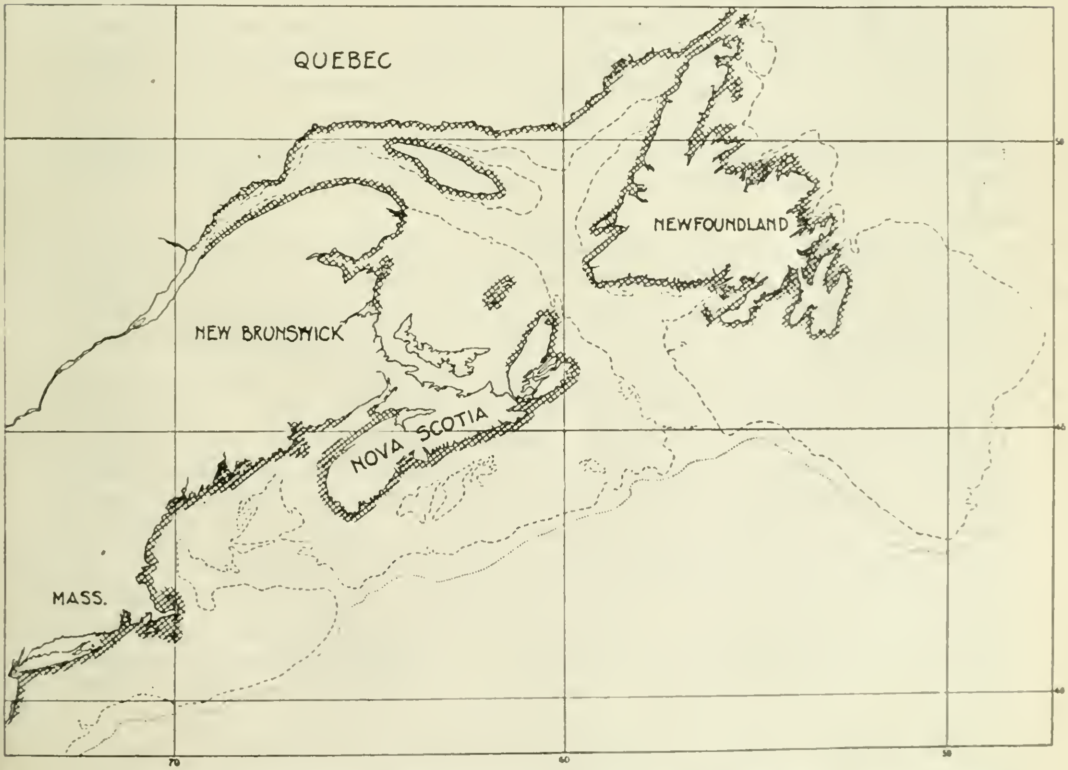


Fig. 2. Chart of Canadian Atlantic coast, the squared lines showing the area inhabited by the lumpfish.

drifting back and forth, and swarm with the animal life on which it feeds. Under similar conditions it is found also in the lower and outer part of the Bay of Fundy as far as the coast of Nova Scotia. The whole of this region seems well adapted to the life requirements of the fish, whose advantages would appear to lie in a generally low water temperature, fairly high salinity, and rocky shores overgrown with wrack and various seaweeds, which provide a suitable habitat for the sedentary period, as well as the material that makes the drift or pelagic life a feature of these waters.

While straggling and generally immature specimens are occasionally obtained in St. John harbour, the lumpfish does not appear to penetrate the upper part of the Bay on the New Brunswick side. On the opposite, or Nova Scotia shore, it is said to be found farther up. The large volume of fresh water poured into the Bay from New Brunswick may in part be the cause of the difference.

The frequent records for the Atlantic coast of Nova Scotia leave little doubt that the lumpfish is fairly common in the shore and off-shore waters from the mouth of the Bay of Fundy to Scatari Island at the eastern end of Cape Breton: (J. M. Jones, F.R.S., 1879, p. 89; M. H. Perley, 1852, p. 218; D. H. Storer, 1850, p. 269; Cornish, 1907, p. 89; Kendall, 1909, p. 217). Between Scatari and Cape North great numbers are caught in the salmon nets and haddock traps in May and June, and it has been observed at many places in the Gulf of St. Lawrence: "Numerous in the Gulf off Cape Breton," Whiteaves, 1873, p. 120; "Miscou Island, N.B.", F. P. Loggie (communicated); "Gaspé," Stafford, 1912, p. 65; "Shores of the River (St. Lawrence) and Gulf . . ." and "along the coast as far as Trois Pistoles," Fortin, 1864, p. 25; "cette espèce arrive (at Anticosti) pour frayer dans la seconde quinzaine de Mai," Schmitt, 1904, p. 286; "Cape Cormorean, N.F.L., Gulf of St. Lawrence," Kendall, 1909, p. 217.

The following records for more northern Canadian occurrences may be of interest to students of ichthyology. Packard found it in the Straits of Belle Isle (1866, p. 273); Storer writes that it occurs "sparingly at Red Bay, Labrador, but plentiful at Bras d'Or, adhering to masses of seaweed," 1850, p. 269; "Bean found it at Chimo, Ungava Bay," Kendall, 1909, p. 233; "A small example of this species was obtained by Mr. Scudder in Davis Strait," Dresel, 1884, p. 250.

Bean also noticed it at Godthaab harbour, Isle Disko, the most northerly station on this side of the Atlantic from which it has been reported (Bean, 1879, p. 115). Its occurrence at Port Churchill, Hudson Bay, has already been mentioned, and W. G. Walton collected some fry at Gray Goose Islands, on the east side of James Bay, in September, 1919, which the writers examined. 140 years ago for Greenland, Fabricius wrote as follows: "Habitat numerosus satis passim in mari groenlandico; mense Aprili vel Maio, littora saxea sinuum ulvis maioribus vestita accedit generandi gratia. . . . Tempore autumnali profundiora maris petit; hieme non obvius; non singulo anno pari multitudine" (1780, pp. 131-2).

The lumpfish, then, is very widely distributed and occupies an enormous range of littoral extending over 30° of latitude on the American side of the Atlantic; and when allowance is made for the striking sinuosities of the coast, due to bays, gulfs, inlets, islands and peninsulas, one is within the mark in estimating the total at 10,000 miles.

5. ANNUAL MIGRATIONS

No fact is more generally noted or commented on by collectors and students of this species than its annual migration to and from the shore waters. The time at which it begins on the American coast cannot be said to be definitely known; for European waters, more extensive and accurate observations are available. In the North Sea and neighbouring waters the spawning period is singularly protracted, extending in some places from January to May (Ehrenbaum, 1905, p. 116); in others, from February to May (McIntosh and also Fulton in Gill, 1907, p. 185), while Möbius and Heincke (1884, p. 226) assign the beginning of May for the Baltic, and Schneider (1900), May to June for Finland (after Apstein, 1910, p. 454.) "The first specimens were brought to the laboratory on the 28th February but as some of them had advanced embryos, it is clear that deposition must have occurred some time previously" (McIntosh, 1885, p. 60).

The anadromous movement does not seem to begin so early nor last so long in American waters; yet on this point there is much uncertainty, owing to a regrettable lack of definite information. Whenever some shore fishery makes known the presence of the lumpfish the migration is said to have begun. As a matter of fact it may have been in operation for some time, as will be shown later when discussing spawning and development of the young.

The expedition to northern Cape Breton and the Magdalen Islands, sent out by the Biological Board of Canada in the summer of 1917, took no lumpfish between 3.3 cm. and 28 cm. in length; all the spawning fish ranged from 30 to 34 cm. There the stock of intermediate sizes does not appear to share in the migration, nor does it make its appearance in the in-shore waters during the season. This raises the question of the age and size at which the lumpfish reaches maturity, about which little is on record. Dr. Fulton's data were derived from fish taken in salmon nets through which the undersized individuals may have escaped, but he found that the males averaged a little above 27 cm., the females about 40 cm. (Gill, 1907, p. 187). Unless stimulated by an increasingly gravid condition and the desire to deposit its spawn, we may assume that the lumpfish, like many other anadromous forms, will not forsake its usual feeding grounds or a well-conditioned environment for a less favourable one, differing in salinity, pressure, and especially temperature; for the shore waters in the Gulf become very much warmer than in the Bay of Fundy, where individuals of all sizes consort during the summer. Immature fish and individuals under 25 cm. in length seem to remain offshore in the Gulf, but in what depth of water or on what kind of bottom is not known. In the Bay of Fundy, however, the summer distribution is in-shore and off-shore near the surface.

Investigations in European waters seem to confirm the belief that, during summer and autumn at least, large and small individuals do not consort on the same grounds.

"In the year 1901, the Baltic, from Rügen to Gotland, was thoroughly investigated by the Deutscher Seefischerei-Verein from August 30 to October 19. During this period, according to Heidrich (1902), 79 hauls were made with the large 'kurre' (Otter-trawl?). In these 79 hauls 466 sea-hares (Lumpfish) were taken. . . . On the average a sea-hare weighed 134 gms., which would correspond, according to Schiemenz (1902, Tab. 20b, p. 278), to a fish about 15 cm. in length . . . the majority from 16 to 19 cm., the largest 22 cm." (Apstein, 1910, p. 454). He had previously purchased one at Kiel in June, length 33 cm., probably a spawning fish. Though the lumpfish does not attain the size in the southern Baltic that it does on the Swedish coast (52 cm., Lilljeborg in Apstein, 1910, p. 454), in the Skagerack (51 cm. Apstein), or on the English coast (70 cm. Day, in Apstein, 1910, p. 454), yet the indications there point to a separation of the spawning and non-spawning fish in late summer and during the autumn.

Its almost entire exclusion from the south-western part of the Gulf of St. Lawrence, namely, from much of New Brunswick, Nova Scotia as far east as the Gut of Canso, and from Prince Edward Island, may be attributed to the shallowness, low salinity and high summer temperature of the water, and the prevalence of smooth, sandy bottoms. "Have fished salmon in the Miramichi Bay for twenty-five or thirty years. . . . Very seldom is a lumpfish seen" (T. Crocker, Newcastle, 1917, communicated). In 1896 the senior author did not succeed in finding it at Rustico, P.E.I., nor did Cornish record it from Tignish (1912).

The lumpfish would seem to prefer fairly deep shore and off-shore waters of low temperature, with rocky bottoms overgrown with Bryozoa and marine plants, where the small organisms, on which it usually feeds, are generally abundant.

6. FOOD

The general absence of food from the stomachs of lumpfish, examined by investigators, has been often noted. They are either entirely empty or contain water or a small quantity of milky fluid. Only a very small percentage show any solid contents. It must be remarked, however, that the bulk of the specimens reported were spawning fish taken during the spring migration; and at such times few fishes feed to any extent. It is a period of excitement in the life history of the fish, when instinct, vital impulses and energies are at tension and directed into other channels.

The structure of the mouth and the relatively feeble teeth point to its feeding on small and weak creatures, and observation has shown that this is the case, for small crustaceans, jelly-fish and worms have, from time to time, been reported among the stomach contents. All the adult lumpfish collected at Cheticamp were, with one exception, spent males, whose stomachs contained only a little water. In one case, however, a small quantity of white liquid of a curdy nature was found which, on microscopic examination, showed fragments of small crustaceans. The fish had been caught in a salmon net and retained a day or two; and it is doubtful if they would have taken food, even if available, under such circumstances; at all events whateve had been eaten would have been digested. In the stomach of one from Passamaquoddy Bay, September 4, several invertebrates were found, namely, 7 adult specimens of *Meganyctiphanes norvegica* (M. Sars); fragments of the jelly-fish *Aurelia flavidula* Per. et Les.; an Amphipod, *Hyperia* sp., that lives in the latter; and some scales of *Clupea*. In a second individual a few fragments of tiny fish bones were seen, probably eaten, as were the scales, in the sardine weir where the lumpfish were taken. A third specimen, 8 cm. long, captured at the same place on September 7, had the stomach distended with *Caprella* sp (?).

McIntosh reports that the stomachs of St. Andrews specimens were empty except that of a large female, procured in March, which was found distended with "fine specimens of *Nereis pelagica*" (1885, p. 61). Benecke declares that it is a voracious species which preys upon small crustaceans, mollusks, and fish spawn (G. Brown Goode, 1884, p. 254). It has been taken occasionally on baited trawls in Iceland (Thorsteinson, 1885, p. 431). Schultz (1911, pp. 285-310) reports it from the North Sea, feeding on *Polychaetes*, *Hydrolia ulvae*, *Mysis*, *Clupea* sp., and *Pleurobrachia* sp.

In 1902, Thomas Scott published the results of an examination of "considerably over three hundred specimens of lumpsuckers. . . . The stomachs of a large proportion of them were either empty or filled with a watery fluid of about the same specific gravity as ordinary sea water. . . . The stomachs containing food, which could be most easily identified, were usually those of male fishes" (1902, pp. 497-499). Small crustaceans and coelenterates were chiefly found.

A second important contribution to our knowledge of its food habits was made by Apstein, who examined 101 specimens, and of whose findings the following is a summary: The stomachs of 69 were entirely empty; 14 had eaten *Mysis*; 19, *Pleurobrachia* and *Sarsia* in large numbers; in solitary cases he found crustacean remains, an amphipod, and the larva of *Ammodytes*. He concludes that crustacea, jelly-fish and worms form its chief food (1910, p. 455).

The presence of *Meganyctiphanes* and *Aurelia* in the stomach contents suggests feeding in midwater or near the surface, which is very common in Passamaquoddy Bay and the Bay of Fundy, the fish occurring in numbers among, or under, drifting masses of seaweed. No evidence of the presence of adults in such waters in the Gulf was obtained.

7. THE SEASON AND MANNER OF SPAWNING

In the above discussion of the vertical and seasonal movements and distribution of the lumpfish, a series of facts and considerations was presented, which would suggest, at least, that if the spring or spawning migration is briefer in American than in European waters, it may still continue for the space of two or three months in much of the range.

At Bay St. Lawrence, Pleasant Bay, Eastern Harbour, Margaree, Port Hood, and other fishing centres on the northern and eastern shores of Cape Breton, its presence in the littoral water becomes apparent only at the opening of the salmon fishery—the last of May or during the first week in June, or at the beginning of the haddock season, earlier in May. Then lumpfish are in abundance and the height of the spawning season is evidently on, for fishermen report the fish ripe and ova and sperm flowing freely. After June 12, when the study of this fish was begun, only one female was seen—a spent one—but some males were secured during the ensuing month, all likewise spent fish. A fortnight later, June 27, the first larval lumpfish, 6 mm. in length, was obtained. Accepting Ehrenbaum's (1904, p. 158) period of incubation for the first of the season, namely, from 50 to 70 days, the ova may have been deposited two months previously or about the middle of April. On July 13 another specimen 6 mm. long was taken with several longer ones in Amherst harbour, Magdalen Islands, but none so small were seen afterwards. There is a considerable difference in the size of larvae escaping from the same egg mass, and the latter may have been one of the smaller ones, but was more likely from ova deposited late in the season, perhaps in June. On June 29 several, 7 mm. long, were collected, indicating a very considerable growth and lapse of time since their escape from the egg membrane. On the whole, then, it seems beyond question that oviposition had ceased by June 12, and had probably been in operation since the middle of April, if not earlier. This is much shorter than in European waters, where it extends from January to May—a fact quite rare among fishes.

The sexual difference in the reproductive season is confined to colour and probably also to relative size. Though the data are not conclusive it is claimed that the males are smaller than the females. Fulton examined 70 individuals taken from a salmon net in the Bay of Nigg, Scotland, between 2nd May and 24th July; 40 were females of an average length of 40 cm. and weight of 6 lbs. 6 oz.; 30 were males, average length 28 cm. and weight 1 lb. 14 oz. On July 7 we examined 7 individuals, all males, taken in a salmon net at Cheticamp Island, Cape Breton, of the following lengths: 2 were 30 cm.; 2, 32.5 cm.; 1, 33.5 cm.; and 2, 34 cm., or an average of 32.4 cm. The average weight was 2 lbs. 11 oz. They were all spent fish. Only one female, length 33 cm., was seen during the summer. Fishermen report examples over 12 pounds in weight.

At what age and size are the sexes mature? If the results of the study of the vertebrae be even approximately correct, this fish is a slow grower and probably late also in reaching maturity. In this connection it is regrettable that the Cheticamp-Magdalen expedition failed in securing there or in Passamaquoddy Bay a series of fresh material, sufficiently large, and varied, to clear up this matter and determine the rate of growth. We examined, however, an alcoholic specimen, taken at the latter place, which was 11 cm. long and in its third year, as indicated by the vertebrae, and found the ovaries relatively well developed. Though shrunken and hardened in the spirit they were still 2 cm. thick, and the ova varied in size from 0.1 to 0.2 mm. in diameter, but judging from their bulk and great number, the fish was nearly mature and would probably have spawned the next season. Indeed it seems almost certain that a study of this question, made at the time spawning is at its height, will show that the lumpfish attains sexual maturity very much earlier, and at a smaller size than the average of Fulton's specimens.

At this time the male and female are easily distinguished by the colour, the former being pinkish or red, especially on the lower sides and ventral surface, intensified around the disk and chin, with rows of scarlet spots between the lower rays of the pectoral, and sometimes on the anal; the latter vary from olive-green to blue-black, with the lower surfaces a pale blue and pectorals greenish. After spawning the brilliance of the nuptial hues is gradually lost by both, and the male assumes in time the duller colouration of the female.

The favourite spawning grounds are rocky shores with much sea-weed and tangle, and here the eggs are deposited in masses at points just below low tide. Recent investigations go to disprove the old idea of nests being scooped out in the sand by the males, indeed "the *Cyclopteri* form no nests, the ova being deposited chiefly on the sides of rocks and stones" (McIntosh in Gill, 1907, p. 185).

The clusters are from 20 to 24 cm. in diameter, and all the ova are frequently not deposited in the one mass, but in two or three contiguous ones, and at intermissions of from 8 to 14 days (Ehrenbaum, 1905, p. 116). The number of eggs produced by a single fish depends on its size, as well as on individual and race variations. Specimens 45 cm. long were found by Fulton to vary in this respect from 79×758 to 136×764 (Gill, 1907, p. 187). Benecke's estimate ranged from 200,000 to 400,000 (In Goode, 1884, p. 254). Apstein's computation was also 200,000 (1910, p. 454). The maximum is for large specimens which reach a length of 70 cm. (Day in Apstein, 1910, p. 454). The weight of the ova at the time of spawning may be one-third that of the mother fish (Fulton, 1891, p. 245).

The eggs adhere not only to the objects on which they are placed but to one another by means of glutinous flaps or facets on the capsule, and thus the mass takes on the character of a sponge and is readily penetrated by the water. Aeration is promoted, and, even if uncovered at extremely low tides, enough water is retained to prevent resultant injury—a provision of some importance.

The female deserts the spawning grounds when oviposition is over and retires off-shore, but the male faithfully guards the egg-masses during an unusually long period of incubation, driving away marauders and kneading the yielding masses by pressing against them with the snout, which conduces to a more rapid and thorough circulation of the water through the intricate network of channels. While performing this duty he is said to expel water forcibly from the mouth and drive it through the spongy mass (Ehrenbaum, 1904, p. 156) and he has frequently been observed fanning the eggs also with the pectoral fins (Fulton in Gill, 1907, p. 189), yet in spite of these extraordinary provisions the uniform and complete aeration of all the ova is by no means effected. Much of the spawn never hatches. Storms tear the clusters from their moorings and cast them upon the beach to perish, while much is doubtless eaten by fishes, crabs and other invertebrates. Moreover, all the eggs in a cluster are not fertilized. The examination of a mass found cast up on the beach at Cheticamp, June 29, revealed the fact that a considerable proportion had escaped ferilization. The latter were quite clear and contained no trace of embryos; many other showed fully developed, but dead, embryos, while the outer layers of the cluster were represented by empty capsules.

During the long vigil the reddish colour of the male has an evident relation to the scene and character of his duties, and is, in the main, protective, harmonizing with the rock-weeds among which the spawn is usually placed, and rendering him invisible to marauders until he darts upon them. It is the sudden rush, more than the warning colour, that is efficacious in driving them off.

When his parental duties are ended and he begins to retreat to deeper water the brilliant hues have faded somewhat and the back and sides are assuming a dull green, dusky olive, or even blue, colour.

8. INCUBATION AND EARLY LARVAL CHARACTERS

The ova are (on extrusion) of a pale red or pink colour, and vary a good deal in size in the same mass, from 2.2 to 2.6 mm. (Fulton, in Gill, 1907, p. 187), but the unfertilized ones and those containing dead embryos, examined at Cheticamp, averaged somewhat larger, many being fully 3 mm., probably due to the absorption of water through the capsules or egg-membranes which were thinned or finely punctured at many points. The eggs contain several little oil globules, which at an early stage of the development fuse into a single large one. "The globule in the gurnard, as also in *Cyclopterus* and *Cottus*, is most mobile, and can be made to pass under the disc when the latter is uppermost. On rolling the egg the globule emerges from beneath the disc, and is liberated with a bound at the edge of the rim. . . . At times the globule appears to ascend directly through the yolk, though this may be a deceptive appearance . . . since in experiments, such as the above, it passes between the disc and the yolk, and never passes through the protoplasmic cortex of the latter, save in rare morbid examples" (McIntosh and Prince, 1890, p. 687). It later becomes enclosed within the body wall of the embryo, and is very apparent as a round, golden-coloured spot in the larva for some days after hatching.

The length of time for hatching depends on the temperature, the degree of aeration maintained, and doubtless also on inherited regional characters. For the early part of the season in the North Sea, near Heligoland, the maximum is 70, the minimum, late in the season, 14 days (Ehrenbaum, 1904, p. 158). Fulton gives 42 days for a period closing May 22 on the coast of Scotland (in Gill, 1907, p. 190). Though Agassiz (1882, pp. 286-288) made excellent contributions to our knowledge of the development of the larvae of this species, we are not aware that the period of incubation for American waters was definitely determined by him or any other American or Canadian investigator. When operations began at Cheticamp in 1917 oviposition was already over, and larvae were obtained a few days later; so the expedition had no means of solving the problem.

The order of escape of the larvae from the egg-mass is from the outside inwards, but the ova in the middle of the cluster or at least some of them, may not hatch at all, the embryos dying and the mass turning black and fetid (Fulton, in Gill, 1907, p. 191). This refers to ova being hatched artificially, for McIntosh complains of it (1885, p. 60), but, as already stated, no such discolouration was seen in the mass we examined. The ill effects were probably due to lack of fertilization of the ova in the middle of the cluster, and of the necessary aeration, as failure of the oxygen supply combined with imperfect removal of the waste products, would have a tendency to prolong and enfeeble the process and result in the death of more or less embryos. The larvae are said to vary a good deal in length when freed from the egg. The smallest we captured were 5.5 mm. on June 29, July 3, 4, and 6. The dead embryos seen in the mass referred to above ran from 5 to 5.5 mm., so that it may be assumed that the newly-born young in

Canadian waters exceed those of the New England littoral, where they range from 4 to 5 mm. (Agassiz, 1882, p. 286), but are smaller than European specimens, which vary in length from 5.8 to 7.4 mm. (Ehrenbaum, 1905, p. 118).

At the time of exclusion from the egg membrane differentiation of the embryonic median fin is slightly indicated by a narrowing of the membrane in the region of the caudal peduncle. The pectoral fins are only rudimentary folds, but generally rays are discernible in them and in the inferior half of the heterocercal caudal fin (Fig. 3). In a specimen 6.5 mm. long, taken July 13, differentiation has advanced, and the two dorsals are outlined but joined with each other and with the caudal by strips of membrane. The anal and caudal are similarly connected, and the pectorals are assuming the usual form with better defined rays. In a larva, 8 mm. long, caught at the same time, the dorsals are nearly distinct, and the second is entirely separated from the caudal, while the anal shows a narrow connection with the latter (Fig. 4). Of two specimens 8.5 mm. long, collected at the same time and place as the above, one showed the fins all distinct, with the lower and anterior portion of the pectorals quite dark; the other had a slight fringe between the dorsals, otherwise the fins were distinct and the caudal quite homocercal. In specimens of 9 mm. and upwards the fin equipment was complete. McIntosh and Prince saw the character attained 26 days after exclusion from the egg (1890, Plate XV, Fig. 6). "By the 12th day the fish has increased considerably in bulk and measures 6.75 mm. . . . the dorsal has now been transformed into two fins, the anal fin has 10 rays, and is joined to the caudal by a strip of larval fin without rays" (McIntosh and Masterman, 1897, p 185) The stage of completeness is reached in the southern part of the North Sea at from 10 to 11 mm. (Ehrenbaum, 1904, p. 159), and Agassiz gives 10 mm. also (1882, Plate IV, Fig. 5), being more than double the original length. It would thus seem to be acquired later, and at a relatively greater size by larvae in the more southern portion of the range on both sides of the Atlantic.

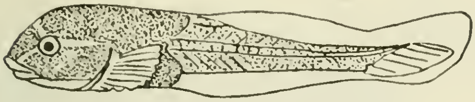


Fig. 3

Fig. 4

Fig. 3. Recently hatched lumpfish, 5.5 mm. long, Cheticamp, June 29, 1917.
Fig. 4. Young lumpfish, 8 mm. long, Magdalen Islands, July 13, 1917.

The "sucker" is an embryonic growth, and is functional when the young escape from the egg-membrane.

The general, or ground colour, at first is yellowish or greenish, with a more or less brassy lustre, and marbled with lighter streaks and patches with a silvery sheen. Groups of chromatophores are soon seen on the head, the pectoral fins, and base of the future caudal, above and below, and when the latter fin is differentiated it, too, is well pigmented. These secondary colour cells, like the primary, are often stellate, and mark assimilation to the colour of the objects among which the fish are usually found, orange and brown being most common. The unpigmented interorbital band, as well as a longitudinal one from the snout through the eye to the gill cleft is fairly constant (Figs. 3 and 4). Though disappearing early and gradually under increased pigmentation, this feature is sometimes very distinct in fish 14 mm. long and over (Fig. 5) Some strange colour freaks are met with. Of two specimens about 10 mm. long from Passamaquoddy Bay one has black pigmented bands, crossing the posterior half of the body irregularly, and enclosing unpigmented areas which are also seen on the anterior half (Fig. 5); the other is black-spotted, recalling *Cyclopterichthys ventricosus* Pallas, but the spots are arranged in several longitudinal series (Fig. 6).

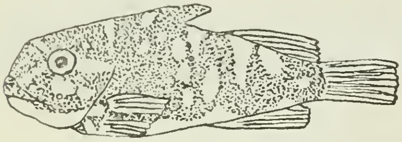


Fig. 5

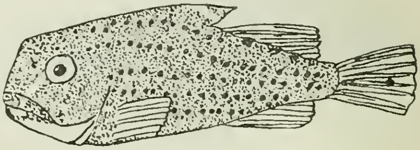


Fig 6

Figs. 5 and 6. Lumpfish of odd colour patterns, 18 mm. long, Passamaquoddy Bay.

The ability of the pigment cells to take on the colouration of surrounding objects is well exemplified in the Bay of Fundy, where the larvae are of a dull orange or brownish red, which blends admirably with the red and brown algae, in the floating masses of which they occur in great numbers, but in the Gulf the rock-weeds are usually a yellowish-green to which the larvae in their earliest stage approximate.

In specimens 18 mm. long the papillae of the horny tubercles were first seen, one or two over the eye and two or three behind it. At 21 mm. a few more postoculars were visible, but none of the dorsal, opercular, or ventral series had appeared. Beyond this size development of the armature seemed to proceed rapidly. In specimens 22 mm. long the post-ocular and opercular rows extend to about the middle of the body, the ventral are just discernible, but the dorsal are not evident (Fig. 7). At 25 mm. the post-ocular series is complete, extending

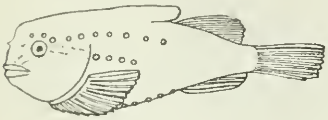


Fig. 7

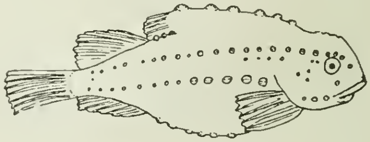


Fig. 8

Fig. 7. Young lumpfish, 22 mm. long, Bay of Fundy, Sept. 8, 1917.

Fig. 8. Young lumpfish, 32 mm. long, with complete series of tubercles, Grand Manan, Sept. 20, 1917.

to the base of the caudal fin; the opercular barely reaches it, and the ventral row is seen as flattened papillae. The dorsal series is just evident behind the head. At 32 mm. the armature is serially complete, and minute papillae are seen scattered over the opercle, and below the post-ocular (Fig. 8). Though the latter is the first series to appear, it is, in time, outgrown by the anterior four or five of the opercular, by the ventral, and also by the dorsal, all of which become spinous-serrate. The five latter series eventually mark prominent ridges, where the skin becomes enormously thickened in the adult fish.

McIntosh saw the first papilla of the horny tubercle in fish 18 mm. long, preserved in liquid. Agassiz found it only in those 34 mm.; 40 taken at Heligoland on January 23, and about a year old, measured when preserved 22-40 mm., averaging 27 or 28. In some of the smallest no trace of the papilla was visible, but in the larger, more or less, but not in the same degree as a 32 mm. one taken in the North Sea, 59° 30N., 2°E., probably from Norway (Ehrenbaum, 1904, p. 159). These observations taken with our experience show that the lumpfish's armature arises earlier and reaches a greater degree of development for a given size in the northern, than in the southern, sections of its range on both sides of the Atlantic. We saw evidence of the same vigorous development in the earlier differentiation of the fins.

9. DISPERSAL AND HABITS OF THE YOUNG

The lumpfish is a semi-pelagic rather than a strictly bottom or shore fish, for, as stated above, it is not limited, in our waters at least, to any particular zone of the littoral, but dispersed to a distance of 15 miles or more seaward. Floating debris and masses of seaweed are tenanted by individuals of all sizes, from the larvae and fry of the season to the adult fish, and such aid is considered by some as essential to the dispersal of the young at least. "By means of the sucker they attach themselves to pieces of seaweed and are carried far seaward as a constituent of the plankton" (Ehrenbaum, 1905, p. 116). "In spite of, or because of, the adhesive disc, they are carried out to sea, and remain planktonic or, at all events, are obtained pelagically even after they have acquired adult characters. They are supposed to be thus more or less planktonic during the first year" (Meek, 1916, p. 358).

It was then a matter of rare interest to find newly hatched larvae 5 mm. long in the plankton 2¼ miles off shore in the Gulf of St. Lawrence where no drift material occurs at that time of the year. Again, on July 4, larvae of the same size, the minimum collected, and bearing the characters of newly freed embryos, were taken at Station 30, 4 miles from land. The direction of the charted currents showed that they had had nothing to do with the occurrence. Observations, however, during the summer, established the fact that a drift of the surface water, sufficient to account for the phenomenom, is caused by winds, blowing from the land.

CYCLOPTERUS LUMPUS. RECORDS OF CAPTURES OF THE YOUNG

ONE METRE PLANKTON NET

Station No.	29	29	30	30	30	33
Date	June 27	July 4	June 27	July 4	July 18	July 16
Time	8.15 a.m.	9.20 a.m.	9.45 a.m.	10.50 a.m.	10.45 a.m.	7.15 a.m.
Depth (metres)	31	31	92	92	92	21
Surface Temp.	13.78°C.	12.84°C.	13.94°C.	12.76°C.	16.44°C.	13.68°C.
Temp. at 20 m.	8.17°C.	10.98°C.	5.89°C.	11.97°C.	7.49°C.	6.88°C.
No. in vertical haul	1	1	0	0	1	0
No. in 0-2 m. tow	5	27	2	1	0	1
No. in 18-23 m. tow	0	2	0	0	0	0

Young Fish Trawl

Locality	*Prince* Sta. 29	Pleasant Bay	Pleasant Bay	*Prince* Sta. 58
Date	July 3	July 13	July 13	August 18
Time	9.40 p.m.	8.45 p.m.	9.30 p.m.	2.05 p.m.
Depth of haul	15-20 m.	4-6 m.	2-3 m.	15 m.
Temperature	10.05°C.	....	....	14.26°C.
Number	1	27	1	2

Dredge

Locality	*Prince* Sta. 35	Off Cheticamp
Date	June 29	July 6
Time	....	....
Depth of haul	6 m.	37 m.
Temperature	....	....
Number	1	1

They were most abundant in the surface plankton. By referring to the tabulated records of capture, herewith given, it is seen that 36 were so taken and only two in the deep tows made simultaneously. It will be seen also that they were obtained at the surface in the daytime and at night only near or at the bottom. After the middle of July none were collected at the surface, and, on but one occasion, at or near the bottom. At this date the temperature of the surface water had risen to about 15°C., and their disappearance from that stratum may be attributed to that cause; yet the young lumpfish can bear a higher temperature and apparently thrive on it. August 16, at House Harbour, Magdalen Islands, we took 2 specimens, 15 and 17 mm., the largest seen up to that date, among eel grass in a foot of water at 22°C.

10. RATE OF GROWTH

The lumpfish is regarded by some authors as a slow grower, but their observations have reference probably to the adult fish, for we found that the rate of increase of the season's young does not differ to any extent from that of ordinary fishes. While there is a great difference in size among individual larvae collected at any one time, due to the long and irregular period of spawning and incubation, as well as to embryonic variation, yet many seem to double their length in a month. For instance, larvae collected July 13 averaged 7.6 mm., and a month later, August 18, the average was 13.5 mm. Earlier in the season the rate of increase did not seem so great, but the intermixture of recently liberated larvae of the minimum size with older and larger ones rendered a comparison of little or no value. The largest larva obtained at Cheticamp was collected August 16, and was 17 mm. long. 8 individuals, taken at Wilson's beach, September 8, ranged from 18-23 mm., the majority being over 20, and were evidently the fry of the season. It is thus seen that the relative size and growth of the larvae of the Gulf and Passamaquoddy Bay did not differ materially during the summer. In the Gulf, on the other hand, there seems to be a marked arrest of growth during the winter as compared with that of the Bay of Fundy. On July 7 we secured an example 33 mm. long (Fig. 9) adhering to the buoy of a lobster trap in 6 fathoms off the south-west point of Cheticamp Island, which was evidently a year old at least, for its size, adult appearance, and marked development of armature (somewhat exaggerated in the drawing) differentiate it sharply from the season's young. On December 12, 2 examples were captured at Grand Manan, in the Bay of Fundy, 41 and 45 mm. respectively, and were evidently the young of the season, having doubled in length since September. A specimen taken at Barrington Passage at the southern end of Nova Scotia, on June 29, 1910, and loaned us by the Victoria Memorial Museum, Ottawa, was 55 mm. in length, and presumably one year old.

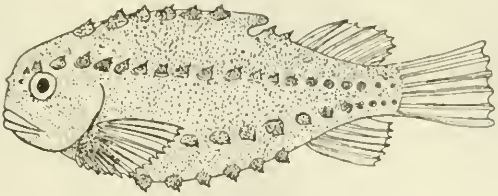


Fig. 9

Fig. 9. Lumpfish, 33 mm. long, south-west point of Cheticamp Island in 6 fathoms, July 4, 1917.

Tosh calculated (1894, p. 333) that one 53 mm. long and taken June 1, 1887, was probably one year old, the assumed month for spawning being May. Between July 26 and August 12 half-a-dozen specimens were collected at Wilson's Beach, Campobello, which ranged from 50 to 74, and averaged 58 mm. These were in their second year. Judging from these coincidences, the biological conditions surrounding the young the first year in the Scotch littoral and in the Bay of Fundy must be a good deal alike.

Tosh also estimated that fish 22-23 mm. long were about 5 months old (1894, p. 333), which agrees with our observations in the Gulf and Bay of Fundy. On the other hand, Ehrenbaum's determinations point to a slower general growth the first year in the Bight of Heligoland than in the Bay of Fundy or the Scotch waters: "40 taken at Heligoland on January 23, were about a year old and measured, when preserved, 22 to 40 mm., average 27 to 28" (1904, p. 159). This approximates closely the size they must attain in the Gulf during the first year (see Fig. 9). The long winter and frigidity of the water at that time must react unfavourably on the delicate young, and retard the growth of the fish, perhaps at all stages.

In the absence of ordinary scales the structure of the vertebrae was studied to try to decide the age at certain sizes, but the backbone of the lumpfish is unusually cartilaginous, and the markings are very faint, or entirely invisible. By staining and partially clearing them, however, we found the conditions improved, but the determinations were made with the greatest difficulty and cannot be regarded as absolutely correct. Fig. 10 is from a specimen 11 cm. long from the Bay of Fundy, judged to be in its third year. The vertebra was 3.5 mm. in diameter and is drawn magnified ten times. Fig. 11 represents the vertebra of a fish 26 cm. in length, taken at St. Andrews, Passamaquoddy Bay, on September 8, and was apparently in its fifth year. An individual 30.6 cm. furnished the vertebra from which Fig. 12 was drawn, where 6 rings were thought to occur. The same number also was seen in a fish 32.5 cm. in length. Another example 34 cm. showed 7 rings. The latter, a spent male, weighed 3 pounds; Specimens 46 and 47 cm. are reported by Fulton as weighing over 10 pounds, another, length not given, was 18¼ pounds (Gill, 1907, p. 193). Cape Breton fishermen tell of taking fish over 2 feet and weighing 20 pounds or more; and Fortin asserts they reach that size and weight in the northern part of the Gulf (1864, p. 150).

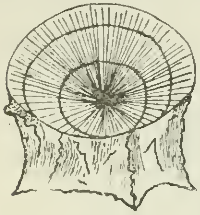


Fig. 10

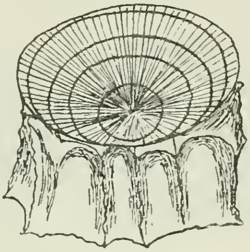


Fig. 11

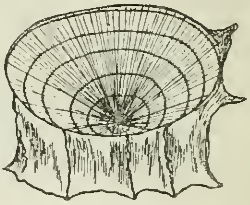


Fig. 12

Fig. 10. Vertebra from lumpfish, 11 cm. long and in its third year, from Bay of Fundy. ×7½.

Fig. 11. Vertebra from lumpfish, 26 cm. long and in its fifth year, from Campobello Island, Bay of Fundy, Sept. 8, 1917. ×3.

Fig. 12. Vertebra from lumpfish, 3.6 cm. long and in its seventh year, from Cheticamp, July 7, 1917. ×3.

For reasons already given no reliable graph to represent the rate of growth from its early stages upward could be constructed for the lumpfish in the Gulf, but the following determinations for the Bay of Fundy may be of some interest and value:

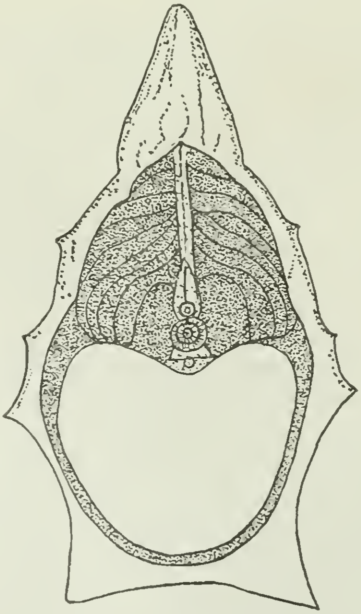


Fig. 13

Fig. 13. Cross-section of lumpfish showing thick skin, hump on back, and thin body-wall.

Date of Capture	Length in mm.	Age	Locality
December 12/17....	41 & 45	First Year	Grand Manan
June 29/10........	55	Second Year	Barrington Passage
July 26-Aug. 12....	50 to 74	Second Year	St. Andrews, Passamaquoddy Bay
(No date).........	110	Third Year	St. Andrews
May, 1907.........	95	Third Year	St. John Harbour
Sept. 8/17.........	260	Fifth Year	Wilson's Beach, Campobello Islan

The weight increases much more rapidly than the length. A fish 7.6 cm. weighed 21.3 gms.; another 9.3 cm. 33.6 gms. Apstein calculated the weight of one 15 cm. at 134 gms., and we found a 30 cm. fish to weigh 1020 gms., and another 32.5 cm. 1474 gms. Fish that attain the length of 70 cm. and upwards may weigh twenty pounds or more.

BIBLIOGRAPHY

AGASSIZ, A. On the Young Stages of some Osseous Fishes. Proc. Amer. Acad. Arts and Sc., vol. 17, pp. 271-303. 1882.

APSTEIN, C. *Cyclopterus lumpus*, der Seehase: seine Fischerei und sein Mageninhalt. Mitt. Deut. Seefisch. Vereins, Bd. 26. Nr. 10, pp. 450-465. 1910.

BEAN, T. H. Fishes. In Contributions to the Natural History of Arctic America. Bull U.S. Nat. Mus. No. 15, pp. 107-138. 1879.

CORNISH, G. A. Notes on the Fishes of Canso. Contr. Canad. Biol., 1902-1905, pp. 81-91. 1907.

Notes on Fishes of Tignish, Prince Edward Island. Contr. Canad. Biol., 1906-1910, pp. 79-81. 1912.

DRESEL, H. J. Notes on some Greenland Fishes. Proc. U.S. Nat. Mus., vol. 7, pp. 244-258. 1884.

EHRENBAUM, E. Eier und Larven von Fischen der deutschen Bucht. III Fische mit festsitzenden Eiern. Wissensch. Meeresunter., n. F., Bd. 6. Abth. Heligoland, pp. 127-200. 1904.

Eier und Larven von Fischen. 1 Teil. Nordisches Plankton, Lief. 4, pp. 218. 1905.

FABRICIUS, O. Fauna Grœnlandica. pp. 452. Havniae et Lipsiae, 1780.

FORTIN, P. Continuation of the List of Fish of the Gulf and River St. Lawrence Rep. Commr. Crown Lands of Canada for 1863, App. 40. 1864.

FULTON, T. W. The Comparative Fecundity of Sea-fishes. 9th Ann. Rep Fish. Board for Scotland for year 1890, pp. 243-268. 1891.

GILL, T. The Lumpsucker; its Relationship and Habits. Smithson. Miscel Coll., vol. 50, pp. 175-194. 1907.

GOODE, G. B. Fisheries and Fishery Industries of the United States. Sect. I Natural history of Useful and Aquatic Animals, p. 895. 1884.

HEIDRICH. Die Ostsee-Expedition des deutschen Seefischerei-Vereins 1901 Abhandl. d. deutsch. Seefischer. Vereins, Bd. 7, pp. 1-84. 1902.

JONES, J. M. List of the Fishes of Nova Scotia. Proc. Trans. Nov. Scot Inst. Nat. Sc., vol. 5, pt. 1, app., pp. 87-97. 1879.

Kendall, W. C. The Fishes of Labrador. Proc. Portland Soc. Nat. Hist., vol. 2, pp. 207-243. 1909.

McIntosh, W. C. Report of the Marine Laboratory, St. Andrews. 3rd Ann. Rep. Fish. Board for Scotland for year 1884, App. F, No. 3, pp. 55-67. 1885.

McIntosh, W. C. and Masterman, A. T. The Life Histories of the British Marine Food Fishes. pp. XV+516. London, 1897.

McIntosh, W. C. and Prince, E. E. On the Development and Life Histories of the Teleostean Food and other Fishes. Trans. Roy. Soc., Edinburgh, vol. 35, pp. 665-946. 1890.

Meek, A. The Migrations of Fish. Pp. xviii+427. London, 1916.

Möbius, K und Heincke, Fr. Die Fische der Ostsee. Vierter Ber. Komm. z. Wissen. Unters. d. deut. Meere in Kiel, 7-9 Jahrgang, pp. 195-296. 1884.

Packard, A. S. List of the Vertebrates Observed at Okak, Labrador, by Rev. Samuel Weiz, with Annotations. Proc. Bos. Soc. Nat. Hist., vol. 10. pp. 264-277. 1866.

Perley, M. H. Reports on the Sea and River Fisheries of New Brunswick, 2nd ed., pp. 294. Fredericton, 1852.

Schiemenz, P. Bericht über die Fischerei-Expedition des deutschen Seefischerei-Vereins in der Ostsee, 1900. Abhandl. d. deutsch. Seefischerei Vereins, Bd. 7, pp. 163-284. 1902.

Schmitt, J. Poissons. Monographie de l'isle d'Anticosti, pp. 282-287. Paris, 1904.

Schneider, G. Ichthyologische Beiträge. 1. Act. Soc. p. Faun. et Flor. Fenn., vol. 20, No. 1, pp. 1-67. 1900.

Schlutz, G. Untersuchungen über Nahrung und Parasiten von Ostseefischen. Wiss. Meeresunter., Abth, Kiel, n.s., Bd. 13, pp. 285-310. 1911.

Scott, T. Observations on the Food of Fishes. 20th Ann. Rep. Fishery Board for Scotland, pt. 3, pp. 486-538. 1902.

Smiley, C. Notes upon Fish and the Fisheries. Bull. Un. States Fish Comm., vol. 5, pp. 65-112. 1885.

Stafford, J. On the Fauna of the Atlantic Coast of Canada. 3rd Report. Contr. Canad. Biol., 1906-1910, pp. 45-67. 1912.

Storer, H. R. Observations on the Fishes of Nova Scotia and Labrador, etc. Bost. Journ. Nat. Hist., vol. 6, No. 2, Art. 15, pp. 147-170. 1850.

Tosh, J. R. On the Rate of Growth of Marine Fishes. 12th Ann. Rep. Fishery Board for Scotland, pt. 3, pp. 333-325. 1894.

Thorsteinson, A. American Halibut Fisheries near Iceland. Bull. Un. States Fish. Comm., vol. 5, pp. 429-432. 1885.

Whiteaves, J. F. Report on a Second Deep-sea Dredging Expedition, etc. Ann. Rep. Dep. Mar. & Fish. for 1872, App. K, pp. 113-132. 1873.

Colonial and Indian Exhibition. Catalogue of Canadian Pinnipedia, Cetacea, Fishes, etc., pp. 1-42. Ottawa, 1886.

No. 2

RESULTS OF THE HUDSON BAY EXPEDITION, 1920
III. THE ECHINODERMS

BY

AUSTIN H. CLARK

WITH AN ADDENDUM

BY

HUBERT LYMAN CLARK

Results of the Hudson Bay Expedition, 1920
III. The Echinoderms

By Austin H. Clark

with

Addendum

By Hubert Lyman Clark

An interesting collection of echinoderms was brought together by Mr. Frits Johansen during the course of a journey along the eastern shores of James and Hudson bays in July-September, 1920. The collection is of especial interest in view of the paucity of records from the Hudson Bay region, and it has been entrusted to me for determination.

The species represented are the following:

Class CRINOIDEA

Heliometra glacialis (Leach)

Richmond Gulf, Hudson Bay; about 15 fathoms; August 24, 1920. Two medium sized specimens.

Class ECHINOIDEA

Strongylocentrotus dröbachiensis (O. F. Müller)

Beach of South Twin Island, James Bay; middle of July, 1920. One specimen 48 mm. in diameter.

Bay inside the point of South Twin Island, James Bay (about 53°N. lat.); 4-5 fathoms; stones and sand; July 27, 1920. Two specimens.

Sound between Long Island and Cape Jones, Hudson Bay; 5 fathoms; stones, sand and algae; August 2, 1920. Three specimens from 30 mm. to 46 mm. in diameter.

Richmond Gulf, Hudson Bay, about 3 miles from the entrance; 12-13 fathoms; stones, sand and *Delesseria*; August 23, 1920. Six small specimens.

Richmond Gulf, about 3 miles from the entrance; 15-20 fathoms; stones, sand and *Delesseria*; August 23, 1920. Six specimens.

Richmond Gulf, about 4 miles from the entrance; about 15 fathoms; stones and algae; August 24, 1920. Nineteen specimens.

Bay between Black Whale and Olaska Harbours (about 55°N. lat.); 10 fathoms; August 28, 1920. About fifteen specimens.

Beach on one of the islands between Long Island and Cape Jones; August 31, 1920. One specimen 43 mm. in diameter.

Beach between Great Whale River and Richmond Gulf; August, 1920. Five specimens from 15 mm. to 50 mm. in diameter.

Islands between Long Island and the mainland north of Cape Jones; from fish nets set along shore; September 2, 1920. Five specimens from 27 mm. to 53 mm. in diameter.

Class HOLOTHUROIDEA

Cucumaria frondosa (Gunnerus)

Long Point Sound, between Long Island and Cape Jones, Hudson Bay; 5 fathoms; stones and sand, with algae; August 2, 1920. Two specimens.

Richmond Gulf, about 3 miles from the entrance; 10-15 fathoms; stones and algae; August 23, 1920. Four specimens.

Bay between Black Whale and Olaska Harbours (about 55°N. lat.); 10 fathoms; August 28, 1920. One specimen.

Class OPHIUROIDEA

Gorgonocephalus eucnemis (Müller and Troschel)

Richmond Gulf, about 3 miles from the entrance; 25 fathoms; stones and sand; August 23, 1920. Four specimens, the diameter of the disc ranging from 13 mm. to 55 mm.

Richmond Gulf, about 4 miles from the entrance; 10-20 fathoms; stones and algae; August 24, 1920. One small specimen.

Ophiacantha bidentata (Retzius)

Richmond Gulf, about 6 miles from the entrance; about 10 fathoms; August 24, 1920. One small and broken specimen.

Ophiopholis aculeata (Linné)

Richmond Gulf, about 3 miles from the entrance; 25 fathoms; stones and sand; August 23, 1920. Two specimens.

Richmond Gulf, about 4 miles from the entrance; 10-20 fathoms; stones and algae; August 24, 1920. One specimen.

Richmond Gulf; August 24, 1920. One specimen, with the disc 11 mm. in diameter.

Ophiocten sericeum (Forbes)

Richmond Gulf, about 4 miles from the entrance; 10-20 fathoms; stones and algae; August 24, 1920. Twenty-eight specimens.

Ophioglyphina robusta (Ayres)

Richmond Gulf, about 3 miles from the entrance; 25 fathoms; stones and sand; August 23, 1920. Ten specimens.

Class ASTEROIDEA

Crossaster papposus (Linné)

Richmond Gulf; about 15 fathoms; August 24, 1920. One small specimen.

Urasterias linckii (Müller and Troschel)

Bay on southern side of Grey Goose Island, James Bay (about 54°N. lat.); 10 fathoms; July 30-31, 1920. One specimen.

Among Paint Hills Islands, James Bay (53°N. lat.); 10 fathoms; stones and sandy mud; September 10, 1920. One specimen; R = 50 mm.

Asterias acervata borealis (Perrier)

Bay inside the southeastern point of South Twin Island, James Bay (about 53°N. lat.); 4-5 fathoms; stones and sand; July 27, 1920. One specimen.

Bay outside Richmond Gulf, Hudson Bay; from fishnet along shore; August 20, 1920. One specimen.

Richmond Gulf, about 4 miles from the entrance; about 15 fathoms; stones and algae; August 24, 1920. Two specimens.

Island between Long Island and Cape Jones; shore-water; September 2, 1920. Two specimens.

There is a specimen of this species in the U.S. National Museum from Cape Churchill, Hudson Bay (Cat. No. 39912) collected by Mr. E. A. Preble in August, 1900.

Leptasterias groenlandica (Lütken)

Sound between Long Island and Cape Jones, James Bay (about 54° 30′N. lat.); 5 fathoms; stones, sand and algae; August 2, 1920. Two specimens.

Among Paint Hills Islands, James Bay (about 53°N. lat.); 10 fathoms; stones and sandy mud; September 10, 1920. Eight specimens.

Addendum

By Hubert Lyman Clark

Class HOLOTHUROIDEA

Cucumaria calcigera (Stimp.) Selenka

Pentacta calcigera Stimpson, 1854. Proc. Boston Soc. Nat. Hist., Vol. 4. p. 67.

Cucumaria calcigera Selenka, 1867. Zeitschr. f. wiss. Zool., Vol. 17, p. 351.

A fine specimen of this species, about 75 mm. long and pale pinkish-purple in colour with whitish or yellowish pedicels, was taken in Richmond Gulf, east side of Hudson's Bay, in June, 1899, by A. P. Low. It was found on a bottom of soft mud in 15-30 fathoms of water. The tapering caudal part of the animal is about one-fourth of its entire length.

Cucumaria frondosa (Gunn.) Forbes

Holothuria frondosa Gunnerus, 1767. Vet. Akad. Handl., Vol. 28, p. 115.

Cucumaria frondosa Forbes, 1841. Brit. Starf., p. 209.

A very young holothurian, only 3-4 mm. long, was taken about three miles within the entrance of Richmond Gulf, Hudson's Bay, on August 23, 1920, by Fritz Johansen. It was found on a bottom of stones, sand and red algae in 12-13 fathoms of water. It is too young to identify but the plates in the skin indicate that it is probably a very young specimen of this common and widely distributed species.

No 3

RESULTS OF THE HUDSON BAY EXPEDITION, 1920
IV. THE ASCIDIACEA

BY

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

Results of the Hudson Bay Expedition, 1920

IV. The Ascidiacea

By A. G. Huntsman
Biologist to the Biological Board of Canada

Material collected by Mr. Frits Johansen, Naturalist of the Department of Naval Service, on a trip to James and Hudson bays in the summer of 1920 under the auspices of the Biological Board of Canada, has formed the basis of this paper. In addition there has been available a number of specimens of Ascidians from the collections of the Victoria Memorial Museum and the former Canadian Fisheries Museum of Ottawa. These have been brought together by the assiduity of Mr. Johansen, whose untiring efforts to assemble material from the northern parts of Canada are much to be commended. The area from which material is here reported consists briefly of Hudson Bay and the salt waters connected with it, as far as the Arctic circle to the north, and the mouth of Hudson Strait to the east. Very few records of Ascidians from this region have hitherto been published, therefore the present report is a distinct contribution to our knowledge. The records are as yet too scattered to indicate peculiarities of distribution within the region.

Of the thirteen species listed, eight are definitely arctic circumpolar forms, and one other (*Cystingia retortiformis*) is probably so. Two (*Molgula septentrionalis* and *Lithonephrya tenax*) seem restricted to the Atlantic part of the arctic region. One (*Boltenia ovifera*) appears to be practically restricted to the American arctic and subarctic, and another (*Cnemidocarpa mollis*) is, so far as known, found only on the American side of the north Atlantic. The last species is the sole indication of the extension of a more southerly fauna into the region. It is clear, therefore, that although no part of this Hudson Bay region is within the arctic circle, being between 51° and the circle, the Ascidian fauna is, nevertheless, almost wholly arctic in character.

Of the three species reported by MacLeay (1825) from Winter Island, Fox Channel, which is just inside the northern limit of the region, one only (*Dendrodoa glandaria* which is the same as *D. aggregata*) has not appeared in the material that we have had, and should, therefore, be added to the list for this area.

Ascidiopsis prunum (Müller)

For synonymy and bibliography see Hartmeyer, 1903, p. 285 (*Ascidia prunum*), and Van Name, 1912, p. 599 (*Phallusia prunum*).

King George Sound, Hudson Strait; 40 fathoms; September 9, 1897; coll. Low and Wakeham, 4 specimens. Near mouth of Povŭngnitok River, east side of Hudson Bay; August, 1898; coll. A. P. Low, 1 specimen. Richmond Gulf (about 4 miles from entrance), east coast of Hudson Bay; in about 10 fathoms; stones and algae; August 24, 1920; coll. F. Johansen, 3 specimens.

It is worth while reiterating the distinguishing characteristics of this, the type species of the genus, a number of which have been overlooked.

The test is firm and cartilaginous. The surface is practically free from papillae (though irregularly grooved) except on the apertural lobes, which usually number 7 (occasionally 6) for the oral, and 6 for the atrial. The dorsal lamina has teeth corresponding to the transverse ribs and vessels. The number of longitudinal bars is very constant in all but small specimens, there being from 15 to 20 on the left side and from 18 to 21 on the right. The bars are provided with both papillae corresponding to the transverse vessels and also intermediate papillae. The oviduct crosses slightly the last bend of the intestine.

A. prunum is a common arctic circumpolar form, and is found as well rather far into subarctic regions, as, for example, southern British Columbia in the Pacific, and the Gulf of Maine and southern North Sea in the Atlantic.

Chelyosoma macleayanum Brod. and Sowerby.

See Van Name, 1912, p. 591, for bibliography.

King George Sound; Hudson Strait; 40 fathoms; September 9, 1897; coll. Low and Wakeham, 2 sp.

An Arctic circumpolar form that extends its distribution into the subarctic (except for the Western Pacific) only on our Atlantic coast, where it occurs rarely and of small size as far south as the Gulf of Maine.

Genus MOLGULA, Forbes (sensu restricto)

Type species—*M. oculata*, Forbes.

This genus has been hitherto so broadly defined as to include many heterogeneous elements. It is proposed to restrict it to several species that may be grouped around the type species, *M. oculata* Forbes, such as *M. siphonalis*, Sars, *M. septentrionalis*, Traust., *M. pannosa*, Verr., *M. pugetiensis*, Herdman, *M. apopioa* (Hntsmn.), *M. hecateia* (Hntsmn.), *M. pacifica* (Hntsmn.), *M. citrina*, Ald. and Hanc., and *M. solenota*, Lac.-Duth. More information is required before the distinctness of these species can be made certain.

The characters possessed by the genus in the restricted sense are as follows:

A gonad on each side of the body, the left above the primary intestinal loop. Testicular lobes arranged along both margins of an elongated ovary and with one or more vasa deferentia opening separately on the inner side of the gonad (not accompanying oviduct). Pharynx with seven folds on each side, most of the folds with several longitudinal bars on each.

Molgula septentrionalis, Traustedt.

1912. *Caesira septentrionalis*, Van Name, p. 478 (with bibliography and synonymy).

1916. *Molgula septentrionalis*, Redikorzew, p. 94 (with bibliography and synonymy).

Richmond Gulf, east coast of Hudson Bay; 15-30 fathoms; soft mud; June, 1899; coll. A. P. Low, 3 sp. Manitouk Sound (bay inside boat opening), east coast of Hudson Bay; 5-7 fathoms; clay-mud, sand and stones; August 27, 1920; coll. F. Johansen, 3 sp. Sound between Paint Hills Islands, about lat. 53°N., James Bay; 10 fathoms; stones and sandy mud; September 10, 1920; coll. F. Johansen, 4 sp.

The largest specimen is 25 mm. long. In the larger specimens the siphons are withdrawn into a groove, which has well defined valve-like margins.

In an individual 20 mm. long and 12 mm. in diameter, the largest tentacles are bi-pinnate, and three series can be distinguished. Those of the largest number eight, of which three near the dorsal tubercle are poorly developed; those of the next series also number eight; the third series consists of very small tentacles, which number presumably sixteen. The pharyngeal folds end posteriorly in simple, pointed processes. The formula for the longitudinal bars on the left side is: Dors. 0 (9) 0 (10) 0 (11) 0 (11) 0 (10) 0 (9) 0 (6) 0 vent.

The dorsal tubercle is small and very high. Its aperture is slit-like with the anterior end bent toward the left. Both gonads have horizontal and ascending limbs, the latter continued into the upwardly directed oviduct which opens close to the base of the atrial siphon. The free portions of six distinct vasa deferentia were observed on the right side, near the upper margin of the gonad and on the inner surface of the horizontal limb. The ovary has both dorsal and ventral series of fairly distinct pouches, numbering 8 to 9 in each series.

The typical condition of the dorsal tubercle as hitherto described is a horseshoe-shaped aperture with the opening between the horns directed backwards and to the left. We have found this in small individuals, but in the large ones examined the aperture was relatively small and the shape not so much like a horseshoe, as if there had been some regression in its development.

The gonads have been well figured by Redikorzew (1916, p. 96). Van Name's (1912, p. 479) and Hartmeyer's (1903, pl. VII, and 1901, p. 54) figures show neither the lobulated condition of the ovary nor the ascending limb and oviduct, perhaps because they represent views from without through the mantle.

In all essential respects these specimens from Hudson Bay agree with the descriptions of this species by the authors mentioned above.

This species is distributed throughout the arctic seas adjacent to the north Atlantic. In the east it has been found as far as Novaya Zemlya and Franz Josef land. It occurs in northern Russia, Spitsbergen, Norway, Faroe Islands, Greenland, Newfoundland, and is now reported from Hudson Bay.

Genus LITHONEPHRYA Giard, 1872

Type species—*L. complanata* (Ald. and Hanc.).

A very distinct small group of species, hitherto included in *Molgula* or *Caesira*, includes, in addition to the one on which Giard based his genus *Lithonephrya*, the following species: *L. tenax* (Traust.) and *L. canadensis* (Hntsmn.). They are characterized by having a gonad on each side of the body and directed anteriorly, the left being above the primary intestinal loop; the testicular lobes are grouped semi-circularly around the posterior end of the short ovary, and the single vas deferens opens on the inner side of the latter; the pharynx has six or seven folds on each side and these are poorly developed, though most of them have two or more bars each.

Other characters are: lobes of apertures with 3 or 5 teeth; dorsal tubercle with opening between horns directed posteriorly or to right; dorsal lamina toothed posteriorly; and stigmata secondarily arranged in transverse rows, each stigma regularly corresponding to one-quarter of circumference of an infundibulum.

L. tenax (Traust.).

1883. *Molgula tenax*, Traustedt, p. 110.
1903. *Molgula tenax*, Hartmeyer, p. 137.
1916. *Molgula papillosa* (part), Redikorzew, p. 68.

King George Sound, Hudson Strait; 40 fathoms; September 9, 1897; coll. Low and Wakeham, 4 specimens.

Van Name (1912) has considered this species to be synonymous with *Molgula papillosa*, Verrill. I believe there are two errors here. In the first place, Verrill's species is not the one described and figured by Van Name, as a careful examination of Verrill's description and figure will show. The true *M. papillosa*, as I regard it, was not found by Van Name in the material from the Bay of Fundy at his disposal, but is nevertheless quite abundant there. It is nearly related to *Molgula manhattensis* (DeKay). Dr. Van Name has written me that Verrill's types had dried up and were not determinable with certainty.* *Caesira papillosa*, Van Name, 1912, p. 497, is, therefore, synonymous with *C. canadensis*, Huntsman, 1912, p. 140. This latter species belongs to the genus *Lithonephrya*, and appears to be distinct from both *L. tenax* and also *L. complanata*, chiefly in that it possesses 7 folds on each side of the pharynx, the other two species having only 6 folds on the left side, as I have been able to verify in specimens of *tenax* from the Gulf of St. Lawrence and Hudson Strait, and of *complanata* from Plymouth, England, and St. Andrews, Scotland.

L. tenax is an arctic form, occurring in the Atlantic part of the polar seas from the White Sea in the east to Hudson Strait in the west. It penetrates the subarctic, but in deep water, and is represented in shallow water farther south by the two other species mentioned above.

Genus Cystingia MacLeay

Pera Stimpson, 1852, p. 232

Type species—*C. griffithsii*, MacLeay.

This genus, instituted by MacLeay in 1825, has been hitherto referred to the family Tethyidae (Cynthiidae). Since MacLeay's time the systematic position of this genus and species has been somewhat uncertain and no specimens of Ascidians have been referable to it. A reperusal of MacLeay's account, after we had worked over a collection of Ascidians from near the place whence MacLeay's specimens came, has made it certain that MacLeay's species is in reality the well-known form that has been going under the name of *Molgula* (seu *Pera*) *crystallina* (Möller). Certain inaccuracies in MacLeay's description are undoubtedly due to the bad state of preservation of his specimens.

We propose to redefine this genus in the following way, so as to fit a small group of species that includes the type of the genus.

A gonad on each side of the body, the left ovary being above the primary

---

*Dr. Van Name has re-examined the types (letter dated June 9, 1922) and finds that "the intestinal loop and the form and structure of the gonads are clearly distinguishable," and agree with the condition in *C canadensis*. We have, therefore, Verrill's original description of *M. papillosa* (external characters only) corresponding with one species, not represented in his material as examined by Van Name, and the specimens labelled as the types corresponding with another species.

intestinal loop; the testicular lobes are more or less separated from the ovary, being to some extent below the renal organ on the right side, and in the intestinal loop on the left. Several vasa deferentia opening separately into peripharyngeal cavity. Pharynx has from five to seven folds on each side, each fold when well developed having several longitudinal bars.

In addition to the two following species this genus includes *Molgula redikorzevi* Oka.

C. griffithsii, MacLeay.

1825. *Cystingia griffithsii*, MacLeay, p. 541.
1842. *Clavelina chrystallina*, Mőller, p. 95.
1852. *Pera pellucida*, Stimpson, p. 232.
1872. *Pera crystallina*, Verrill, p. 213.
1903. *Molgula crystallina*, Hartmeyer, p. 137.
1909. *Caesira crystallina*, Hartmeyer, p. 1323.
1912. *Caesira crystallina*, Van Name, p. 494 (with bibliography).
1916. *Molgula crystallina*, Redikorzew, p. 58 (with bibliography).

Sound between Paint Hills Islands, east coast of James Bay, about lat. 53° N.; 10 fathoms; stones and sandy mud; September 10, 1920; coll. F. Johansen, 9 sp. Floating near surface, east coast of James Bay, about lat. 53½°N.; attached to red algae; September 9, 1920; coll. F. Johansen, 8 sp. Old Factory Bay, east coast of James Bay, about lat. 52½°N.; 5 fathoms; stones, sandy mud and algae; September 11, 1920; coll. F. Johansen, 12 sp.

This is an arctic circumpolar species, with a distribution similar to that of *Chelyosoma macleayanum*. It is found in the subarctic region to a very limited extent, but occurs on our Atlantic coast in small numbers as far south as the Gulf of Maine. MacLeay's, the original, record of this species, was from Winter Island, in Fox Channel, just inside the northern limit of the region we are considering.

C. retortiformis, Verrill.

1912. *Caesira retortiformis*, Van Name, p. 509 (with bibliography and synonymy).

1916. *Molgula retortiformis*, Redikorzew, p. 85 (with bibliography and synonymy).

Beach at Fort Churchill, Hudson Bay; October, 1910; coll. J. M. Macoun, 1 sp. Long Point Sound (between Long Island and Cape Jones), east coast of Hudson Bay (about 54½°N. lat.); 5 fathoms; stones, sand and algae; August 2, 1920; coll. F. Johansen, 2 sp. Sound between Paint Hills Islands, east coast of James Bay (about 53°N. lat.); 10 fathoms; stones and sandy mud; September 10, 1920; coll. F. Johansen; 15 sp. Old Factory Bay, east coast of James Bay (about 52½°N. lat.); 5 fathoms; stones, sandy mud and algae; September 11, 1920; coll. F. Johansen, 1 sp.

This species has a similar distribution to that of the preceding, but extends farther south than the latter on both coasts of America, and not so far south on the coasts of north-eastern Asia and north-western Europe. It has not been reported from the Canadian Arctic archipelago, which raises the question of whether or not it is truly circumpolar.

Rhizomolgula globularis (Pallas).

1916. Redikorzew, p. 128 (with bibliography).

Bay between Black Whale and Olaska harbours, east coast of Hudson Bay (about 55°N. lat.); 10 fathoms; sandy mud and algae; August 28, 1920; coll. F. Johansen, 47 sp. From stomach of *Cottus quadricornis*, east coast of Hudson Bay, about 55°N. lat.; August 30, 1920; coll. F. Johansen, 38 sp. Cape Hope Islands, east coast of James Bay, about 52½°N. lat.; washed up on beach; September 12-14, 1920; coll. F. Johansen, 16 sp.

This is an arctic circumpolar species. It is distinctly a shallow water form and invades the subarctic zone to a less extent than almost any other of our species. The above record is believed to constitute the southernmost limit of its distribution.

Goniocarpa lovenii (Koren et Daniel.).

1912. *Tethyum coriaceum*, Van Name, p. 560 (with bibliography and synonymy).

1915. *Styela lovenii*, Hartmeyer, p. 326.

1916. *Goniocarpa coriacea*, Redikorzew, p. 244 (with bibliography and synonymy).

King George Sound, Hudson Strait; 40 fathoms; September 9, 1897; coll. Low and Wakeham, 4 sp. Sound between Paint Hills Islands, east coast of James Bay (about 53°N. lat.); 10 fathoms; stones and sandy mud; September 10, 1920; coll. F. Johansen, 15 sp. Old Factory Bay, east coast of James Bay (about lat. 52½°N.); 5 fathoms; stones, sandy mud and algae; September 11, 1921; coll. F. Johansen, 2 sp.

I have followed Hartmeyer in using Koren and Danielssen's name for the species, as their article is not accessible to me. There is a strong tendency at present among Ascidiologists to lump species wherever practicable. Simplicity is achieved, but at the expense of neglect of many more or less distinct forms that undoubtedly exist. If we follow the authors listed under the synonymy we must consider as belonging to this species the following: *Cynthia coriacea*, Alder and Hancock, *Cynthia placenta* Packard, *Cynthia granulata* Alder, *Styela armata* Lac.-Duth. et Delage, *Styela northumbrica* Alder and Hancock, *Tethyum compressum*, Redikorzew, *Goniocarpa coccodes* Huntsman, and *Styela hemicaespitosa* Ritter. It is undoubtedly true that these are all closely related and that they are not all distinct, but among them are clearly different forms. Their satisfactory elucidation must be left to the future. These forms may best be considered as subspecies. A very distinct one is the *granulata* of Alder with which the *armata* of Lacaze-Duthiers et Delage is synonymous. This form has tapering, sharp spinules and very short gonads, the ducts of the latter falling far short of reaching the atrial velum.

The specimens from Hudson strait agree with what seems to be the usual condition in this species, but those from James bay differ from any Pacific, Atlantic or arctic specimens that have been available for examination. The gonoducts end close to the atrial velum as is usual. The outer surface of the test possesses granules that are considerably more prominent than is usual. The greatest peculiarity, however, consists in the character of the spinules.

These are not pen-shaped, but round, and they taper to a sharp point. They are from 0.016 to 0.024 mm. long. In the elongation of the spinules this form approaches the condition found in *Katatropa greeleyi* (see Huntsman, 1913, p. 495). It seems desirable to give this form a name. It may be called *Goniocarpa lovenii jacobaea*.

This species is circumpolar and extends well into the subarctic.

Goniocarpa rustica (L.).

1912. *Tethyum rusticum*, Van Name, p. 549 (with bibliography and synonymy).

1916. *Goniocarpa rustica*, Redikorzew, p. 229 (with bibliography and synonymy).

King George Sound, Hudson Strait; 40 fathoms; September 9, 1897; coll. Wakeham and Low, 1 sp. Fort Churchill, west side of Hudson Bay; on beach; October, 1910; coll. J. M. Macoun, 2 sp.

This species is circumpolar, and extends into the subarctic regions but not so far as does the preceding.

Cnemidocarpa rhizopus (Redikorzew).

1874. *Cynthia villosa*, Kupffer, p. 244.

1903. *Styela villosa*, Hartmeyer, p. 225.

1907. *Styela rhizopus*, Redikorzew, p. 523.

1909. *Tethyum kupfferi*, Hartmeyer, p. 1360.

1916. *Cnemidocarpa rhizopus*, Redikorzew, p. 271 (with bibliography and synonymy).

Richmond Gulf, east coast of Hudson Bay; 15-30 fathoms; soft mud; June, 1899; coll. A. P. Low, 1 sp. Manitouk Sound (bay inside boat opening), east coast of Hudson Bay; 5-7 fathoms; clay-mud, sand and stones; August 27, 1920; coll. F. Johansen, 17 sp.

This species has the following characters. The body is elongated, with the apertures on short contractile siphons at one end, and with from 1 to 8 branched radicoid filaments at the other end. The surface is usually coated with adherent sand grains and the anterior half of the body in the contracted state is thrown into transverse wrinkles. The pharyngeal folds are much reduced, having from one to seven longitudinal bars on each and none between the folds. The stomach is placed transversely and has from 16 to 20 folds in its wall. The intestinal loop is short. The rectum is long and ends close to the atrial velum in the anus, which has from 15 to 18 lobes on its margin. The gonads are transverse or nearly so, and number from 2 to 5 on each side.

The single specimen from Richmond Gulf is 11 mm. long and 8 mm. in diameter. There are about 40 oral tentacles, and the dorsal tubercle is horseshoe-shaped, with the opening between the horns directed posteriorly and slightly to the left. The formula for the pharyngeal folds is:

Left —Dors. 0 (5) 0 (2) 0 (4) 0 (2) 0 vent.
Right—Dors. 0 (7) 0 (1) 0 (4) 0 (2) 0 vent.

The atrial velum varies in width from point to point, in some places being quite narrow. Its margin is undulating. The atrial tentacles are filiform or somewhat clavate, and placed in a single row at the base of the velum. There are two gonads on each side.

The largest specimen from Manitouk Sound is 7 mm. long and 4½ mm. in diameter. The pharyngeal formula is:

Left —Dors. 0 (5) 0 (1) 0 (3) 0 (2) 0 vent.
Right—Dors. 0 (5) 0 (1) 0 (3) 0 (1) 0 vent.

There are four gonads on the right side and three on the left.

These specimens agree sufficiently well with the brief accounts by Kupffer and Hartmeyer of a specimen from Greenland. From Redikorzew's description of his species (and also of the variety *murmanense*) they differ in a somewhat smaller number of gonads, and in a somewhat larger number of bars on the pharyngeal folds. It is an interesting fact that so far as reported the numbers of bars on the various pharyngeal folds vary inversely with the number of gonads. Taking for simplicity the gonad of the right side and the most dorsal pharyngeal fold, we have the following:

	Gonads	*Longitudinal bars*
C. rhizopus (type)	6	3
C. rhizopus murmanense	5	4
Manitouk Sound specimen	4	5
Richmond Gulf specimen	2	7

It appears unlikely that these differences in numbers are important enough to warrant our considering these forms as distinct species. The uniformly lower number of gonads in the specimens from Greenland and Hudson Bay as compared with those described by Redikorzew from the Eurasian arctic is sufficient reason for provisionally considering the American specimens as belonging to a different subspecies, which we may call *C. rhizopus americana*.

This species is very definitely limited to arctic waters, as it has been found in Eurasia only within the Arctic circle (northernmost part of Siberia and Novaya Zemlya), and in America hitherto only from north-east Greenland. Its presence is indicative of the arctic character of the waters of Hudson Bay, even though they are not within the arctic circle.

Cnemidocarpa mollis (Stimpson).

1912. *Tethyum molle*, Van Name, p. 571 (with bibliography and synonymy).

1916. *Cnemidocarpa mollis*, Redikorzew, p. 265 (with bibliography and synonymy).

Manitouk Sound (bay inside boat opening), east coast of Hudson Bay; 5-7 fathoms; clay-mud, sand and stones; August 27, 1920; coll. F. Johansen, 13 sp.

The largest specimen is 11 mm. long and 9 mm. in diameter, with the oral and atrial apertures on the dorsal side and equidistant respectively from the anterior and posterior ends. The surface of the body is quite well covered with sand grains adhering to filaments of the test, which near the apertures are simple and scattered, and on the ventral surface arise in clusters from points on the test or from more or less distinct pedicels.

The formula for the bars on the pharyngeal folds is:

Left—Dors. 0 (14) 2 (6) 2 (14) 3 (14) 2 vent.

Right—Dors. 0 (16) 2 (8) 2 (15) 3 (9) 2 vent.

There are 8 gonads on the right side, and 5 on the left. There are 10 anal lobes.

The smallest specimen is 3 mm. in diameter and not definitely elongated in any direction. No gonads are discernible. The anal lobes are indistinct. There are about 20 longitudinal bars on each side of the pharynx, but the arrangement in folds is not clear.

A very exceptional specimen is 13 mm. long and 8 mm. in diameter, with the apertures close together at one end. At the opposite end the body is drawn out into a fleshy wrinkled root with only a few filaments. The remainder of the surface is thickly covered with simple filaments. There are 3 gonads on each side. In spite of the peculiar shape there can be little doubt that it belongs to the same species as the others, but it is an example of how deceptive form may be in Ascidians, in this case probably as the result of growth in a peculiar situation.

This species, known only from the east coast of North America, has not previously been reported from any point north of the Gulf of St. Lawrence. It occurs as far south as Long Island Sound. It is remarkable that the European form *Cnemidocarpa vestita* (Stanger), which is by some considered as identical with this species, is known only from the northern coasts of Great Britain.

Boltenia echinata (L.).

See for synonymy Van Name, 1912, p. 523, under the name *Pyura echinata*, and also Redikorzew, 1916, p. 154.

King George Sound, Hudson Strait; 40 fathoms; September 9, 1897; coll. Wakeham and Low, 6 sp.

These specimens are of the typical arctic type, with spines showing a whorl of branches and the stem continued far beyond the whorl. They differ, therefore, from the variety *hirsuta* (*Boltenia hirsuta*, Huntsman, 1912, p. 147) of the Bay of Fundy and Gulf of Maine.

This species is arctic and circumpolar. It is found far into the subarctic zone.

Boltenia ovifera (L.)

For synonymy and bibliography see Van Name, 1912, p. 527, and Redikorzew, 1916, p. 143.

King George Sound, Hudson Strait; 40 fathoms; September 9, 1897; coll. Wakeham and Low, 1 sp. Fort Churchill, west side of Hudson Bay; on beach; October, 1910; coll. J. M. Macoun, 2 sp.

MacLeay (1825, p. 536) recorded this species (as *B. reniformis*) from Winter Island, Fox Channel, which is in the northern part of the region we are considering. Halkett (1898, p. 83) recorded *Boltenia* from the south shore of Hudson Strait taken in the summer of 1897, and (1906, p. 368) has reported specimens of *Boltenia*, which, doubtless were of this species, from Port Burwell, Hudson Strait, and from Fullerton, N.W. part of Hudson Bay, obtained in 1903-04.

The distribution of this species is quite peculiar. It is found from the sea of Okhotsk and Kamchatka through arctic America to Greenland, and our Atlantic coast as far south as the Gulf of Maine. From Eurasia and the islands to the north (except as indicated above) it has not been reported.

LITERATURE

GIARD, A. 1872. Deuxième étude critique des travaux d'embryogenie, etc. *Arch. Zool. Expér. et Génér.*, t. I, pp. 397-428.

HALKETT, A. 1898. List of zoological specimens, etc., in *Report of the Expedition to Hudson Bay and Cumberland Gulf . . . in the year 1897*, pp. 80-83.

1906. Report of the Canadian Fisheries Museum. *38th Annl. Rep. Dept. Marine and Fisheries*, pp. 362-370.

HARTMEYER, R. 1901. Holosome Ascidien. *Meeresfauna von Bergen*, 1901, pp. 19-63.

1903. Die Ascidien der Arktis. *Fauna Arctica*, Bd. III, pp. 91-412.

1909. Ascidien. *Bronn's Kl. u. Ordn. d. Tier-Reichs*, Bd. III, suppl. pp. 1281-1488.

1915. Alder und Hancocks Britische Tunicaten. *Mt. Zool. Mus. Berlin*, Bd. VII, pp. 303-344.

HUNTSMAN, A. G. 1912. Ascidians from the Coasts of Canada. *Trans. Can. Inst.*, Vol. IX, pp. 111-148.

1913. The classification of the Styelidae. *Zool. Anzeiger*, Bd. XLI, Nr. 11, pp. 482-501.

KUPFFER, C. W. 1874. Tunicata. *Die zweite deutsche Nordpolarfahrt*, etc., Bd. II, pp. 244-245.

MACLEAY, W. S. 1825. Anatomical observations on the natural group of the Tunicata, etc. *Trans. Linn. Soc. Lond.*, Vol. XIV, pp. 527-555.

MÖLLER, H. P. C. 1842. Index Molluscorum Groenlandiae. *Nat. Tidsskrift*, Vol. IV, pp. 76-97.

REDIKORZEW, V. V. 1907. Die Ascidien der russischen Polar expedition, 1900-1903. *Zool. Anzeig.* Bd. XXXI, pp. 521-525.

1916. Faune de la Russie. Tunicies. Livr. 1, pp. 1-336.

STIMPSON, W. 1852. Descriptions of several new Ascidians from the coast of the United States. *Proc. Bost. Soc. Nat. Hist.*, Vol. IV, pp. 228-232.

TRAUSTEDT, M. P. A. 1883. Vestindiske Ascidiae simplices. Anden Afdel. *Vidensk. Meddel. fra den naturh. Foren. i Kjöbenhavn*, 1882, pp. 108-136.

VAN NAME, W. G. 1912. Simple Ascidians of the coasts of New England and neighboring British provinces. *Proc. Bos. Soc. Nat. Hist.*, vol. 34, pp. 439-619.

VERRILL, A. E. 1872. Recent additions to the Molluscan fauna of New England, etc. *Amer. Journ. Sci. and Arts*, ser. 3, vol. III, pp. 209-214 and 281-290.

No. 4

SOME PHYSICAL AND CHEMICAL FACTORS INFLUENCING THE DISTRIBUTION OF MARINE FLORA AND FAUNA IN THE STRAIT OF GEORGIA AND ADJACENT WATERS

BY

A. T. CAMERON

AND

IRENE MOUNCE,
University of Manitoba

With a

NOTE ON THE OXYGEN CONTENT OF THESE WATERS

BY C. J. BERKELEY

Some Physical and Chemical Factors Influencing the Distribution of Marine Flora and Fauna in the Strait of Georgia and Adjacent Waters

By A. T. Cameron and Irene Mounce (in part)
University of Manitoba

With a Note on the Oxygen Content of these Waters

By C. J. Berkeley
Marine Biological Station, Nanaimo, B.C.

INTRODUCTION

The marine waters between the Mainland and Vancouver Island present an unusual complexity of conditions; in addition these show marked differences during the winter and summer months. In summer there is a very large inflow of fresh water from the Fraser and similar rivers northwards. In winter this diminishes materially, but smaller streams show large increases in volume, causing distinct local variations near their mouths.

The Strait of Georgia itself is some 150 miles long and its greatest width is about 30 miles; it contains a large pocket of maximum depth 240 fathoms, while the Ocean inflow passes through channels which to the south do not exceed 80 fathoms, nor probably is this exceeded in any of the northern channels (complete depth-figures for these are not shown in the charts). In addition there are various other pockets, such as those in Sansom Narrows and Saanich Inlet, to which Ocean water must flow over much shallower passages. The numerous islands produce a variety of currents, many of which are rapid, amounting to several miles per hour. All of these varying tidal currents are further changed by altering wind conditions. The variations are noticeable to a considerable depth.

During summer, even in the open Strait, the surface temperature remains steadily more than five degrees higher than in the adjacent open sea.

In agreement, and perhaps as a result of this diversity of conditions, the distribution of species in these waters is singularly complex. Species are found within the limits of the Strait which extend northwards to the Arctic, but no further south, and other species which extend at least to the waters of Southern California, but no further north.

Some of these species appear to exhibit a difference in character and rate of growth which can be traced to the different physical and chemical conditions within and outside the Strait. It has been already pointed out (Cameron, 1916; Fraser and Cameron, 1916) that the giant kelp *Nereocystis lütkeana* is much less luxuriant in growth within the Strait than nearer the open ocean, and that the similar species *Macrocystis pyrifera* and the shell-fish *Haliotia gigantea* (an abalone) are not found within the Strait at all, though appearing north and south of it, since they apparently require a habitat of specific gravity constantly greater than 1.018. Gail (1919) has shown that both temperature and hydrogen-ion concentration are important factors controlling the germination and development of Fucus.

Certain pelagic forms and free-moving shore forms, which occur constantly throughout the summer at Friday Harbour (where surface conditions more similar to those of the open Ocean persist), disappear from near the surface at Departure Bay and adjacent waters early in summer, making the question of migration a matter of importance (cf. Fraser, 1918). This is especially noticeable with diatoms (cf. Mounce). The importance of changes in hydrogen-ion concentration in determining such migrations is gradually becoming realized. Thus Powers (1921), working at Friday Harbour, has recently shown that herring appear to be attracted towards a sea-water with a pH value of 7.7, while water in which they are found exhibits pH values between 7.7 and 7.9. Certain other species of fish show similar limits, while others do not appear to be attracted or repelled by hydrogen-ion changes.

Our knowledge of the distribution of definite classes of marine organisms in localities in the vicinity of the two marine stations is gradually accumulating. These represent respectively typical conditions within the Strait and near the open Ocean. Such knowledge, when complete, will undoubtedly lead to a much more accurate correlation between these distributions and the accompanying physical and chemical factors. In this paper we have attempted to obtain information about the latter throughout the region in which are situated these stations.

While further observations, especially during the winter months, will be necessary in order to obtain all the requisite data, from those now and previously recorded (Fraser and Cameron, 1916; Fraser, 1920) it is possible to foretell the general conditions throughout the year.

Such generalizations are, of course, essential as a basis for further accurate and more specific series of observations and correlations; we hope that the data which follow will be of service to both chemists and biologists who shall make these in the future.

METHODS OF WORK

Our observations fall into two parts:

1. An almost complete series of measurements on the surface water at the Station Wharf at Departure Bay, of temperature, specific gravity, and hydrogen-ion concentration, from June 20th to September 2nd, 1921.

2. A similar series of readings on water samples from various depths throughout the Strait and adjacent waters, carried out from the latter part of July to the latter part of August. In addition, halide and bicarbonate content were measured on these samples, and in a few cases calcium and magnesium content.

All samples of water, except surface samples, were obtained in a Pettersen-Nansen deep-sea water bottle.

Temperature. The surface measurements at Departure Bay were made with ordinary thermometers calibrated against a Kew standard. The results can, therefore, be considered accurate to within ±0.1°C. The remaining measurements were made with a Negretti and Zambra standardized reversing thermometer, and can be considered accurate to within ±0.02°C. In one or two instances, when making deep-sea measurements, it was doubtful whether the thermometer had been "tripped" satisfactorily, and the readings were excluded.

SPECIFIC GRAVITY. The surface readings at the Station were made with a series of long hydrometers calibrated with known solutions whose densities were accurately determined in a pyknometer. The probable error of these readings is estimated to be not greater than ±0.0001. All readings were corrected for temperature to 15°C. as compared with pure water at 15°. The smaller amounts of water available from the deep-sea samples necessitated the use of a short hydrometer. This was similarly standardized, but the probable error was at least two or three times greater.

CHLORIDE CONTENT. The total halide content, expressed as chloride was determined by Mohr's method, 5 c.c. samples of water being titrated directly with standard silver nitrate solution, with potassium chromate as an indicator. Although this method is not usually regarded as very accurate, it permits a rapid estimation, and under the parallel conditions of our determinations the results are probably closely comparable, and furnish an accurate check on the specific gravity determinations. Certain samples were subsequently analysed gravimetrically in Winnipeg, the silver halide in 5 c.c. samples being weighed in a Gooch crucible at 120°C. The results by the two methods are very concordant.

"ALKALINITY" was determined on 100 c.c. samples by titration with standard hydrochloric acid, using methyl orange as an indicator. The results are expressed in terms of the HCO_3 ion.

CALCIUM and MAGNESIUM. A certain number of determinations were carried out at Winnipeg, in order to furnish further information of the type of water under examination. Since only approximate (and comparable) figures were required, Dittmar's procedures on 40 c.c. samples were employed, the calcium oxide and magnesium pyrophosphate being weighed after ignition in Gooch crucibles. Our figures for calcium are, therefore, somewhat too high (*vide* Dittmar).

HYDROGEN-ION CONCENTRATION. This was determined colorimetrically, using Clark and Lub's indicators, thymol blue, cresol red, and phenol red, and the colour chart in Clark's handbook for comparison. For the purpose of this comparison 10 c.c. samples of sea-water were taken, and ten drops of the dilute indicator added to them in a test-tube of clear glass 16 mm. in diameter. The readings were usually made a few minutes after the sample had been obtained, and before its temperature had materially changed (in the interval it was kept in a stoppered bottle), so that there was no appreciable loss of carbon dioxide. Use of the colour chart permitted the comparison to be carried out on board the Station boat at the actual times when the samples were collected.* The chart

---

*The samples taken on August 4th at Stations 4, 5 and 6 were not measured till from five to six hours later. Those taken on August 25th at Stations 17 and 18 were not measured till from nine to ten hours later. Experiments 1 to 3 (below) indicate that the error with carefully sealed samples is within that of the method employed.

was subsequently calibrated, the thymol blue and phenol red colours being standardized against those of cresol red with appropriate sea-water samples, and the cresol red colours against the Sörensen phosphate- and Palitsch borate-boric acid-mixtures. Neglecting the salt-error, the pH figures in the tables are probably accurate to ±0.05.

Wells has determined the salt error for cresol red. From his figures it would appear that the Maximum correction to be applied to our results is of the order 0.1, the correction changing proportionately with the salinity. Since the degree of accuracy of our results is scarcely greater we have considered it better to attempt no correction for salt error.

POSITIONS OF STATIONS

Samples from the Marine Biological Station at Departure Bay were obtained from the end of the Station Wharf. The other points at which sea-water samples were obtained have been numbered from north-west to south-east and the approximate positions are shown by these numbers in parentheses in the map. The exact positions follow. At each point the deepest sample was first obtained, and then the others in order to the surface.

Station 1. Centre of Departure Bay, drifting slowly west.

Station 2. In Northumberland Channel, a quarter of a mile from Gabriola Island, and two and one-half miles from Dodd's Narrows. Drifted one mile south-east.

Station 3. Eight miles east by north of Departure Bay.

Station 4. One mile south-east by east of Entrance Island. Drifted one mile south, inshore towards Gabriola Island.

Station 5. Two miles north-east by north of Thrasher Rock.

Station 6. Three miles north-east by north of Thrasher Rock. Drifted south one mile.

Station 7. Six miles east of Thrasher Rock. Drifted south, then north.

Station 8. Three miles Magnetic West of Sandheads Lightship. Drifted one and one-half miles north.

Station 9. One half mile Magnetic West of Lightship. Drifted north one mile.

Station 10. At Sandheads Lightship.

Station 11. Three miles south-west of Lightship. Drifted north-west one-half mile.

Station 12. Five miles east of Porlier Pass. Drifted north one-half mile.

Station 13. Two miles east of Porlier Pass. Stationary.

Station 14. One-half mile within Porlier Pass. Drifted north a quarter mile.

Station 15. Two hundred yards west of the Shark Factory on Parker Island. Drifted one hundred yards south.

Station 16. North of Sansom Narrows. Fairly stationary.

Station 17. Open Strait outside Saanich Inlet.

Station 18. South end of Saanich Inlet.

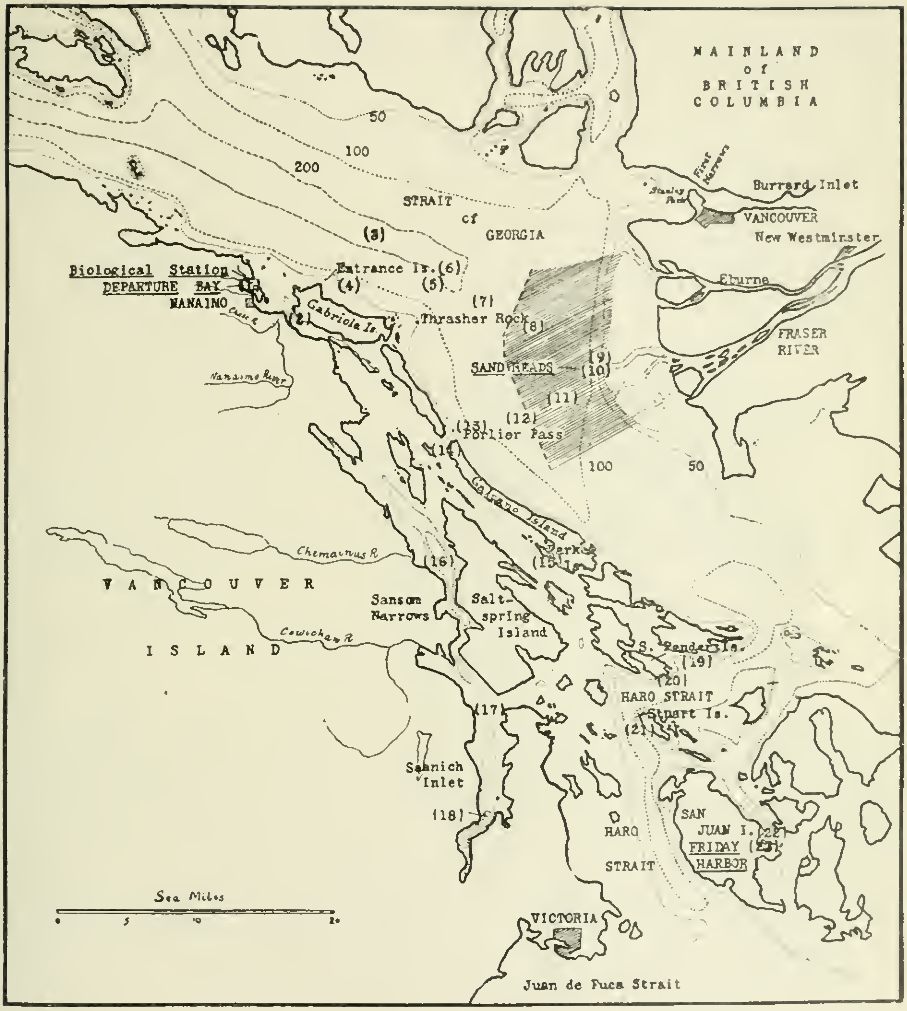


PLATE I.

Map showing location of Stations. The Station numbers are in parentheses.

Station 19. In Haro Strait, two miles east of the eastermost point on South Pender Island. Drifted 200 yards south.

Station 20. In Haro Strait. One to one and one-half miles south of south-east point of South Pender Island. There was a strong current east at this point, so that while the samples at 150, 50, 5, 3, 1 and 0 fathoms depth were taken at approximately this position, those at 100, 20 and 10 fathoms were taken at approximately three-quarters of a mile further east, it being necessary to return twice to the original point.

Station 21. Haro Strait, half-mile west of Stuart Island. Drifted east towards the Island, and the last two samples were obtained after returning to the original position.

Station 22. Off Cape Caution, San Juan Island. Drifted south one mile.

Station 23. At the Marine Biological Station, Friday Harbour.

In addition, two samples were taken on the south shore of the First Narrows, in Stanley Park, and fresh water samples were taken at the following points:

(*a*) The Stream at the Biological Station, near its mouth.
(*b*) The Stream at the head of Departure Bay, near its mouth.
(*c*) The Mill Stream, north of Nanaimo, one mile from its mouth.
(*d*) The Chase River, just west of the Island Highway.
(*e*) The Nanaimo River, just west of the Island Highway.
(*f*) The Fraser River, at Eburne, from an island in mid-stream.
(*g*) The Fraser River, at New Westminster, from a wharf well out in the Stream.

TABULATION OF RESULTS

In Table I the observations and measurements at the Station are given; in Table II those at various dates from depth samples in Departure Bay; in Table III a small series in the Departure Bay area, taken at approximately the same time; in Table IV those of other sea-water samples; and in Table V those for fresh water samples. Table VI shows the comparative halide values given by different methods, and the figures for calcium and magnesium. Certain other data are included in the tables. Under "Tide," "H" indicates at or near high tide, "L" at or near low tide, "M" between tides. "E" indicates an east wind, "W" a west wind, "O" calm, "D" dull, and "B" bright sunshine, "a" a.m., "p" p.m. We are indebted to Dr. C. M. Fraser for the air temperature and rain records.

TABLE I.

Surface Sea-water Samples from the Wharf, Marine Biological Station, Departure Bay

Date	Time	Tide	Wind	Sky	Rain inch	Air Temp. Max. °C.	Air Temp. Min. °C.	Water Temp. °C.	Specific Gravity to 15°C.	PH
June 16	8.30 a.	L.	E	D	....	17.8	9.9	13.8	1.0216	8.45
17	8.30 a.	L.	E	B	....	15.9	6.9	14.3	1.0142	8.5
	5.20 p.	H	..	..	....	....	....	14.9	1.0144	8.5
18	5.45 p.	H	E	D	0.02	13.9	10.8	14.7	1.0157	8.7
19	8.45 a.	L	E	D	....	18.1	7.1	14.0	1.0179	8.6
	6.15 p.	H	..	..	....	....	....	14.3	1.0198	8.5
20	8.30 a.	M	E	D	0.34	17.4	12.7	12.9	1.0190	8.55
	7.00 p.	H	..	..	....	....	....	13.8	1.0198	8.6
21	8.30 a.	M	E	B	....	18.6	10.7	11.7	1.0218	8.45
	7.40 p.	H	..	..	....	....	....	12.9	1.0204	8.5
22	8.30 a.	M	O	B	....	20.1	7.6	13.1	1.0154	8.6
	8.10 p.	H	..	..	....	....	....	15.2	1.0118	8.75
23	8.30 a.	M	W	D	....	21.4	10.4	15.0	1.0113	8.8
	8.45 p.	H	..	..	....	....	....	17.3	1.0119	8.7
24	7.00 a.	H	O	D	0.03	18.0	10.1	15.2	1.0119	8.8
25	8.10 a.	H	E	D	....	17.3	10.9	16.3	1.0147	8.7
26	9.00 a.	H	E	D	0.15	17.6	11.8	14.5	1.0176	8.7
27	10.00 a.	H	E	D	....	16.7	10.0	14.7	1.0179	8.65
28	11.30 a.	H	E	B	....	20.0	6.6	14.6	1.0206	8.65
29	1.00 p.	H	E	D	0.13	16.2	11.9	17.0	1.0138	8.7
30	12.30 p.	H	E	B	0.31	19.4	11.2	18.2	1.0143	8.6
July 1	3.00 p.	H	W	B	0.16	16.3	9.6	15.7	1.0147	8.7
2	8.30 a.	L	W	B	....	18.9	9.9	15.1	1.0141	8.55
	5.30 p.	H	..	..	....	....	....	15.6	1.0143	8.75
3	9.00 a.	L	E	B	....	18.3	8.0	15.8	1.0150	8.7
	8.30 p.	H	..	..	....	....	....	16.6	1.0144	8.7
4	8.20 a.	M	W	D	....	18.4	12.4	15.2	1.0171	8.5
	7.00 p.	M	..	..	....	....	....	16.8	1.0181	8.6
5	8.15 a.	M	W	B	....	20.1	8.4	15.3	1.019[illegible]	8.5
	7.00 p.	H	..	..	....	....	....	15.8	1.0151	8.5
6	8.30 a.	M	E	B	....	19.8	12.0	15.3	1.0166	8.6
	6.00 p.	M	..	..	....	....	....	17.1	1.0163	8.7
7	8.30 a.	M	O	D	....	20.3	11.5	15.2	1.0192	8.7
	7.00 p.	H	..	..	....	....	....	15.8	1.0186	8.5
8	8.30 a.	M	W	B	....	19.0	8.9	13.8	1.0210	8.4
	7.00 p.	H	..	..	....	....	....	14.8	1.0205	8.5
9	8.30 a.	H	W	B	....	21.8	8.6	15.3	1.0198	8.6
	7.00 p.	M	..	..	....	....	....	16.8	1.0141	8.7
10	9.00 a.	H	W	B	....	23.4	12.3	15.8	1.0153	8.7
	7.30 p.	M	..	..	....	....	....	17.1	1.0153	8.6
11	8.30 a.	M	W	B	....	23.3	12.5	16.3	1.0154	8.65
	7.00 p.	M	..	..	....	....	....	17.9	1.0154	8.7
12	8.30 a.	M	W	B	....	21.9	10.8	17.3	1.0156	8.7
	7.00 p.	M	..	..	....	....	....	18.4	1.0156	8.55
13	8.30 a.	M	W	B	....	21.3	11.7	16.8	1.0161	8.6
	7.00 p.	M	..	..	....	....	....	18.4	1.0164	8.6

TABLE I—*Cont.*

Date	Time	Tide	Wind	Sky	Rain inch	Air Temp. Max. °C.	Air Temp. Min. °C.	Water Temp. °C.	Specific Gravity to 15°C.	PH
14	8.30 a.	L	E	B	....	19.9	11.4	17.3	1.0172	8.6
	7.00 p.	H	..	..	....	....	....	18.0	1.0177	8.6
15	8.15 a.	L	E	D	0.02	17.9	8.6	17.5	1.0180	8.55
	7.00 p.	H	..	..	....	....	....	17.5	1.0184	8.5
16	8.10 a.	M	W	B	....	22.3	11.1	15.1	1.0198	8.5
	7.00 p.	H	..	..	....	....	....	17.6	1.0192	8.5
17	9.00 a.	L	W	B	....	24.6	11.7	17.2	1.0177	8.5
	7.30 p.	H	..	..	....	....	....	17.7	1.0174	8.5
18	8.30 a.	M	E	B	....	21.7	11.8	17.5	1.0181	8.5
	7.00 p.	H	..	..	....	....	....	19.2	1.0162	8.6
19	8.30 a.	M	E	D	0.02	17.9	12.6	18.1	1.0167	8.6
	7.10 p.	H	..	..	....	....	....	18.5	1.0169	8.65
20	8.30 a.	H	O	D	0.73	19.0	13.3	18.6	1.0168	8.6
	7.00 p.	H	..	..	....	....	....	18.7	1.0170	8.65
21	8.20 a.	M	E	B	....	21.8	9.6	17.9	1.0173	8.65
	7.00 p.	H	..	..	....	....	....	19.4	1.0178	8.5
22	8.20 a.	M	E	D	....	20.2	11.7	17.1	1.0192	8.55
	7.00 p.	M	..	..	....	....	....	18.2	1.0186	8.5
23	8.20 a.	M	W	B	....	24.6	10.9	16.7	1.0197	8.5
	7.00 p.	M	..	..	....	....	....	19.1	1.0183	8.65
24	8.45 a.	H	W	B	....	23.3	14.1	18.8	1.0167	8.65
	7.00 p.	M	..	..	....	....	....	20.0	1.0154	8.7
25	8.40 a.	H	E	D	....	19.0	13.7	19.3	1.0153	8.7
	6.45 p.	M	..	..	....	....	....	19.5	1.0152	8.6
26	8.20 a.	H	E	D	....	20.3	13.6	18.6	1.0154	8.6
	6.45 p.	M	..	..	....	....	....	19.4	1.0169	8.7
27	8.30 a.		E	B	....	21.7	9.9	18.0	1.0177	8.7
28	8.15 a.		..	B	....	23.4	12.6	18.0	1.0190	8.65
29	8.30 a.		..	B	....	25.9	18.9	18.9	1.0156	8.7
30	8.30 a.		..	B	....	26.1	14.8	19.4	1.0156	8.75
31	9.00 a.		W	D	....	26.6	15.3	19.8	1.0164	8.75
Aug. 1	4.00 a.		..	D	....	24.4	13.0	19.0	1.0163	(8.55)
2	3.00 p.		..	..	....	23.4	12.6	20.7	1.0182	8.75
3	8.30 a.		..	..	....	21.3	12.2	18.7	1.0183	8.7
4	8.15 a.		..	..	....	20.6	10.4	18.0	1.0153	8.8
5	8.30 a.		..	..	0.26	18.1	10.8	17.6	1.0155	8.85
6	8.30 a.		..	..	0.01	21.2	11.2	17.7	1.0179	..
7	8.30 a.		..	..	....	26.2	13.5	18.6	1.0174	..
8	8.30 a.		..	..	....	25.2	14.8	19.5	1.0143	..
9	8.30 a.		..	..	....	21.8	16.1	19.7	1.0150	
10	8.30 a.		..	..	....	23.6	12.2	19.2	1.0152	8.7
11	8.30 a.		..	..	....	24.2	10.7	19.1	1.0161	8.8
12	8.45 a.		..	..	....	28.6	13.6	19.6	1.0164	8.7
13	8.30 a.		..	..	....	29.8	12.4	19.1	1.0169	8.8
14	9.00 a.		..	..	....	21.6	13.4	19.0	1.0176	8.7
15	8.30 a.		..	..	....	18.7	13.1	17.5	1.0182	8.6
	7.15 p.		..	..	....	....	....	17.5	1.0190	8.5
16	5.00 a.		..	..	0.07	20.3	12.4	16.3	1.0196	8.55
17	8.30 a.		..	..	0.58	15.6	13.9	14.9	1.0206	..

TABLE I—*Cont.*

Date	Time	Tide	Wind	Sky	Rain inch	Air Temp. Max. °C.	Air Temp. Min. °C.	Water Temp. °C.	Specific Gravity to 15°C.	P_H
18	8.30 a.		..	..	....	18.5	11.7	13.2	1.0220	....
	2.15 p.		..	..	....	....	....	14.5	1.0223	8.45
19	8.30 a.		..	..	....	20.8	11.2	14.2	1.0215	8.5
20	8.15 a.		..	..	0.17	18.6	13.6	16.2	1.0153	8.55
21	8.45 a.		..	..	0.07	16.8	9.3	15.7	1.0149	8.55
22	8.30 a.		..	..	0.13	14.9	10.2	15.0	1.0160	8.65
23	8.30 a.		..	..	0.12	15.8	10.7	14.2	1.0175	8.6
24	8.30 a.		..	..	0.52	14.3	10.6	13.7	1.0196	8.55
25	8.30 a.		..	D	0.01	18.2	10.6	13.7	1.0203	8.5
			(at 1 fathom)		....	....	....	13.5	1.0203	8.5
	4.00 p.		..	B	....	....	....	16.2	1.0200	8.55
26	8.30 a.		..	B	....	20.8	9.4	14.7	1.0174	8.55
27	8.30 a.		O	B	....	20.8	8.6	15.0	1.0173	8.6
28	8.45 a.		O	B	....	21.8	9.4	16.7	1.0175	8.6
29	8.15 a.		O	B	....	19.9	10.2	16.7	1.0175	8.6
30	8.30 a.		O	B	....	19.2	10.2	17.0	1.0178	8.55
31	8.30 a.		..	D	0.18	17.6	12.1	15.6	1.0190	8.5
Sept. 1	8.30 a.		..	D	0.15	16.0	9.2	13.6	1.0211	8.5
2	9.00 a.		..	..	....	....	....	12.7	1.0222	8.3

TABLE II

Depth Samples, Departure Bay

Date	Time	Depth fathoms	Temp. °C.	Specific Gravity to 15°C.	P_H	NaCl per litre	Alkalinity as $'HCO_3$ per litre
July 27	11.10 a.	15	9.87	1.0254	8.0	....	....
		10	11.00	1.0234	8.1	....	....
		5	13.02	1.0228	8.5	....	....
		4	14.35	1.0225	8.65	....	....
		3	15.11	1.0221	8.7	....	....
		2	15.94	1.0207	8.75	....	....
		1	17.98	1.0203	8.7	....	....
28	1.00 p.	20	10.40	1.0227	7.9	26.73	0.161
		10	10.78	1.0215	8.15	26.14	0.161
		5	15.80	1.0205	8.65	23.13	0.147
		4	16.62	1.0194	8.7	22.39	0.142
		3	16.85	1.0190	8.7	22.17	0.141
		2	17.98	1.0188	8.75	21.34	0.142
		1	18.22	1.0185	8.75	20.81	0.139
		0	18.65	1.0172	8.75	20.59	0.139
Aug. 29	8.45 a.	20	10.09	1.0234	8.05	26.56	....
		10	11.78	1.0234	8.3	25.80	....
		5	13.00	1.0219	8.35	25.00	....
		3	14.65	1.0212	8.4	23.74	....
		1	16.78	1.0181	8.6	19.44	....
		0	17.00	1.0177	8.7	19.18	....

TABLE III

Comparison of Surface Samples in Vicinity of Departure Bay

Date	Time	Place	Temp. °C.	Specific Gravity to 15°C.	P_H
June 27	10.10 a.	Wharf, Departure Bay	14.7	1.0175	8.65
	10.45 a.	Entrance to Bay	13.3	1.0192	8.55
	10.30 a.	Inside Five Finger Island	14.0	1.0190	8.55
	10.15 a.	1.5 miles outside Five Finger Island	13.4	1.0184	8.45

TABLE IV

Depth Samples: Stations in Strait of Georgia and Neighbouring Waters

Station No.	Date	Time	Depth fathoms	Temp. °C.	Specific Gravity to 15°C.	P_H	NaCl per litre	$'HCO_3$ per litre	Remarks
2	July 28	a.m.	50	8.54	1.0246	7.85	26.79	0.165	
			20	....	1.0229	7.95	26.31	0.157	
			20	9.95	1.0229	7.9	26.38	0.157	
			10	12.50	1.0219	8.3	24.96	0.155	
			5	16.36	1.0206	8.7	22.33	0.145	
			4	17.24	1.0202	8.7	21.67	0.141	
			3	17.44	1.0188	8.75	21.50	0.142	
			2	17.61	1.0198	8.8	21.50	0.142	
			1	17.92	0.0188	8.85	21.37	0.140	
			0	18.04	1.0200	8.8	21.50	0.140	
3	Aug. 23	10 a.	200	8.48	1.0241	7.95	27.94	....	
			150	8.52	1.0244	8.0	28.40	.....	
			100	8.90	1.0247	8.1	28.14	.....	
			50	8.60	1.0245	8.05	27.32	.....	
			20	9.65	1.0241	8.05	26.66	.....	
			10	10.22	1.0239	8.1	26.02	.....	
			5	13.23	1.0221	8.3	23.30	.....	
			3	14.05	1.0212	8.5	22.64	.....	
			1	14.83	1.0201	8.55	20.54	.....	
			0	15.44	1.0172	8.6	18.78	.....	
4	Aug. 1	5.15 a.	50	8.44	1.0239	7.85	27.50	0.166	In tide rip.
			20	10.00	1.0232	7.85	26.18	0.157	
			10	13.82	1.0230	7.85	26.00	0.157	
			5	17.24	1.0202	8.5	21.30	0.142	
			3	17.58	1.0173	8.75	19.50	0.133	
			1	18.58	1.0171	8.8	18.76	0.127	
			0	18.70	1.0180	8.85	19.16	0.130	
5	"	6.40 a.	120	.....	1.0261	7.65	28.48	0.173	2 f. from bottom.
6	"	7.30 a.	200	.....	1.0252	7.8	27.66	0.168	1 f. from bottom.
			150	8.36	1.0248	7.7	28.58	0.170	
			100	.....	1.0251	7.8	28.20	0.172	
			50	8.62	1.0247	7.85	27.54	0.163	
			20	9.77	1.0238	7.9	26.74	0.162	
			10	10.42	1.0227	7.9	26.18	0.158	
			5	14.65	1.0224	8.5	23.62	0.154	

TABLE IV—*Cont.*

Station No.	Date	Time	Depth fathoms	Temp. °C.	Specific Gravity to 15°C.	P_H	NaCl per litre	$'HCO_3$ per litre	Remarks
6	Aug. 1	7.30 a.	3	17.80	1.0202	8.65	21.20	0.146	
			1	18.95	1.0164	8.8	17.76	0.128	
			0	19.03	1.0154	8.7	16.90	0.121	
7	"	10.00 a.	150	8.40	1.0252	7.75	28.44	0.170	
			100	8.83	1.0240	7.8	28.03	0.171	
			50	9.07	1.0234	7.8	27.46	0.164	
			10	10.04	1.0225	7.85	26.22	0.157	
			1	19.00	1.0159	8.8	17.62	0.126	
			0	19.54	1.0158	8.8	17.04	0.125	
8	"	11.20 a.	100	9.82	1.0239	7.85	27.74	0.172	
			50	8.59	1.0238	7.85	27.52	0.173	
			20	9.43	1.0238	7.85	26.58	0.162	
			10	10.30	1.0233	7.85	25.96	0.161	
			5	12.10	1.0224	8.1	24.92	0.162	
			3	15.12	1.0208	8.6	22.96	0.148	Clear.
			1	18.43	1.0125	8.8	12.52	0.107	Almost clear.
			0	18.25	1.0055	8.45	5.06	0.088	Cloudy.
9	"	12.45 p.	50	9.40	1.0246	7.85	27.36	0.172	
			20	9.68	1.0239	7.85	26.36	0.162	
			10	10.96	1.0223	7.9	25.22	0.159	
			5	14.35	1.0224	8.15	22.56	0.155	
			3	16.78	1.0176	8.7	18.04	0.135	
			1	17.58	1.0158	8.7	15.52	0.117	Clear.
			0	18.02	1.0024	7.9	1.78	0.079	Cloudy.
10	"	1.50 p.	10	10.87	1.0239	7.85	25.56	0.161	
			5	13.20	1.0228	8.3	23.34	0.150	
			3	13.50	1.0222	8.3	23.28	0.150	
			1	17.97	1.0149	8.7	14.90	0.123	Clear.
			0	18.48	1.0073	8.3	6.40	0.088	Cloudy.
11	Aug. 1	3.20 p.	97	8.97	1.0255	7.9	28.75	0.172	½ f. from bottom.
			50	9.30	1.0248	7.85	27.42	0.167	
			10	10.78	1.0243	7.9	25.74	0.160	
			5	10.26	1.0230	8.15	24.80	0.157	
			3	14.23	1.0207	8.5	23.44	0.148	
			1	16.38	1.0201	8.7	19.24	0.135	
			0	19.65	1.0077	8.7	5.52	0.091	Slightly cloudy.
12	"	4.30 p.	150	8.37	1.0239	7.85	28.18	0.168	
			100	8.59	1.0237	7.8	28.22	0.169	
			50	8.94	1.0233	7.85	27.34	0.161	
			20	9.55	1.0231	8.05	26.70	0.157	
			10	10.25	1.0227	8.2	26.12	0.154	
			5	13.36	1.0225	8.7	24.46	0.151	
			3	16.79	1.0204	8.65	22.42	0.140	
			1	19.42	1.0156	8.8	16.94	0.120	
			0	19.53	1.0160	8.8	15.88	0.119	
13	"	6.10 p.	50	9.02	1.0238	7.85	27.46	0.168	
			20	10.00	1.0238	7.85	26.38	0.162	
			10	10.82	1.0238	8.15	25.76	0.164	
			5	14.63	1.0213	8.55	22.94	0.151	
			3	16.80	1.0192	8.7	20.20	0.142	

TABLE IV—*Cont.*

Station No.	Date	Time	Depth fathoms	Temp. °C.	Specific Gravity to 15°C.	P_H	NaCl per litre	$'HCO_3$ per litre	Remarks.
13	Aug. 1	6.10 p.	1	20.00	1.0165	8.7	17.38	0.126	
			0	20.22	1.0165	8.6	17.40	0.129	
14		7.30 p.	20	10.82	1.0244	8.05	26.62	0.163	
			10	12.77	1.0236	8.65	23.62	0.154	
			5	13.57	1.0230	8.65	23.64	0.157	Water-bottle did not close perfectly.
			3	14.20	1.0223	8.7	22.56	0.154	
			1	15.38	1.0209	8.7	22.36	0.148	
			0	16.07	1.0201	8.7	21.94	0.151	
15	Aug. 16	10.00 a.	20	10.68	1.0239	7.95	27.04	0.168	
			10	11.62	1.0237	7.95	25.88	0.164	
			5	12.82	1.0225	8.3	24.76	0.159	
			3	13.42	1.0231	8.6	24.64	0.158	
			1	14.18	1.0224	8.6	24.06	0.155	
			0	16.41	1.0207	8.85	22.68	0.150	
16	Aug. 17	7.00 p.	100	9.78	1.0243	7.85	27.16	0.168	
			50	10.04	1.0243	7.85	27.00	0.169	
			20	10.83	1.0242	7.95	26.82	0.166	
			10	12.03	1.0239	8.3	26.14	0.166	
			5	13.44	1.0228	8.5	25.14	0.161	
			3	14.46	1.0224	8.5	24.52	0.153	
			1	15.30	1.0221	8.55	23.50	0.154	
			0	15.30	1.0221	8.55	23.60	0.153	
17	Aug. 25	11.10 a.	40	11.22	1.0247	7.85	28.32	.....	At bottom.
			20	10.24	1.0246	8.15	27.40	.....	
			10	10.82	1.0244	8.2	.....	.....	
			5	11.08	1.0241	8.3	.....	.....	
			3	11.43	1.0240	8.3	.....	.....	
			1	11.98	1.0231	8.55	26.24	.....	
			0	12.63	1.0230	8.5	.....	.....	
18	"	9.00 a.	100	8.61	1.0263	7.65	28.26	.....	
			50	8.74	1.0259	7.75	.....	.....	
			20	9.84	1.0241	8.0	27.48	.....	
			10	10.63	1.0241	8.05	.....	.....	
			5	11.14	1.0232	8.1	26.34	.....	
			3	11.58	1.0233	8.3	26.54	.....	
			1	13.53	1.0232	8.7	26.22	.....	
			0	13.98	1.0231	8.7	.....	.....	
19	Aug. 16	10.00 p.	50	8.96	1.0255	7.85	29.06	0.175	
			10	10.22	1.0249	8.05	27.46	0.172	
			1	11.17	1.0239	8.05	26.46	0.167	
			0	11.82	1.0239	8.05	26.14	0.167	
20	"	2.15 p.	150	7.84	1.0265	7.85	30.22	0.177	At bottom.
			100	7.82	1.0255	7.85	30.14	0.179	
			50	8.25	1.0254	7.85	29.62	0.174	
			20	10.00	1.0247	8.0	28.00	0.168	
			10	10.59	1.0235	8.05	27.04	0.164	
			5	10.83	1.0236	8.05	26.84	0.165	
			3	10.87	1.0239	8.2	27.00	0.165	In and out of tide-rip.
			1	10.82	1.0242	8.2	27.00	0.168	
			0	11.02	1.0237	8.1	26.84	0.168	

TABLE IV—*Cont.*

Station No.	Date	Time	Depth fathoms	Temp. °C.	Specific Gravity to 15°C.	P_H	NaCl per litre	$'HCO_3$ per litre	Remarks.
21	Aug. 17	2.00 p.	150	7.53	(1.0276)	7.85	30.30	0.178	
			100	7.75	1.0268	7.85	30.22	0.177	
			50	7.82	1.0255	7.85	30.03	0.179	
			20	10.57	1.0250	8.05	27.34	0.168	
			10	10.75	1.0241	8.05	27.32	0.164	
			5	10.67	1.0242	8.05	27.34	0.166	
			3	10.92	1.0242	8.1	27.08	0.167	
			1	11.17	1.0242	8.15	26.90	0.167	In tide-rip.
			0	11.23	1.0242	8.15	26.92	0.169	
22	Aug. 16	5.10 p.	50	10.28	1.0252	8.05	28.02	0.169	
			20	10.22	1.0246	8.0	27.88	0.169	
			10	10.44	1.0246	8.05	27.54	0.170	
			5	10.70	1.0239	8.05	27.40	0.168	
			3	10.82	1.0240	8.1	27.26	0.168	
			1	10.82	1.0239	8.05	27.16	0.165	
			0	10.85	1.0238	8.05	27.12	0.164	
23	"	6.00 p.	0	12.0	1.0237	8.15	27.08	0.164	
First Narrows	Aug. 6	3.10 p.	0	16.1	1.0193	8.5	.....	.....	Low tide.
	Aug. 9	10.00 a.	0	15.4	1.0175	8.1	.....	.....	High tide.

TABLE V

FRESH WATER SAMPLES

Date	Source			Temp. °C.	Specific Gravity to 15°C	P_H	Remarks
June 24	Stream,	Biological	Station	....	....	7.65	No rain for 4 days.
26	"	"	"	12.6	0.9992	7.45	A little rain.
July 4	"	"	"	....	....	7.55	
12	"	"	"	....	....	7.4	No rain, 2nd to 14th, and very little to 19th; 0.73 inches on night of 19th/20th. Fine weather till Aug. 5.
13	"	"	"	....	....	7.55	
14	"	"	"	....	....	7.2	
15	"	"	"	....	....	7.25	
18	"	"	"	....	....	7.2	
20	"	"	"	....	....	7.15	
21	"	"	"	....	....	6.95	
22	"	"	"	....	....	6.95	
25	"	"	"	....	1.0004	7.15	
30	"	"	"	....	....	7.2	
Aug. 22	"	"	"	....	....	7.65	
July 26	Stream, Head of Departure Bay			....	1.0002	7.85	
"	Mill Stream, Nanaimo			....	1.0019	7.25	
"	Chase River			....	1.0014	8.05	
"	Nanaimo River			....	1.0016	7.1	
Aug. 8	Fraser River at Eburne			18.1	1.0027	7.8	Flowing out strongly.
Aug. 9	Fraser River at New Westminster			17.5	1.0019	7.65	

TABLE VI

HALIDE, CALCIUM AND MAGNESIUM CONTENT

Sample		Total Halide as NaCl (gm. per litre)			Calcium	Magnesium
Station No.	Depth	Mohr method	Gravimetric method		Gm. per litre	Gm. per litre
1	10	25.80	25.78		.	....
	....	.....	25.71	Mean, 25.74	..	....
3	200	28.31	28.53	.....	....	....
	....	....	28.50	" 28.51		....
3	150	28.40	28.38			....
	....	....	28.29	" 28.33	...	....
3	100	28.14	28.37			....
	....	....	28.31	" 28.34		....
3	50	27.32	27.53	.....	....	....
3	10	26.02	26.04	.....	....	....
3	1	20.54	20.58	.....	....	....
6	200	27.66	27.65	.....	0.51	1.07
	....	....	27.75	" 27.70	....	....
6	150	28.58	28.65	.....	0.46	1.12
	....	....	28.72	" 28.68	....	....
6	1	17.76	.....	.....	....	0.70
9	50	27.36	.....	.....	0.33	1.15
9	1	15.52	.....	.....	0.23	0.61
12	150	28.18	28.61	.....	0.41	1.13
12	100	28.22	28.40	.....	....	....
12	10	26.12	.....	.....	....	1.06
12	1	16.94	.....	.....	0.26	0.68
21	150	30.30	30.46	.....	0.62	1.21
21	1	26.90	.....	.....	0.58	1.07
22	1	27.16	.....	.....	0.59	1.08

FRASER RIVER WATER

The sample obtained at New Westminster on August 9th was cloudy. On standing a fine silicious deposit settled quickly, leaving a slightly opalescent water. The colloidal constituent only settled after some weeks. Time did not permit an accurate examination of this water. Alkalinity, expressed in terms of $'HCO_3$, was only 0.055 gm. per litre, halide, as NaCl, less than 0.008 gm. per litre, while calcium, magnesium and sulphate were present only as traces, unweighable in 40 c.c. samples. The water is evidently a very soft water, and, as far as its dilution effects on the Strait water are concerned, can be considered as almost pure. Its pH value is approximately that of ocean water.*

---

*E. A. Thompson has recently made an important series of detailed analyses of Fraser River water throughout the year (see W. A. Johnson, 1921). Total dissolved solids are distinctly low (44 to 100 parts per million); the water remains of a single type. The average chlorine figures are usually between 3 and 4 parts per million rising to a maximum of 14 in May. Carbonate ($''CO_3$) varies between 14 and 28, calcium between 5.8 and 17, and magnesium from a trace to 4.4 parts per million. Suspended material is also relatively low (average 65 parts per million) when compared with similar large rivers. The maximum, 230 parts per million, consisting chiefly of silica, was observed during the freshet.

DISCUSSION OF RESULTS

Chemical Composition.

The composition of all the sea-water samples examined is, within the limits of error of the methods employed, that of an ocean water diluted with varying amounts of an almost pure water. This is shown in the following table, in which comparison is made with two samples of Ocean water from the northern Pacific, for which the corresponding figures are calculated from Dittmar's and Buchanan's figures.

TABLE VII

Composition of Typical Sea-water Samples Compared with Challenger Samples

Station No.	Depth fathoms	Specific Gravity to 15°C.	Halides as NaCl gm. per litre	Ca gm. per litre	Mg gm. per litre	$'HCO_3$ gm. per litre	Mg/NaCl
Fraser River	0	1.0019	0.008	trace	trace	0.055	....
8	0	1.0055	5.06	....	....	0.088	....
10	0	1.0073	6.40	....	....	0.088	....
8	1	1.0125	12.52	....	....	0.107	....
9	1	1.0157	15.52	0.23	0.61	0.117	0.0393
12	1	1.0156	16.96	0.26	0.68	0.120	0.0401
6	1	1.0164	17.76	0.33	0.70	0.148	0.0394
8	3	1.0208	22.96	....	....	0.148	....
12	150	1.0239	28.18	0.41	1.13	0.168	0.0401
6	150	1.0248	28.58	0.46	1.12	0.170	0.0392
21	150	(1.0276)	30.30	0.58	1.21	0.178	0.0399
Challenger Nos.							
910	0	1.02566	32.50	0.43	1.32	....	0.0406
865	3950	1.02558	32.26	0.44	1.33	....	0.0415

Dittmar's figures for calcium were corrected for absorption of magnesium, etc. We cannot lay any stress on our calcium figures, however, on account of difficulties encountered during filtration; the samples brought to Winnipeg were too small to permit repetition.

It will be seen that the Mg/NaCl ratio is very constant and in good agreement with Dittmar's figures for the surface sample.

In order to compare the halide and $'HCO_3$ figures the water of the Strait of Georgia has been regarded as a varying mixture of ocean water, halide content 30.2 grams per litre, $'HCO_3$ content, 0.178 gram per litre, and Fraser River water, halide content 0.00 gram per litre, and $^1HCO_3$ content, 0.055 gram per litre. The ocean-water figures have been calculated from the average figures at 100 and 150 fathoms at Stations 20 and 21 in Haro Strait, and are therefore approximate only.

In Table VIII the $'HCO_3$ values have been calculated from the halide values on the assumption that the equation

$$\frac{NaCl_x - NaCl_{Fraser}}{NaCl_{ocean} - NaCl_{Fraser}} = \frac{'HCO_{3\,x} - 'HCO_{3Fraser}}{'HCO_{3\,ocean} - 'HCO_{3Fraser}}$$

is true (the suffixes indicate the sample concerned, x being any point within the waters of the Strait). It will be seen that there is good agreement between the observed and calculated values, indicating that to all intents and purposes the waters of the Strait are simple mixtures of ocean water and fresh water similar to that of the Fraser River.

TABLE VIII

Bicarbonate Values

Depth fathoms	Station 6		Station 9		Station 12		Station 21	
	Obsd.	Calcd.	Obsd.	Calcd.	Obsd.	Calcd.	Obsd.	Calcd.
200	0.168	0.168	.....	.....	.....	.....	.....	.....
150	0.170	0.171	.....	.....	0.168	0.170	0.178	0 178
100	0.172	0.170	.....	.....	0.169	0.170	0.177	0.177
50	0.163	0.167	0.172	0.166	0.161	0.166	0.179	0.177
20	0.162	0.164	0.162	0.162	0.157	0.164	0.168	0 166
10	0.158	0.162	0.159	0.158	0.154	0.161	0.164	0.166
5	0.154	0.151	0.155	0.147	0.151	0.155	0.166	0.166
3	0.146	0.141	0.135	0.128	0.140	0.144	0.167	0.165
1	0.128	0.127	0.117	0.118	0.120	0.124	0.167	0.165
0	0.121	0.124	0.079	0.062	0.119	0.120	0.169	0.165

Temperature and Specific Gravity

The values found for surface samples taken at the wharf of the Biological Station, Departure Bay, are plotted in Figure 1. The specific gravity shows sudden marked falls, followed usually by slower rises. Fraser and Cameron have already excluded tidal effects as a possible influence, and have attributed the sudden falls to influxes of fresh water from the Fraser River (and not, during summer, from local streams). A predominating east wind, with calm weather, affords the best condition for passage of this fresh water across the Strait in amount to produce a maximum effect at Departure Bay. With calm weather, and such a change of wind and current that the fresh water drifts elsewhere, there is slow mixing in the Bay, and slow rise of specific gravity. Any disturbance will accelerate the mixing and produce a more rapid rise of specific gravity.

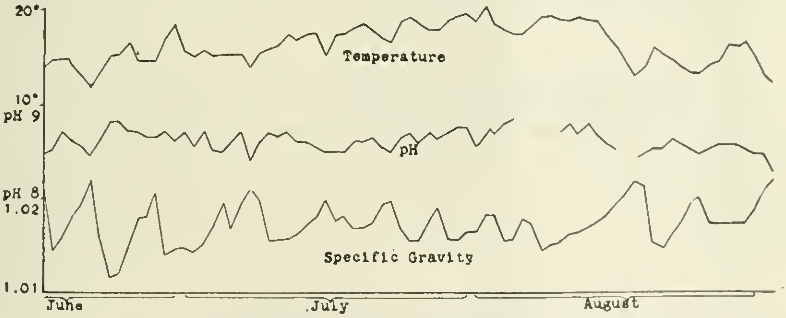


Figure 1. Temperature, pH, and specific gravity curves for Departure Bay (Table I). Only morning observations have been used.

While the surface water-temperatures are almost always between the maximum and minimum air-temperatures, both the curves in Fraser and Cameron's paper, and that now given show a very marked relationship between the curves for temperature and specific gravity, any marked rise in the one corresponding to a fall in the other, and *vice versâ*. The cause is probably complex. Any sudden lowering of temperature with rise of specific gravity is obviously connected with stormy weather and admixture of surface with heavier and colder water. The weather conditions will probably give lower air temperatures also. Any rise in temperature obviously takes place under steady good weather conditions, where there is an optimum chance that the Fraser River can exert its maximum effect to produce a fall in specific gravity.

The temperature curves for depth samples all show a gradually decreasing temperature from the surface downwards. But very different types of curve are shown by plotting the results for stations in the Strait of Georgia and for those in the Haro Strait area. The type curve for the first series shows a slight increase from 200 to 10 fathoms of about 2.5°C. only, the increase being somewhat more rapid above 50 fathoms, and then a much more rapid increase to 4 or 3 fathoms, and from that depth usually a slow increase to the surface, depending on local conditions (currents, tide-rips, etc.). The specific gravity curves also show a marked change in slope at about 10 fathoms.

The few results from the Haro Strait area show on the other hand a type curve in which, although the temperature gradient increases slightly above 50 fathoms, there is then no greater increase in slope until the surface is reached. The specific gravity curves also do not show a change in slope at 10 fathoms.

These type curves are shown in Figure 2.

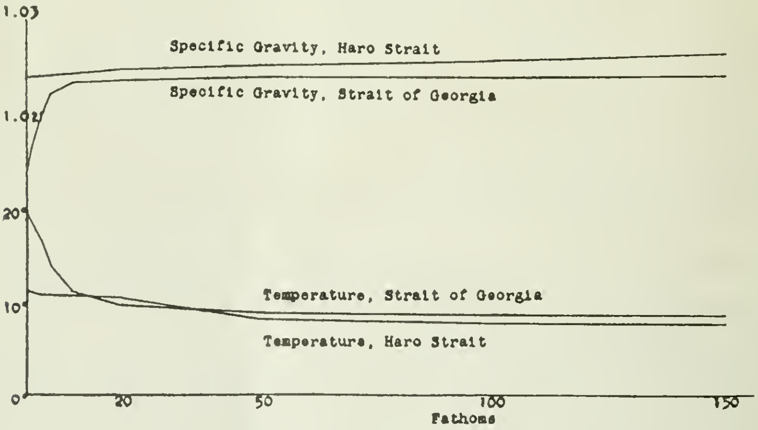


Figure 2. Curves of temperature and specific gravity for Strait of Georgia and Haro Strait.

These results afford the necessary proof for the statement made above that admixture with water from lower depths is the main factor concerned with sudden increases of density with accompanying lowering of temperature of surface waters such as those in Departure Bay.

The general effect of the large influx of Fraser River water is shown very well by the specific gravity figures. The maximum effect is produced on a thin surface layer of only a few feet in depth. Subsequent mixing is, with normal summer conditions, slow, depending on tides and currents. The rate of admixture is shown by the curves of equal density in Figure 3. Halide figures have been used instead of the actual specific gravities found, as being more accurate. Distances from the mouth of the Fraser are shown along the abscissae, the entrance N.E. of the Sandheads Lightship being chosen as the point of main discharge. It is evident that the dilution at any particular depth is very variable to at least five fathoms. At 10 fathoms it has become more constant, but is slightly greater at points nearer the river. At fifty fathoms mixing within the Strait seems fairly complete, but the water is distinctly diluter than that from similar depths in Haro Strait.

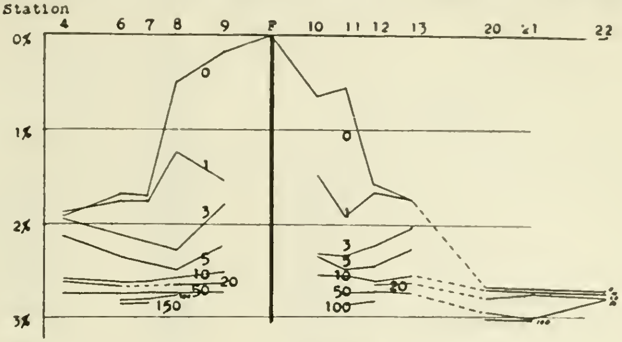


Figure 3. Curves for halide values at corresponding depths (fathoms). The figures along the upper abscissa are the Station numbers, the distances from "F" being proportional to the distances from the mouth of the Fraser River.

The actual effect of the stream water was apparent on the day when the measurements were taken, by marked discolouration and opacity of the sea-surface. The demarcation line was distinct, and is shown approximately in the map, the shaded area showing the extent of the discoloured water. It was also noted, as shown in the tables, that within this area suspended matter was not observable in samples from three fathoms, and scarcely perceptible in samples from one fathom.

IRREGULARITIES AT LOW DEPTHS

According to Dittmar's and Buchanan's results, the density and salinity of ocean water diminishes from the surface to a depth of 800 to 1,000 fathoms, and then increases to the bottom. It is evident that a large flow of fresh water into a relatively confined space brings about a very different distribution to a depth of at least a hundred fathoms. But examination of our figures for depths below this reveals irregularities. These are shown in Table IX.

It is evident that at any rate at Station 6, in the centre of the Strait of Georgia, on August 1st the water at 150 fathoms was definitely of higher salinity that that at 200 fathoms. Further measurements would be necessary to determine whether this lesser salinity at the greater depth constantly occurs (and can be shown definitely elsewhere in the Strait). If such is the case, the conclusion can be drawn that at a depth of 150 fathoms an equilibrium has been reached, and that below that point there is a decrease corresponding to that occurring in ocean waters. It seems more probable that the tidal movements of vast bodies of water into the Strait through comparatively shallow passages at times cause variations at considerable depths, one of which has been observed.

TABLE IX

	Station No.	Depth in fathoms			
		50	100	150	200
Specific Gravity	3	1.0245	1.0247	1.0244	1.0241
	6	1.0247	1.0251	1.0248	1.0252
	7	1.0234	1.0240	1.0252	......
	12	1.0233	1.0237	1.0239	......
	20	1.0254	1.0255	1.0265	......
	21	1.0255	1.0268	(1.0276)	......
Halide (Mohr	3	27.32	28.14	28.40	28.31
Halide (Gravimetric)	3	27.53	28.34	28.33	28.51
(Mohr)	6	27.54	28.20	28.58	27.66
(Gravimetric)	6	....	....	28.68	27.70
(Mohr)	7	27.46	28.03	28.44	....
(Mohr)	12	27.34	28.22	28.18	....
(Gravimetric)	12	.....	28.40	28.61	.....
(Mohr)	20	29.62	30.14	30.22	.....
(Mohr)	21	30.03	30.22	30.30	.....
Magnesium	6	.....	.....	1.12	1.07
HCO_3	6	0.163	0.172	0.170	1.68
	7	0.164	0.171	0.170	.....
	12	0.161	0.169	0.168	.....
	20	0.174	0.179	0.177	.....
	21	0.179	0.177	0.178	.....

It is to be noted that examination of the figures of Michael and McEwen (1915, 1916) for Pacific Ocean waters in the neighbourhood of Southern California shows a diminution in specific gravity from surface to 10 fathoms, and then usually a steady increase to below 50 fathoms; occasional irregularities are apparent.

Hydrogen-Ion Concentration

All attempts to associate changes in hydrogen-ion concentration of sea-water with tide changes and rainfall failed (data are given in the first six weeks' observations recorded in Table I). On the other hand, Figure 1 shows immediately a striking parallelism between the pH and surface temperature curves, and hence also an inverse relation between the pH and specific gravity curves. Any direct relationship between pH and specific gravity is rendered unlikely by the fact that all except one of the fresh waters examined showed pH values of 7.8 or less, so that direct admixture with such waters should lower the pH value, whereas it usually happened that a lowering of specific gravity of the water in Departure Bay was accompanied by a rise in pH. (See, however, some experimental results on mixing, recorded below.) Rainfall tends to lower the pH of water from the smaller streams (Table V).

The actual pH values recorded in the Bay varied between 8.3 and 8.85 during the period of observation, and were, therefore, uniformly higher than ocean values (7.7 to 8.0) and the similarly lower values recorded at Friday Harbour.

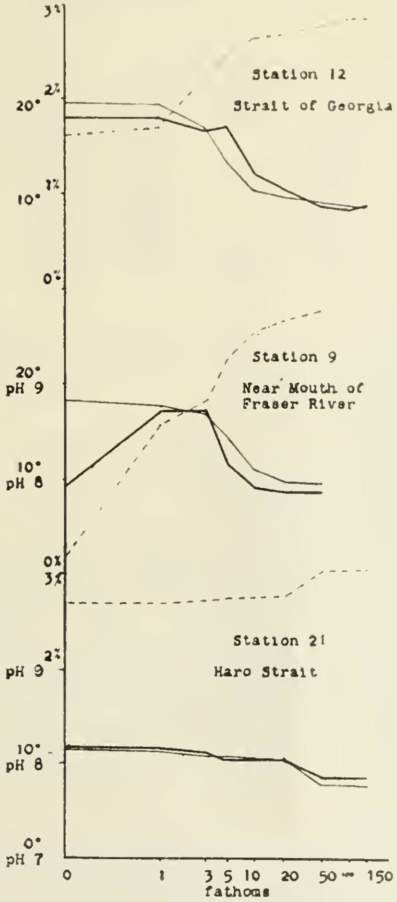


Figure 4. Curves showing relation of pH to temperature and salinity (using halide values). The thick lines represent pH, thin lines represent temperature, and dotted lines halide values. Logarithmic values of the depths (fathoms) have been used.

The changes of pH which were recorded were apparently chiefly due to temperature as is shown by examination of the figures for depth samples. Figure 4 shows three typical curves, logarithms of the depths being used to reveal the surface changes more clearly. Only in samples obviously largely consisting of Fraser River water do the pH and temperature curves cease to be parallel. With the exception of samples obviously largely contaminated with Fraser River water, the simple relationship holds, where *t* is temperature expressed in degrees C., and K_p is a constant,

$$10(\mathrm{pH}-7)\ \ \mathrm{t} = \mathrm{K_p}$$

within the limits of error of the pH measurements. This is shown in Table X.

TABLE X

Values for $10(\text{pH}-7)\ t = K_p$

Depth fathoms	Station No.								
	2	3	4	7	8	9	12	20	21
200	....	1.12	....	....	....	....	....	....	....
150	....	1.17	....	0.89	....	....	1.01	1.08	1.12
100	....	1.23	....	0.91	0.95	....	0.93	1.08	1.10
50	1.00	1.21	1.01	0.88	0.99	0.90	0.95	1.03	1.10
20	0.90	1.09	0.85	....	0.90	0.88	1.10	1.00	1.00
10	1.04	1.08	0.62	0.85	0.82	0.82	1.17	0.99	0.98
5	1.04	0.97	0.87	....	0.91	0.80	1.27	0.97	0.99
3	1.00	1.07	1.00	....	1.06	1.01	0.92	1.10	1.01
1	1.03	1.04	0.97	0.95	0.98	0.97	0.93	1.10	1.03
0	1.00	1.02	0.99	0.92	0.79	0.50	0.92	1.00	1.03

It is evident that K_p is approximately unity. The surface water at Station 9 was almost pure Fraser River water. For this the relationship does not hold. That at Station 8 was also largely diluted.

Before considering further the significance of this relation we shall present the results of some direct experiments on the effects of temperature and of mixing fresh and salt water samples.

Experiment 1. August 18th. A surface sample from the Bay showed a pH value of 8.45 for a temperature of 14.5°C. The sample was allowed to remain in the laboratory exposed to air. During the 4.5 hours the temperature rose steadily to 19.7°. The pH value did not change. It did not observably change during six days. Another portion of the original sample was heated to 40° for a few minutes. No definite change was observed. After heating for two hours to a maximum temperature of 67° the sample gave a pH value of 8.55.

Experiment 2. A sample from station 20 at 150 fathoms, obtained on August 16th, gave when examined immediately a pH value of 7.85, the corresponding temperature being 7.84°. The sample was transferred to the laboratory in a sealed vessel. On August 22nd this sample, at laboratory temperature, showed a pH value of 7.8. After 1.5 hours' exposure to air this had risen to 7.95, and after 5 hours' exposure, to 8.3.

Experiment 3. A sample from Station 3, at 200 fathoms, taken on August 23rd, was examined two hours later in the laboratory, having been kept in a sealed vessel in the interval. The pH value was 7.95. A series of test-tubes were completely filled and corked with rubber stoppers, while a further sample was transferred to a wide beaker, so that a relatively large surface was exposed to air. Examined at intervals of 1.5, 4.75 and 20 hours, the water in the beaker gave pH values of 8.0, 8.3 and 8.3, while that from three of the filled tubes was 8.0, 7.95 and 8.05.

These experiments show that surface water is apparently in such a state of equilibrium that a moderate rise of temperature does not affect its pH values. Water from a considerable depth, so long as it is kept from contact with air, maintains its original value, even with a change of temperature 10° (from depth temperature to that of the laboratory), but when exposed to air the pH definitely rises, though not to the maximum figure actually observed with surface waters.

McClendon has shown that, when the carbon dioxide tension is kept constant, pH varies directly with the temperature, 1° corresponding to 0.01 pH, Since, therefore, a 10° rise of temperature only causes a "temperature effect" of 0.1 pH, this does not account for most of the increases noted, which must, therefore, be traceable to equilibria disturbances.

Experiment 4. June 20th. Sea-water from the surface of the Bay of temperature 14.6° and pH 8.7 was mixed in varying proportions with water from the stream at the Station of temperature 12.6° and pH 7.45. A mixture of ratio 2:1 gave pH 8.35, and after 8 hours 8.3, the theoretical mean being 8.3; that of ratio 1:1 gave 8.05, and after 8 hours 7.65 (theoretical mean 8.05); that of ratio 1:2 gave 8.2, and after 8 hours 7.9 (theoretical mean 7.9).

Experiment 5. July 13th. A similar experiment to 4. The results are shown in the following table.

TABLE XI

Effect on pH of Mixing Surface Sea-water and Fresh Water

Sample	Theor. mean	Time in hours			
		0	2	9	24
Sea-water	...	8.6	8.55	8.45	8.3
Mixture 3:1	8.3	8.5	8.45	8.3	7.65
Mixture 1:1	8.1	8.3	8.3	8.05	7.45
Mixture 1:3	7.8	7.65	7.8	7.8	....
Fresh-water	...	7.55	7.6	7.0	....

Experiment 6. July 21st. A sample of surface sea-water from the Bay was allowed to stand exposed to air in the laboratory. The original pH figure was 8.7. After 24 hours there was no change. After 48 hours the value was 8.4. A sample kept in a corked vessel exhibited no change after 48 hours.

July 23rd. A similar sample of original value 8.5 showed no definite change in 48 hours, the actual final reading being 8.45.

Experiment 7. August 14th. Samples of Fraser River water, pH 7.65, were mixed in equal proportions with various depth samples. All had been kept in closed bottles since collection on August 1st and were at the same laboratory temperature. The pH values were determined immediately after mixing. The results were (the number is the Station No., the suffix the depth in fathoms): sample 2_{10}, pH 7.65, mixture, 7.85, theoretical mean 7.65. Sample 8_5, pH 8.3, mixture 8.35, mean 8.0. Sample 8_{10}, pH 8.4, mixture 8.5, theory 8.0. After 1.5 hours the mixture values had very slightly increased.

Experiment 8. August 22nd. A similar experiment to 7. Mixtures were made of various depth samples, with samples of Fraser River water, that from the local stream, and distilled water. The results are shown in Table XII. It will be noticed that certain of the deep-sea samples had increased in pH values during the three weeks since they had been collected. The containing vessels had been opened on several occasions to withdraw samples for analysis. The original pH values are given in brackets.

Experiment 9. August 23rd. A sample from Station 3, showing pH 8.5 was mixed with another from the Biological Station stream, pH 7.65. The mixture showed pH 8.35, the theoretical mean being 8.1.

While experiments 4 and 5 appear to show that mixing produces little deviation from the theoretical mean (since these measurements were made chiefly with cresol red, varying salt error due to dilution is in most cases not greater than 0.1), the later experiments show a definite increase above the theoretical mean in all cases where depth samples were mixed with fresh water.

Mixing takes place between such extremes as we have used in our experiments, only at the height of summer at the surface of contact of outflowing river water and the underlying salter water. At such a point it may be a factor in bringing the pH of the dilute mixture to the higher value of the surrounding and underlying salter water (compare the figures for Stations 8, 9 and 10 in Table IV). It is obviously due to changes in the carbonate equilibria of the sea-water. At all points throughout the Strait of Georgia a slow mixing continually takes place in summer and through the resulting shift in the carbonate equilibria becomes an important factor in determining the rise of pH. It happens that the time of maximum dilution and that of maximum temperature are practically the same, and it is probably due to this that there exists an empirical relationship between temperature and pH.

TABLE XII

Effect on pH of Mixing Sea-water from Various Depths with Fresh Water

Sea-water Sample		Fresh-water Sample		Mixture	Theoretical Mean
No.	pH	Source	pH	pH	pH
19_{50}	8.3 (7.85)	Fraser	7.65	8.3	8.0
19_{50}	"	Station	7.65	8.3	8.0
19_{10}	8.6 (8.05)	Fraser	7.65	8.4	8.15
19_{10}	"	Dist. Water	6.6	8.5	7.6
19_{1}	"	Biol. Stn.	7.65	8.45	8.1
19_{1}	"	Dist. Water	6.6	8.55	7.6
20_{150}	8.0 (7.85)	Fraser	7.65	8.0	7.8
20_{150}	"	Dist. Water	6.6	7.9	7.3

On standing the mixtures showed little, if any, change.

Returning to consideration of this relation $10(\text{pH}-7)/t=K_p$ = approximately unity, since 7 is the pH value of pure water, the equation indicates that an empirical relation exists between the excess of concentration of (OH^-) ions over that of pure water, and temperature. McClendon, Gault and Mulholland (1917) have shown that the pH of ocean water is practically independent of salinity and temperature, between 10° and 30°C., being determined solely by the ratio of the concentration of the buffers, including CO_2 and other weak acids, to the concentration of bases combined with them. The most important changes are those concerned with carbonate equilibria. The ions $''CO_3$ and $'HCO_3$, and the molecules H_2CO_3 and CO_2, besides the carbonates and bicarbonates of all the bases present, are affected. Since, however, the "total carbon dioxide" in sea-water is almost, but not quite, sufficient to account for all bases as bicarbonate, while the proportion held simply in solution as gas is small, the chief change can be regarded as expressed by the equation

$$'HCO_3=OH^-+CO_2.$$

This, therefore, can be regarded as the net result of the changes in equilibrium brought about both by temperature changes and by dilution. It results in an increase in carbon dioxide tension with increased value of pH. There will, therefore, be established a carbon dioxide gradient, superimposed on any already in existence, the maximum value being reached at the surface layer. It seems probable that such a higher value may persist without loss of carbon dioxide to the atmosphere, since according to Prideaux (1919) normal sea-water tends to gain carbon dioxide from the atmosphere (only that of highest acidity being in equilibrium with atmospheric carbon dioxide) and also from the subjacent layers of water with lower pH values. Since McClendon, Gault and Mulholland consider that the carbon dioxide tension of sea-water is of great importance in the respiration of marine animals, it follows that such a persistent higher tension may become an important conditioning factor in their development and distribution.

We do not propose to consider more fully in this paper the relative effects of the marked salinity and temperature variations occurring in the waters of the Strait of Georgia, and leading to the empirical relationship that we have ascertained. An accurate study of carbon dioxide tensions of the complex series of equilibria involved would be necessary, with more accurate determinations of pH values than we have been able to make.*

Summing up the results of our observations and experiments, we conclude that the pH changes observed in waters in the Strait of Georgia are primarily due to changes in the bicarbonate equilibrium with an increase in carbon dioxide tension and concentration of hydroxyl ions having definite empirical relationship to rise in temperature, due to the coincidence in time of temperature and dilution effects. These changes are of the second order of magnitude lower than those recorded under the heading of $'HCO_3$ in the tables, and dealt with especially in Table VIII, and, therefore, do not affect the deductions from that table.

Since the pH changes are much greater in the Strait of Georgia than in Haro Strait, though the same relation between pH and temperature appears to hold, it seems possible to formulate the probable pH conditions in the Strait of Georgia throughout the year.

Surface temperature falls steadily from September and remains low throughout the winter (cf. Fraser, 1920) so that the temperature gradient even becomes reversed at times. Dilution with Fraser River water steadily lessens and similarly remains minimal. Values of pH will fall correspondingly. Dr. Fraser has informed us that already, in October, 1921, much lower pH values were being recorded at the Biological Station. During the winter period the effect of the small streams is increased near their mouths. The net result will be an average increase in specific gravity, with marked variations near the

---

*Professor McClendon has pointed out to us that assuming that the carbon dioxide tension of the air is 0.03 per cent. of an atmosphere, and that the sea-water is in equilibrium with air, and titrates 0.0025 alkalinity (figures usually found in surface water of the open sea) it is possible from the tables given in McClendon, Gault and Mulholland's paper to show the following relationship:

	0°	10°	20°	30°
C.c. CO_2 per litre sea-water	49.0	47.0	45.5	44.0
pH for this vol. of CO_2 per litre	7.91	8.03	8.13	8.23
pH of sea-water	7.90	8.03	8.13	8.23

This, while showing the direct dependence of pH on change of carbon dioxide tension, accounts for but a small proportion of the pH changes that we have observed.

Professor McClendon's observations on Gulf-Stream waters show pH values of 8.21 to 8.22 and are presumably for higher temperatures than any we encountered, whilst the highest alkalinity that he has observed was in a shallow lagoon of an atoll, for which the temperature was 35° and the pH was 8.46

mouths of streams. It is uncertain whether the "mixing" effect will be so marked at lower temperatures as in those experiments that we have quoted. In any case it will not be great. The general effect will, therefore, be a lowered temperature, a specific gravity more nearly approaching ocean values, but with local depression near mouths of all streams, and pH values generally approximating to ocean values.

A number of measurements have been carried out by Powers and Gail in the vicinity of Friday Harbour Biological Station during the summers of 1918 and 1919. These are in good agreement with our own figures for our Stations 22 and 23.

Powers measured pH values in the Sound between Lopez, San Juan, and Orcas Islands, on various dates between the middle and end of July, 1918. The extremes observed for surface samples were 7.8 and 8.2. Samples taken at various depths showed sometimes a slight increase from surface downwards, sometimes irregularities. The differences observed in the irregular series were slight, and not much greater than the limit of error of the colorimetric error employed. Powers attributes them to water at different layers, arriving from different sources through the various possible channels. Values at a Station at approximately the same position as our Station No. 22 showed at surface 7.77, and at 140 metres (76 fathoms), 7.79. The surface temperature was 10.75°, that at 80 metres (44 fathoms) 10.3°. Values at a station one-half mile further north were, at surface, 8.03, and at 120 metres 7.63. Various readings at the Station itself between June 30th and July 31st showed extremes of 7.52 and 8.03.

Gail's figures for sea-water away from visible shore vegetation for June-August, 1919, showed extremes of 7.9 to 8.25, the average morning value (5-6 a.m.) being 8.0, and the average afternoon value (1-4 p.m.) being 8.15. Powers gives slightly greater extremes for the same period, 7.6 to 8.4. His figures show a general parallelism between pH and temperature, similar to that we have described.

LAGOONS

Powers studied the variations of pH in a lagoon, in communication with water of the Sound, but cut off at half tide. It has apparently no fresh-water inlet. Values of pH varied between 7.9 and 8.6. They were usually much higher than those of water outside the lagoon. Temperature also showed considerably higher values. Thus for respective temperatures of 11.4°, 13°, 16.2°, 17.8°, 18.2° and 19° the corresponding pH values were 7.89, 8.07, 8.38, 8.07, 8.62 and 8.54. The lagoon bottom was covered with *Ulva*, and this is probably a factor in the pH changes, though temperature would appear to be the main factor.

TIDEPOOLS

Gail has studied the changes in tidepools at Friday Harbour. Here the results are similar to those for lagoons, but the variations are accentuated. Values of pH as high as 8.8 were observed. The early morning values were as low as 7.43. This Gail attributes chiefly to plant life producing more carbon-dioxide during the night. The temperature of these tidepools between 1 and 4 p.m. averaged 24.7°. Here also, therefore, temperature would appear to be a controlling factor, though vegetation in the tidepools may be an equally important one.

EFFECT OF VEGETATION ON HYDROGEN-ION CONCENTRATION

Generally speaking, pH content of water bathing vegetation is raised during daylight through photosynthetic activity (Palitzch, McClendon, Gaarder). Powers gives figures as high as 9.3 for water bathing *Ulva.* The value is almost always higher than that of immediately adjacent water. It falls during the night. Eel-grass (*Zostera marina*) produces similar effects, while for kelp (*Nereocystis lütkeana*) they do not appear to be so marked. Powers' figures show, however, that the increased alkalinity so produced is unable to affect materially any large volume of water. While the factor becomes of importance in small volumes of water where the amount of vegetation is relatively large (lagoons, tidepools), and for life in actual groves of ulva, eel-grass, fucus and kelp, it can be neglected as a factor influencing pH changes in large bodies of water. Similarly the effect of animal life is of a smaller order of magnitude, except when the animals are present in such numbers (*e.g.*, shoals of fishes) that their volume is of comparable order to that of the containing water.

OXYGEN CONTENT

Mr. Berkeley's figures indicate a regular gradation in oxygen content, maximum figures being obtained for surface samples, while at 50 fathoms the values have already fallen to less than 50 per cent. Surface figures are distinctly higher than the average of those found by Powers for the Friday Harbour area. An approximate comparison is shown in the following table. The probable specific gravity for Powers' samples is supplied from our figures for Station 22.

TABLE XIII

COMPARISON OF OXYGEN CONTENT OF SURFACE WATER

Observer	Station No.	Temp. °C.	Specific Gravity	pH	Oxygen Content
Berkeley	1	17.00°	1.0177	8.7	6.00
"	3	15.44	1.0172	8.6	6.26
"	16	15.30	1.0218	8.55	6.66
Powers	Q	9.75–14.1	(1.024)	7.78–8.12	4.18–4.77

The oxygen content is expressed in c.c. per litre. Certain of Powers' values are higher (*e.g.*, at Station L, 7.54 c.c. for water at 12°C. and pH 7.87). Powers found that in any small area a higher oxygen content usually was accompanied by a higher pH value, but that this did not hold for comparisons through large areas. It is, therefore, probably only a minor factor in controlling oxygen content.

The important factors determining oxygen content of surface waters in large bodies of water are undoubtedly temperature and salinity. Increase in either causes diminished solubility. The extent is shown in the following table, in which the figures for pure water are calculated from Van Nostrand's tables, and those for ocean water are taken from Dittmar's figures. All the figures express c.c. of oxygen per litre, corrected to 0°C. and 760 mm. pressure, when the solvent is saturated with atmospheric air.

TABLE XIV

Maximum Solubility of Atmospheric Oxygen in Water and in Sea Water at Various Temperatures

	5°	10°	15°	20°
Water	9.01	7.98	7.17	6.51
Ocean water	7.22	6.45	5.83	5.31

Berkeley's figures are not corrected for temperature and pressure. Powers figures do not appear to be. It is not possible to make accurate calculations, but it would appear that the surface waters within the Strait of Georgia, at higher temperature and lower salinity, are relatively more nearly saturated than those in the vicinity of Friday Harbour, and are actually not far from saturation point. We cannot account for the discrepancy.

The water of shallow lagoons appears to be saturated with oxygen (Powers), while that bathing vegetation has its oxygen content raised during daylight through photosynthetic activity (Powers, in agreement with Palitzch, McClendon, etc.).

APPLICATION OF THE RESULTS TO THE DISTRIBUTION OF FLORA AND FAUNA IN THE STRAIT OF GEORGIA AND ADJACENT WATERS

The chemical composition of any sample of water in this area is determined by the degree of admixture with fresh water, and can be regarded as sufficiently determined by knowledge of the halide content and bicarbonate value.

The chief factors governing distribution of flora and fauna appear to be degree of illumination, temperature, duration of exposure to atmosphere (if between tides), nature of sea-bottom, current variations, specific gravity and salinity, carbon dioxide tension, oxygen content, and pH (indicating hydrogen-ion concentration).

The following may be regarded as typical Stations where variations of one or more of these factors may present determining conditions.

(i) Open water, Strait of Georgia.

(ii) Open water, Haro Strait.

(iii) Embayments, Strait of Georgia, with no marked influx of fresh water in summer (*e.g.*, Departure Bay).

(iv) Points between tides at the openings of large rivers (*e.g.*, in the various mouths of the Fraser River).

(v) Points between tides at the openings of small streams.

(vi) Lagoons (*a*) to which salt water only has access, and (*b*) to which salt and fresh water have access.

(vii) Rock pools.

(viii) Water bathing luxuriant vegetation.

Before considering these in detail it may be remarked that points near large towns or cities, where there is any considerable discharge of sewage into the sea, obviously present special features and require special study. Such cases will not be considered here.

Numbers i and ii, above, obviously apply only to free swimming species. Numbers iii to vii will within themselves present variations in illumination (depth), duration of exposure to atmosphere, nature of sea-bottom, and current variations. Carbon dioxide tension will, if our conclusions are correct, tend to increase slightly with increase in pH. Oxygen content will be near the saturation figure for surface values and will gradually decrease with increasing depth.

(i) Open water, Strait of Georgia.

(*a*) May to September. Surface temperature gradually rises from 10° to a maximum of approximately 20°C. During July and August the average value is 17° to 18°. During September there is a gradual fall. The higher surface temperatures gradually establish a sharper gradient for the first ten fathoms. At 10 fathoms' depth the average reading is between 10° and 11°. Below this depth there is a slow fall to ocean values. Surface specific gravity values show a fall, the lowest average value corresponding to the maximum height of the Fraser River (June-July) and depending on the distance from that or similar large sources of fresh water. Depth values show a corresponding but lessening decrease, the influence of the Fraser being distinctly shown throughout the Strait, when comparison is made with outside waters.

Values of pH at the surface show a rise from ocean value 7.7 to 8.0 to a maximum value of 8.8. Depth values are lower in proportion to the lower temperature. Values not greatly differing from ocean values are shown below 10 fathoms.

(*b*) October to April. Surface temperatures fall steadily, minimum values being shown in January-February. These are occasionally as low as 3° or 4°, and during such periods the temperature gradients from surface downwards will be reversed. Specific gravity values rise steadily, the effect of large rivers becoming less and more local. The average value will probably be in the neighbourhood of 1.022 to 1.023, the increase with depth becoming correspondingly less marked. Surface pH values will fall to about 7.8 to 8.0, the average minimum value corresponding to the period of minimum temperature. There will be little difference between surface and depth values.

(ii) Open water, Haro Strait.

Surface values of temperature during summer do not appear to exceed 11.5°. The temperature gradient with increasing depth is much slighter; at 150 fathoms the figure is about 7.5°. During winter months the surface value will fall to some figure much nearer the depth value or even below it. Specific gravity values are throughout the year much nearer ocean values, though at the height of summer the influence of the Fraser is slightly shown. The actual figure is about 1.024. Values of pH are slightly increased in summer at the surface, and for the first ten fathoms, but the maximum reached is seldom above 8.1.

(iii) Embayments, Strait of Georgia, *e.g.*, Departure Bay.

Conditions vary according to the distance from the Fraser River. They are, during the summer, approximately the same as those for (i). During winter small streams may produce a marked local effect on the surface water. Thus in Departure Bay at times specific gravity values below 1.01 are recorded in January and February. Such lowering of specific gravity is only transitory. The local influxes of fresh water will not affect temperature, but may depress pH values below 7.8.

(iv) Points between tides in the estuaries of the Fraser.

In summer the temperature may rise to 18°, but the pH value will approximate to that of the Fraser itself, 7.65, at low tide, and at high tide will rise to somewhat higher figures, probably not greatly exceeding 8.0. The surface specific gravity similarly will show an increase from that of the Fraser River water to a slightly higher figure, probably never exceeding 1.01. In winter temperature will fall; minimal values will approach 0°C. Specific gravity may increase to somewhat greater values at high tide Values of pH will remain uniformly low, and probably below those of ocean water.*

(v) Points between tides in small streams.

At any point continually submerged there will be greater variations in summer than in locations (i) to (iv). At low tide temperature will fall to the stream value, 12° to 14°. Specific gravity will not be far from that of pure water. The value of pH may be that of neutral water and will for most streams be distinctly below ocean values. At high tide the temperature may rise to 20°, pH to 8.8, and specific gravity to figures between 1.015 and 1.02.

During winter the same minimum values for pH will be attained. The maximum values will not be greater than 8.0. Temperatures will be uniformly low and show little variation, but specific gravity will vary more, perhaps from 1.001 to 1.024.

(vi) (*a*) Lagoons with no fresh water influx.

In summer, when the lagoons are cut off from surrounding water during the day, temperatures may rise higher than in embayments, perhaps to well above 20°. Values of pH will rise correspondingly, perhaps to above 9.0 There may be greater daily variations, therefore, than in embayments. Specific gravity also show these accentuations, especially in shallow lagoons where the

---

*W. A. Johnson, 1921, has just published a series of observations on the Fraser River Delta. Temperature and specific gravity measurements taken near the Sandheads Lightship are in substantial agreement with our own figures; similar measurements at different points within the delta show to what extent sea-water flows up the river at high tide. It enters the river in the deepest channel, and usually occupies only a small depth at the bottom. It is not observed in any of the passes leading from the main river southwards, probably owing to the shallowness of the river over the south sand-banks. Marine shell-fish enter the river during the low-water stage, and are found as far up as Steveston. They are killed during the freshet, and their shells accumulate in places. Marine life is most abundant in the seaward part of the delta in places away from the main channel, but during large freshets large numbers of barnacles and mussels are killed along the coast away from the mouth of the river. Bottom samples at the mouth contain marine shell-fish, worms and sea-cucumbers.

surface layer of water may even become saturated for short periods. In winter these differences from embayment values will not occur.

(vi) (*b*) Lagoons with fresh water influx.

The fresh water will affect certain points in the lagoons, lowering pH, specific gravity and temperature.

(vii) Rockpools.

The remarks for (vi) (*a*) apply to an even greater extent.

(viii) Water bathing luxuriant vegetation.

High values of pH, above 9.0, may be reached. This is obviously an effect largely confined to summer, since then only is such luxuriant vegetation met with, and since the effect is due to photosynthesis.

In general it may be stated that the conditions for February-April in most parts of the Strait of Georgia are not markedly different from those at points much nearer the ocean. Therefore early development of animal life will take place under approximately the same conditions. Growth, taking place during summer, will be affected. Species requiring ocean conditions for optimum development may die, or develop poorly, or, if free swimming, may find their correct habitat at lower level, or even without the Strait.

The same is true of plants, and is in many cases obvious; the luxuriance of algal growth being distinctly less in less saline waters. The actual conditions may at certain localities totally inhibit spore development of certain species where this takes place during summer months.

We do not propose to discuss the relative importance of temperature, pH, and salinity in controlling development. Probably all three are concerned. Careful study of the actual distribution, relative abundance, and relative development of species in different localities may permit a conclusion as to relative importance to be drawn, though probably experimental control will be necessary.

SUMMARY

A comparable study has been made of the chemical composition and physical properties of the waters in the Strait of Georgia and adjacent localities. These waters appear to be true mixtures of ocean water and Fraser River water. In winter there are local variations due to small streams; the main effect, that of the Fraser, decreases.

During summer surface waters within the Strait become distinctly more alkaline; the increase (maximum pH 8.85) is apparently due to increased temperature and admixture with a less saline water changing the carbonate equilibrium, $'HCO_3$ dissociating to $'OH$ and CO_2.

From the results now published, and those previously recorded by Fraser and Cameron (1916) and Fraser (1920) the probable variations throughout the year for typical localities are deduced.

We wish to thank the Biological Board of Canada for the facilities afforded us to carry out this investigation. We wish also to acknowledge our great indebtedness to Dr. C. McLean Fraser, the Curator at the Nanaimo Station, for his assistance throughout the investigation, and especially in obtaining the depth samples, and to thank Professor C. H. O'Donoghue for much kindly and valuable criticism.

REFERENCES

We have had access to few of the recent studies of similar problems in European waters, so that these references are incomplete.

Buchanan, J. Y., 1884. The specific gravity of samples of ocean water. *Challenger Expedition Reports, Physics and Chemistry*, Vol. I.

Cameron, A. T., 1916, The commercial value of the kelp-beds of the Canadian Pacific Coast. *Contrib. to Canadian Biol., Ottawa, 1914-15*, 25-39.

Clark, W. M., 1920. The determination of hydrogen ions. Baltimore.

Dittmar, W., 1884. The composition of ocean water. *Challenger Expedition Reports, Physics and Chemistry*, Vol. I.

Fraser, C. M., 1918. Migration of marine animals. *Trans Roy. Soc. Canada, 12*, Sect. iv, 139-43.

Fraser, C. M., 1920. Temperature and specific gravity variations in the surface waters of Departure Bay, B.C. *Contrib. to Canadian Biol., Ottawa, 1918-20*, 35-47.

Fraser, C. M., and Cameron, A. T., 1916. Variations in density and temperature in the coastal waters of British Columbia, *Contrib. to Canadian Biol., Ottawa, 1914-15*, 133-43.

Gail, F. W., 1919. Hydrogen-ion concentration and other factors affecting the distribution of Fucus. *Publ. Puget Sound Biol. Station, 2*, 287-305.

Johnson, W. A., 1921. The sedimentation of the Fraser River Delta. *Memoir No. 125, Geological Survey of Canada.*

McClendon, J. F., 1917. The standardization of a new colorimetric method for the determination of the hydrogen-ion concentration, etc. *Journ. Biol. Chem., 30*, 265-88.

McClendon, J. F., Gault, C. C., and Mulholland, S., 1917. The hydrogen-ion concentration, CO_2 tension and CO_2 content of sea-water. *Carnegie Instn. Publ. No. 251*, 21-69

Michael, E. L., and McEwen, G. F. Hydrographic, Plankton and Dredging Records of the Scripps Institution. *Univ. of California Publications in Zoology, 1915, 15*, 1; *1916, 15*, 207.

Mounce, Irene, 1922. The effect of marked changes in specific gravity upon the amount of Phytoplankton in Departure Bay waters. *Contrib. to Canadian Biol.*, N.S., Vol. I.

Powers, E. B., 1920. Variation of the condition of sea-water, especially the hydrogen-ion concentration, and its relation to marine organisms. *Publ. Puget Sound Biol. Station, 2*, 369-85.

Powers, E. B., 1921. Behavior of marine fishes toward hydrogen-ion concentration of the sea-water in relation to their migratory movements and habits. *Publ. Puget Sound Biol. Station, 3*, 1-22.

Prideaux, E. B. R., 1919. Effect of sea-salt on the pressure of carbon dioxide and alkalinity of natural waters. *Journ. Chem. Soc., 115*, 1223-1230.

Wells, R C., 1920. The salt error of cresol red. *Journ. Am. Chem. Soc., 42*, 2160-67.

The Oxygen Content of Waters in the Strait of Georgia

By C. J. Berkeley

Dissolved oxygen was determined in three of the series of samples dealt with in the foregoing paper. The method of L. W. Winkler (Treadwell and Hall's "Analytical Chemistry," Vol. II, 1919, p. 760) was used. Only volumes of water measuring little more than 100 c.c. were available, after the other determinations to be made on the samples were provided for. The Winkler method, as laid down, requires samples of 250 c.c. The reagents used were accordingly diluted 2.5 times, and the volumes of them prescribed adhered to. Working under these conditions on several distinct fractions of a single sample the results were found to be subject to a variation averaging about 4.8 per cent., with a maximum variation of 7.1 per cent. Under the precise conditions laid down by Winkler the results obtained are still subject to irregularity, but the variation was considerably smaller, averaging about 2.8 per cent. The irregularity appears to be due to the salts dissolved in sea-water. Perfect agreement was obtained with duplicate samples of tap-water, but on adding magnesium sulphate in about the proportion found in sea-water (1 per cent.) the results became irregular. It is not clear why the variations should become more marked when working with smaller quantities.

The results recorded in the table which follows are thus subject to errors of ±5 per cent. due to the method. In addition to this slight corrections would have to be applied for temperature and pressure for full accuracy, but these would be small in relation to the error inherent in the method as applied. The oxygen content has been calculated as though measured at 0° and 760 mm. Only in the case of series 3 were the operations involved in the Winkler method performed immediately after the samples were taken. In the other two cases

TABLE XV

Oxygen Content

Station No.	Depth fathoms	Oxygen c.c. per litre	Station No.	Depth fathoms	Oxygen c.c. per litre	Station No.	Depth fathoms	Oxygen c.c. per litre
1	0	6.00	3	0	6.26	16	0	6.06
Aug. 29	1	6.09	. .	1	6.17	. .	1	6.24
	3	5.87	. .	3	5.27	. .	3	5.52
	5	5.28	. .	5	4.69	. .	5	4.38
	10	4.75	. .	10	3.98	. .	10	4.18
	20	3.58	. .	20	3.51	. .	20	3.54
	. .	. . . .	. .	50	3.02	. .	50	2.88
	. .	. . . .	. .	100	3.05	. .	100	3.66
	. .	. . . .	. .	150	2.74	. .	. .	
	. .	. . . .	. .	200	1.63		.	

the samples were taken in bottles fitted with tightly fitting rubber bungs, and completely filled with water, and the analysis was carried out immediately the sample reached the laboratory. Tests showed that the error introduced by the lapse of a few hours between taking the sample and analysing it was considerably smaller than that involved in the method itself, provided the container was full and tightly stoppered; this error could, therefore, be neglected

The close agreement between samples drawn at the same depth from the three stations indicates a remarkable uniformity over the area within which they lie, whilst the very regular gradation in oxygen content from the surface to the lowest depths reached suggests that the diffusion of oxygen from the surface downwards is not greatly interfered with by currents. This regular gradation of oxygen content with depth is not in accordance with the observation of Powers at Friday Harbour. It agrees in a general way, however, with those of other workers The surface samples show a higher oxygenation than those recorded by Powers whilst those drawn from greater depths than 20 fathoms run distinctly lower.

No. 5

A NOTE ON THE RELATIVE CHLORINE, BROMINE AND IODINE CONTENT IN THE WATERS OF THE STRAIT OF GEORGIA, B.C.

BY

A. T. CAMERON
University of Manitoba

A Note on the Relative Chlorine, Bromine, and Iodine Content in the Waters of the Strait of Georgia, B.C.

By A. T. Cameron
University of Manitoba

Bromine and iodine contents of sea-waters have been estimated by numerous observers. The most important observations are reviewed briefly in the following paragraphs:

BROMINE.

Berglund (1885) summarized previous determinations and pointed out that the ratio of bromine to 100 grams of chlorine varied from 0.131 to 2.141 grams. Of the figures quoted by him only Dittmar's need be considered.

Dittmar (1884), partially precipitating sea-water with silver nitrate, and converting the total bromide and partial chloride mixture into silver chloride by treatment with chlorine, found an average value of 0.343 gm. bromine to 100 gm. chlorine. For a mixture of surface waters the actual bromine content was 0.06704 gm. per litre.

Berglund (1885) liberated bromine by treatment in the cold with a mixture of potassium hydrogen sulphate and potassium permanganate; the bromine was aspirated into dilute sodium hydroxide. His values, expressed in ratio to 100 grams of chlorine, were, in grams: for various samples from the North Sea, 0.330 to 0.344; from the Atlantic Ocean, 0.337 to 0.341; from the Gulf of Mexico, 0.341; from the Mediterranean, 0.343; from the Adriatic, 0.341; from the Kattegat, 0.337; from two stations in the Baltic, 0.316 and 0.344.

Makin (1898), using Fresenius' method (evaporation of the water to dryness with sodium carbonate, extraction with alcohol, and conversion of the alcoholic extract, containing all the bromide and some chloride, into the silver salts, and then into silver chloride), obtained the corresponding figure of 0.325 for Atlantic surface waters. The mean of three determinations showed 0.0671 gm. per litre.

Denigès and Chelle (1912), using a colorimetric method, found for waters in the Bay of Arcachon 0.060 gm. per litre. Chelle (1914), using the same method, found that in 17 samples of sea-water the figure for the ratio varied between 0.3 and 0.4.

Winkler (1915), using a method which will be described below, obtained for the ratio the figure 0.3472±0.0004.

Considering the variety of methods employed and the small amount of bromine actually present, these figures show a remarkable agreement.

IODINE.

Macadam found a maximum iodine content of 0.00012 mg. per litre.

Sonstadt (1872) found that sea-water from near the Isle of Man, of specific gravity 1.027, and therefore containing about 30 grams of sodium chloride per litre, contained about 0.0025 gm. of iodine per litre, a ratio of 0.014 gm. to 100 of chlorine. He considered that iodide could not permanently exist as such in presence of a (slightly) alkaline medium such as sea-water, but that all the iodine present must be in the form of iodate.

Koettstorffer (1878) obtained the figure 0.02 mg. per litre.

Gautier (1899) evaporated sea-water to the crystallizing point with alkali, and after separation of as much salt as possible estimated iodine in the mother liquor by distillation with bichromate. He found in five litres of sea-water from the English Channel 2.6 mg. iodine in the organic debris (plankton), 9.4 in soluble organic form, and no inorganic iodine. He obtained similar figures for Mediterranean surface water. That from a depth of 880 metres contained 0.1 mg. plankton, 2.13 mg. in soluble organic combination, and 0.15 mg. in inorganic combination per litre. Water from 990 metres gave similar results. The total iodine in soluble form was, therefore, of the order 2 mg. per litre, so that the amount corresponding to 100 gm. chlorine was of the order 0.01 gm.

Gautier (1920) records that in subsequent analyses of Mediterranean waters he found no trace of soluble iodine.

Winkler (1916) found with water from the Adriatic Sea of specific gravity 1.0222 and chlorine content 16.25 gm. per litre, no iodine in organic combination, 0.008±0.001 mg. iodine as iodide, and 0.030±0.001 mg. as iodate per litre, a total of 0.038 mg. per litre, the ratio to 100 gm. chlorine being 0.00023.

These values show no reasonable agreement. Winkler's method, recorded below, is the only one that suggests any degree of accuracy.

In connection with studies in the biochemistry of iodine carried out on marine material from the Strait of Georgia (Cameron, 1914, 1915) it seemed desirable to ascertain the chlorine-bromine-iodine ratio for sea-water from that locality. The iodine determinations were carried out at the Biological Station, Nanaimo, but since time did not permit completion of the work there, bromine and accurate chlorine determinations were carried out on parts of the same samples, brought to Winnipeg. Winkler's procedures were used for bromine and iodine.

METHODS AND RESULTS

Two samples of water were analysed. The first, a surface sample from Departure Bay, was collected on August 30th, and had a specific gravity (corrected to 15°C.) of 1.0178. The second, collected at 10 fathoms in a Nansen-Pettersen water-bottle on August 29th had a specific gravity (corrected to 15°C.) of 1.0239. Both were carefully filtered and analysed only for soluble constituents.

Total halide.

This was determined by precipitating with excess of silver nitrate in slightly acid solution, and weighing the precipitate in a Gooch crucible dried at 110°C. The results, expressed as chloride, follow:

Sample	Amount taken c.c.	Silver chloride gm.	Sodium chloride gm.	Mean gm.	Chlorine per 100 c.c. gm.
Surface (1)	10.01	0.4763	0.1943	......	......
(2)	10.01	0.4792	0.1954	0.1948	1.180
10-Fathom (1)	10.01	0.6326	0.2580	......	......
(2)	10.01	0.6309	0.2573	0.2576	1.561

Bromine.

Winkler's method depends on the principle that when bromide is distilled with a small amount of permanganate in presence of acid and a much larger amount of chloride, all the bromine is liberated and only a small amount of chlorine, while when only a small amount of chloride is present (20 mg. chlorine) and the minimum amount of permanganate is added to produce a permanent pink in the boiling solution, no chlorine is liberated.

Into a distillation flask, with a long delivery tube fitted with a condenser, and connected to a burette by a ground-glass junction (greased with honey-thick phosphoric acid), was placed 100 c.c. of the sea-water sample, 25 c.c. of 50 per cent. sulphuric acid (two volumes of acid to three of water) and a little powdered pumice-stone. The burette was filled with N/20 potassium permanganate in strong sodium sulphate solution (250 gm. of the hydrated salt per litre, tofacilitate mixing). The solution was boiled to expel all air, and then six c.c. of permanganate run in, at first quickly, and finally a few drops at a time. The distillate was collected in a 50 c.c. flask containing 5 c.c. of distilled water and 1 c.c. of nearly saturated sulphur dioxide solution. Distillation was continued until about 20 to 25 c.c. had distilled over, a procedure requiring ten minutes. The distillate was transferred to a second flask, 5 c.c. of 50 per cent. sulphuric acid added, some pumice, and water to a total volume of 120 c.c. The flask was first closed with a cork and boiled for ten minutes to expel all sulphur dioxide, about 20 c.c. of water distilling over. Testing some drops of the distillate at this stage invariably showed no trace of sulphur dioxide. The burette was then attached, prior to which 20 c.c. of 50 per cent. sulphuric acid was added. The contents of the flask were boiled till all air was displaced, and then permanganate run in until a permanent pink was just reached. The distillate was collected in freshly prepared potassium iodide solution, and the liberated iodine titrated against approximately N/100 thiosulphate. The thiosulphate was standardized against potassium biniodate, itself standardized against re-sublimed iodine.

On testing this method it seemed susceptible to several sources of error. The principal appeared to be (*a*) insufficient removal of air from the distillation apparatus, or too rapid distillation, both leading to loss of bromine, (*b*) addition of more than the minimum quantity of permanganate in the second distillation, leading to too high results through distillation of a trace of chlorine. Continued boiling for sufficient time destroyed the pink colour. An end point was chosen at which addition of one drop of permanganate produced a colour which did not entirely disappear in one minute.

The chemicals employed were tested in control experiments with 100 c.c. of distilled water. Two experiments gave perfectly negative results. In the second, after addition of 0.25 c.c. permanganate in the second distillation had given a pink colour permanent for one minute, with no liberation of iodine, 20 mg. of sodium chloride were added to the flask, and the distillation continued. Three drops of permanganate were required to restore the permanent pinkness, and iodine was liberated corresponding to 0.00014 gm. bromine. Using the convention as to permanence that has been indicated, this is certainly more than the maximum error of experiment from this source, but emphasizes (*b*) as a potential source of error.

An artificial sea-water containing 30 grams of sodium chloride (Kahlbaum pre-war "K" standard) and 0.0806 sodium bromide (Merck, U.S.P. IX) was tested. In 100 c.c. of this, containing 0.626 gm. bromine, 0.636 was found, an error of +1.6 per cent.

The following results were obtained with the samples from Departure Bay:

Sample	Amount taken c.c.	Bromine found gm.	Chlorine corrected gm.	Ratio, 100 gm. Cl to Br in gm.	Mean
Surface (1)	99.98	0.00413	1.178	0.351	. .
(2)	99.98	0.00436	1.178	0.370	. .
(3)	99.98	0.00407	1.178	0.346	0.356
10-Fathom (1)	99.98	0.00570	1.559	0.366	
(2)	99.98	0.00550	1.559	0.355	
(3)	99.98	0.00556	1.559	0.358	0.360

The mean of all six determinations gives a ratio of 100 gm. chlorine to 0.358 gm. bromine, as compared with Winkler's figure of 0.347. Since the latter is within the extremes observed, and the chief source of error would seem to be the distillation of a slight amount of chlorine leading to too high a figure, my average figure may perhaps be regarded as somewhat too high. The results illustrate the high degree of constancy in the chlorine-bromine ratio of sea-water throughout the oceans. It is doubtful whether observations by two different individuals using this method are sufficiently accurately comparable to decide whether or not the chlorine-bromine ratio is absolutely constant.

IODINE.

Winkler's method consists of alternate liberation of iodine by nitrite in acid solution with subsequent removal by carbon tetrachloride, and reconversion into iodide by sulphur dioxide in presence of water, until such a degree of concentration is attained that colorimetric comparison is possible.

One litre of filtered sea-water is treated in a 1,500 c.c. cylindrical separation funnel with 50 c.c. purified carbon tetra-chloride, 5 c.c. one per cent. sodium nitrite, and 5 c.c. concentrated hydrochloric acid, with repeated shaking for one-half hour. The CCl_4 is run off, and the process repeated twice with fresh quantities of 50 c.c. The CCl_4 is collected in a smaller separation funnel, to which is added 10 c.c. water and 5 drops of 0.1 per cent. sulphur dioxide solution. After brisk shaking the CCl_4 is removed, and to the aqueous solution are added 5 drops of nitrite solution and 10 drops of 10 per cent. sulphuric acid. After 10 minutes this is thrice extracted with successive 5 c.c. portions of CCl_4. The CCl_4 is then collected in a 15 c.c. separation funnel, with a graduation mark at 0.5 c.c. One c.c. of water and two drops of sulphur dioxide solution are added, the mixture well shaken, and all the CCl_4 except 0.5 c.c. run off. The 5 drops of sulphuric acid and 2 drops of nitrite solution are added, the mixture shaken, and transferred to a small cylindrical glass-stoppered vessel.

Colorimetric comparison is made with a similarly concentrated iodine-carbon tetrachloride solution prepared from an artificial sea-water of approximately the same composition (in my experiments this contained 20 gm. pure NaCl, 10 gm. pure $MgSO_4$, $7H_20$, and 0.07 gm. pure KBr) containing known quantities of iodide. The final comparisons are carried out in vessels of the same size.

Total iodine is determined by initial reduction with 5 c.c. of N/100 arsenious acid in presence of HCl, allowing one-half hour for complete reduction before addition of nitrite.

According to Winkler, the final concentrate from the iodide estimation should be faintly pink in colour ("blassrosenrot") while that from the total iodine estimation is markedly rose red ("kraftigrosenrot"). I did not obtain these depths of colour. A test of the reagents employed, using artificial sea-water with no addition of iodide, gave a perfectly blank result. This was also obtained with one litre of sea-water, testing for iodide only. Two litres of sea-water (iodide only) gave a just perceptible pink tinge, while one litre (total iodine) gave a just distinct pink tinge. These could only be roughly compared with similar faint colours from artificial sea-waters containing known amounts of iodine.

These differences from Winkler's results were only in slight part attributable to the somewhat diluter water tested. The chief cause was probably due to the fact that I had not available at the Station a large separation funnel for the initial treatment, which was therefore carried out in a Winchester bottle, the carbon tetrachloride being pipetted off. This did not permit such complete separation of the two phases.

The following results were obtained:

Surface sample.

Iodide present was of the order 0.005 mg. iodine in two litres.

Iodide plus iodate present were of the order 0.025 mg. iodine per litre (0.0225 mg. iodine as iodate, 0.0025 mg. as iodide).

10-Fathom sample.

No iodine could be detected in one litre without reduction.

The total iodine present was distinctly greater than that in the surface sample.

These results, though only so approximate, permit the following conclusions:

The iodine in sea-water is present chiefly as iodate. The ratio of chlorine to total iodine is of the order 100 to 0.0002 (Winkler's figure was 0.00023).

I have not considered the question of organically combined iodine. Winkler's negative results appear certain on this point, the only possible error being decomposition during transit and before analysis. This would be more likely to result from decomposition of plankton than from change in soluble organic iodine compounds.

BROMATE AND CHLORATE.

In view of the fact that most of the iodine in sea-water is in combination as iodate, it would seem possible that some trace of bromate or of chlorate might also be present. I have been unable to find any references in the literature to the presence or absence of bromate or chlorate in sea-water, though Thresh reports bromate present in deep well waters contaminated by sea-water.

I have carried out the following experiment to test the possibility of presence of these ions:

To 100 c.c. of filtered sea-water was added 7 gm. silver nitrate (a little more than sufficient to precipitate all the halide present) dissolved in distilled water, and 10 c.c. of strong nitric acid The silver halide was filtered off. To the perfectly clear filtrate was added 2 gm. sodium nitrite dissolved in distilled water. A faint opalescence was produced.

This opalescence was almost exactly matched by a mixture of the same quantities of silver nitrate, nitric acid, and sodium nitrite in 100 c.c. distilled water. Further it was much less than that given by the addition of one drop of silver nitrate of which 1 c.c. was equivalent to 0.01 gm. NaCl, to 150 c.c. sea-water, *i.e.* to a suspension of silver chloride equivalent to 0.002 gm. chlorine in one litre. Any possible trace of chlorate must be, therefore, considered of at least a lower order, *i.e.*, containing chlorine of the order 0.0002 gm. per litre.

The conclusion can, therefore, be drawn that the amount of chlorine present as chlorate cannot be more than one fifty-thousandth of the total chlorine present. The maximum quantity of bromine as bromate, estimated in the same way, cannot be greater than one per cent. of that present as bromide.

SUMMARY

The ratio of chlorine : bromine : iodine in sea-water of the Strait of Georgia, B.C., is 100 : 0.358 : 0.0002.

Winkler's corresponding figures for water from the Adriatic Sea are 100: 0.347 : 0.00023.

Most of the iodine present is combined as iodate (confirming Winkler's results and Sonstadt's conclusion).

Any bromate present cannot exceed one per cent. of the bromide, and chlorate can only be present to a negligible extent.

This work is connected with a series of researches on the biochemistry of iodine. I desire to acknowledge my indebtedness to the Biological Board of Canada for the facilities provided me in carrying on the work, and to the Chemical Society (London) for a grant, part of which has been used in defraying some of the expenses connected with it.

REFERENCES

BERGLUND, E., Ber. d. deutsch. chem. Ges., 1885, *18*, 2888, and Zeitschr. f. anal. Chem., 1885, *24*, 184.
CAMERON, A. T., J. Biol. Chem., 1914, *18*, 335; 1915, *23*, 1.
CHELLE, L., Bull. soc. pharm. Bordeaux, 1914, *53*, 289.
DENIGÈS, H., and CHELLE, L., Compt. rend., 1912, *155*, 1010.
DITTMAR, W., Challenger Reports, Physics and Chemistry, Vol. I, p. 89, 1884.
GAUTIER, A., Compt. rend., 1899, *128*, 1069; *129*, 9; 1920, *170*, 261.
KOETTSTORFFER, Zeitschr. f. anal. Chem., 1878, quoted by Gautier.
MACADAM, S., Journ. f. prakt. Chem., *8*, quoted by Gautier.
MAKIN, C. J. S., Chem. News, 1898, *77*, 155.
SONSTADT, E., Chem. News, 1872, *25*, 196, 231, 241.
THRESH, J. C., "Examination of Water and Water Supplies" (London), 2nd Edit., 1913, p. 423.
WINKLER, L. W., Zeitschr. f. angew. Chem., 1915, *28*, 477; 1916, *29*, 68, 205.

No. 6

THE EFFECT OF MARKED CHANGES IN SPECIFIC GRAVITY UPON THE AMOUNT OF PHYTOPLANKTON IN DEPARTURE BAY WATERS

BY

IRENE MOUNCE, M.A., M.Sc.
Hudson's Bay Research Fellow, University of Manitoba

The Effect of Marked Changes in Specific Gravity upon the Amount of Phytoplankton in Departure Bay Waters

By Irene Mounce, M.A., M.Sc.
Hudson's Bay Research Fellow, University of Manitoba

It has been noted by Cameron[3] " . . . . that certain pelagic and free-swimming shore forms which occur constantly throughout the summer at Friday Harbour (where surface conditions more similar to those of the open ocean persist) disappear from near the surface at Departure Bay and adjacent waters in the early summer, making the question of migration a matter of importance." This paper summarizes observations which were made on the disappearance of diatoms during the summer months from the waters of Departure Bay, and attempts to show some of the causes for this.

During the summer months of the years 1919, 1920 and 1921 I made daily collections of plankton diatoms at the Biological Station, Departure Bay, for Professor A. H. Hutchinson, of the University of British Columbia. Each day the amount of diatoms collected was measured, the direction of the wind was recorded, and notes were made on the general weather conditions. The daily readings of the temperature and specific gravity of the surface water were taken from the Station records made by Dr. Fraser.

Each summer in Departure Bay it was noticed that, although plankton diatoms were plentiful in the early part of May, they gradually became scarcer and, by the end of June or early in July, had almost or entirely disappeared from both surface tows and tows taken at a depth of from one to one and one-half fathoms. It seemed unlikely that this rapid decrease in the number of diatoms should be due solely to seasonal variations, firstly, because diatoms could readily be obtained by making depth hauls of 5-25 fathoms in the bay and, secondly, because a plentiful supply could be obtained from the surface waters near False Narrows, about twenty miles from the station, even when no diatoms were found in the waters of Departure Bay itself. It was also found, on those occasions when comparisons could be made, that the specific gravity of the sea-water near False Narrows was much higher than that recorded the same day for Departure Bay waters. This fact suggested that there might be some relation between the wide variations in specific gravity of the water in Departure Bay and the disappearance of plankton diatoms from the surface tows.

It has been found that, if the varying amount of diatoms in a constant volume of sea-water is compared with the fluctuating densities, when both diatoms and densities refer to surface samples, then in Departure Bay the following simple relationship can be shown to exist between the two: *a marked decrease in specific gravity is followed by a decrease or total disappearance of diatoms.* The converse is not necessarily true. In the period during which these observations were made this factor—specific gravity—seems to be the predominating one in its influence on the presence of diatoms, although the figures obviously show the presence of other factors as yet not accurately determined.

METHODS

All collections of diatoms were made with a conical net of bolting-silk (length about 25 inches, width of orifice 16 inches) and an eight-ounce bottle tied to the end of it. This was towed for two minutes over a definite course, without reference to the distance covered and at a speed rapid enough to keep the net just below the water's surface. At the end of that time the contents of the net were carefully washed down into the bottle, which was then removed and labelled. A second tow was immediately taken in the same way and over the same course, but with a weight attached to the net so that it remained 7-9 feet below the surface. This method of collecting material was used throughout the three summers, except that in 1919 the net was towed a definite distance instead of for a definite period of time. These tows were taken at about half-past eight in the morning and at seven o'clock in the evening, regardless of the height of the tide. But, since no measurements of the temperature and specific gravity of the sea-water were made in the evening, the records for the evening collections of diatoms have been omitted here.

Two methods have been employed in measuring the amount of diatoms obtained in each sample. (1) During the summer of 1919 the apparatus consisted of pieces of glass tubing about two and one-half feet in length, about one-fourth of an inch in diameter, and sealed at one end. Immediately after a sample had been taken, a fixed volume of it was poured into each of two such tubes. The water was allowed to stand for twelve hours and, at the end of that time, the depth of sediment in mm. was recorded. In those cases where there was some discrepancy between the readings obtained from the two tubes the average was taken. (2) During the summers of 1920 and 1921 a water-power centrifuge was used. Two graduated centrifuge tubes were filled with 15 c.c. of liquid from each sample. When the material had been centrifuged for 10 minutes, the number of c.c. of sediment was measured and afterwards used as the basis for comparisons. Occasionally, when the diatoms were particularly abundant, the liquid, before being centrifuged, was diluted to one-half, and the probable amount in 15 c.c. was then calculated from the volume of the sediment.

TABULATION OF RESULTS

The data thus collected during the three summers have been set down in Tables I, II and III.

Diatoms. The relative amounts of diatoms in the samples have been recorded in two ways: in Table I the amount of diatoms is expressed as the height in mm. to which the glass tube was filled with sediment (see methods); in Tables II and III the amount of diatoms in each daily sample is expressed as the number of c.c. of sediment thrown down by 15 c.c. of sea-water from the tow.

Temperature. The measurements given in Tables I and II were made with ordinary thermometers and are uncorrected, but those recorded in Table III were made with a thermometer which had been calibrated against a Kew standard and can, therefore, be considered accurate to within ±0.1°C.

Specific Gravity. Specific gravity measurements were made from water samples immediately after they had been taken. As before, those recorded in Tables I and II are uncorrected, but those recorded in Table III were made by means of an accurately graduated hydrometer which was calibrated in solutions whose densities had been determined in a pyknometer. The probable error of these readings is estimated to be not greater than ±0.0001. I am indebted to Professor Cameron, of the University of Manitoba, for the corrected temperature and specific gravity readings.

In the remainder of the Tables the following abbreviations have been used:

Wind: E. = wind from east; W. = wind from west; C. = calm; B. = light breeze.

Weather: B. = bright; D. = dull; R. = rain.

The asterisk placed beside the amount of diatoms denotes the presence in the collection of a proportionately large amount of horned forms, such as *Chaetoceras*, which do not pack well either in settling or centrifuging and consequently give a reading which is higher than the actual number of diatoms would justify.

TABLE I

Date	Weather	Wind	Water temp. °C.	Specific gravity as read	Specific gravity to 15°C.	Diatoms	
						Surface	Depth
1919							
May 20	..	E.	11.0	1.0211	1.0206	1.0	3.0
21	..	C.	13.0	1.0176	1.0173	25.0	6.0
22	..	C.	14.0	1.0171	1.0170	20.0	6.0
23	..	C.	13.0	1.0178	1.0175	27.0	....
24	R.	E.	12.6	1.0147	1.0144	3.2	3.5
25	R.	E.	12.1	1.0182	1.0178	6.7	9.7
26	..	W.	10.0	1.0213	1.0207	8.0	5.0
27	..	C.	10.0	1.0211	1.0205	0.0	0.0
28	..	W.	10.3	1.0213	1.0207	3.0	3.0
29	..	..	12.1	1.0183	1.0179	5.0	1.5
30	..	W.	12.8	1.0172	1.0169	4.0	6.0
June 12	B.	W.	13.0	1.0213	1.0210	142.0	170.0
13	D.	C.	13.7	1.0212	1.0210	150.0	37.0
14	B.	E.	13.9	1.0209	1.0207	105.0	68.0
15	B.	C.	14.0	1.0221	1.0220	88.0	25.0
16	D.	C.	14.0	1.0215	1.0214	22.0	30.0
17	B.	C.	14.5	1.0214	1.0213	2.0	2.0
18	B.	W.	14.5	1.0205	1.0204	2.0	3.0
19	B.	W.	16.0	1.0184	1.0185	1.0	1.0
20	B.	C.	14.8	1.0203	1.0203	16.0	10.0
21	D.	C.	15.8	1.0191	1.0192	23.0	25.0
22	R.	C.	15.2	1.0172	1.0172	87.0	20.0
23	D.	C.	14.0	1.0184	1.0183	130.0	35.0
24	B.	C.	12.5	1.0212	1.0209	120.00	50.0
25	R.	E.	15.5	1.0149	1.0150	3.0	5.0
26	D.	E.	15.5	1.0159	1.0160	6.0	20.0
27	B.	B.	15.3	1.0180	1.0180	17.0	65.0
28	D.	B.	14.8	1.0188	1.0188	....	....
29	B.	B.	15.8	1.0175	1.0176	10.0	36.0
30	B.	C.	15.6	1.0181	1.0182	100.0	55.0
July 1	B.	B.	16.2	1.0188	1.0190	140.0	20.0
2	B.	B.	17.7	1.0126	1.0131	4.0	7.0

TABLE I.—*Cont.*

Date	Weather	Wind	Water temp. °C.	Specific gravity as read	Specific gravity to 15°C.	Diatoms	
						Surface	Depth
July 3	B.	B.	18.8	1.0106	1.0112	*2.0	*55.0
4	D.	C.	18.3	1.0113	1.0118	2.0	20.0
5	D.	B.	18.2	1.0141	1.0146	0.0	15.0
6	..	..	17.0	1.0145	1.0148	....	....
7	B.	B.	17.3	1.0145	1.0148	2.0	5.0
8	B.	B.	18.0	1.0153	1.0158	0.0	0.0
9	B.	C.	19.2	1.0127	1.0134	0.0	0.0
10	B.	W.	19.5	1.0141	1.0148	0.0	0.0
11	D.	B.	20.0	1.0130	1.0139	0.0	0.0
12	D.	B.	17.5	1.0145	1.0149	*7.0	*47.0
13	B.	C.	16.1	1.0191	1.0193	*60.0	*55.0
14	B.	B.	17.6	1.0151	1.0155	0.0	0.0
15	B.	B.	18.8	1.0154	1.0160	0.0	0.0
16	B.	B.	18.8	1.0154	1.0164	0.0	0.0
17	B.	B.	17.7	1.0165	1.0165	0.0	0.0
18	B.	B.	17.5	1.0177	1.0181	63.0	40.0
19	B.	B.	17.3	1.0184	1.0187	40.0	130.0
20	B.	B.	17.4	1.0188	1.0191	0.0	0.0
21	B.	B.	17.3	1.0188	1.0191	*165.0	*120.0
22	D.	B.	16.9	1.0191	1.0194	*185.0	*190.0
23	D.	B.	17.0	1.0190	1.0193	*220.0	*190.0
24	B.	B.	16.7	1.0192	1.0197	*200.0	*300.0
25	D.	C.	16.7	1.0196	1.0199	160.0	140.0
26	..	..	16.0	1.0202	1.0204	0.0	0.0
27	..	C.	16.6	1.0202	1.0205	200.0	....
28	..	E.	17.2	1.0176	1.0179	180.0	73.0
29	..	..	18.2	1.0151	1.0156	....	....
30	D.	B.	17.2	1.0178	1.0181	145.0	130.0
31	D.	W.	15.3	1.0195	1.0195	120.0	100.0
Aug. 1	R.	E.	16.8	1.0181	1.0184	160.0	....
24	D.	W.	18.8	1.0174	1.0178	*150.0	*200.0
25	D.	C.	18.8	1.0159	1.0165	* 18.0	*210.0
26	D.	C.	18.1	1.0187	1.0192	*150.0	*150.0
27	D.	C.	17.2	1.0172	1.0175	160.0	....

TABLE II

Date	Weather	Wind	Water temp. °C.	Specific gravity as read	Specific gravity to 15°C.	Diatoms CC. of residue	
						Surface	Depth
1920							
May 15	..	..	12.6	1.0236	1.0233	.7	....
16	D.	C.	12.5	1.0236	1.0233	1.8	....
17	B.	W.	12.6	1.0236	1.0233	2.7	2.2
18	D.	E.	13.0	1.0239	1.0236	1.0	2.0
19	B.	W.	11.2	1.0240	1.0235	.5	.4
20	D.	E.	12.0	1.0239	1.0235	1.8	2.1
21	B.	W.	11.7	1.0240	1.0236	*4.5	*1.2

TABLE II—*Cont.*

Date	Weather	Wind	Water temp. °C.	Specific gravity as read	Specific gravity to 15 C.	Diatoms CC. of residue	
						Surface	Depth
1920							
May 22	B.	C.	10.8	1.0240	1.0235	1.7	2.5
23	D.	C.	11.3	1.0238	1.0233	1.5	2.5
25	D.	E.	10.2	1.0178	1.0172	3.7	1.5
26	D.	E.	10.3	1.0239	1.0233	.2	.4
27	D.	W.	11.3	1.0234	1.0229	2.0	.5
28	D.	E.	10.9	1.0233	1.0228	.5	.8
29	R.	E.	10.9	1.0230	1.0225	*2.0	*2.5
30	D.	W.	11.3	1.0234	1.0229	2.0	1.2
31	B.	E.	11.3	1.0219	1.0214	.4	.4
June 1	B.	E.	13.0	1.0218	1.0215	.7	.3
2	B.	E.	15.0	1.0220	1.0220	0.0	0.0
3	B.	B.	16.5	1.0175	1.0172	.1	.3
4	D.	E.	16.5	1.0143	1.0146	.4	.3
5	R.	E.	14.5	1.0190	1.0189	.5	.7
6	R.	E.	13.8	1.0192	1.0190	.5	.8
7	B.	E.	13.8	1.0204	1.0202		
8	B.	E.	13.4	1.0197	1.0194	.9	.3
9	B.	E.	12.2	1.0220	1.0216	.5	.9
10	R.	E.	11.9	1.0205	1.0201	.8	.6
11	R.	E.	12.1	1.0201	1.0197	.5	.3
12	B.	E.	13.2	1.0175	1.0172	.8	.6
13	D.	E.	15.5	1.0163	1.0164	.9	.6
14	R.	B.	14.9	1.0162	1.0162	.5	.5
15	D.	E.	12.7	1.0218	1.0215	.9	.3
16	B.	E.	12.7	1.0218	1.0215	1.1	1.3
17	D.	W.	14.8	1.0198	1.0198	.6	1.1
18	B.	B.	14.0	1.0197	1.0196	.4	.3
19	D.	E.	14.5	1.0164	1.0163	1.3	1.5
20	B.	W.	14.7	1.0185	1.0185	1.0	1.0
21	D.	C.	16.1	1.0162	1.0164	1.0	.8
22	B.	W.	14.7	1.0136	1.0136	.6	1.0
23	D.	W.	15.4	1.0128	1.0128	.5	.5
24	D.	W.	15.3	1.0156	1.0156	.4	.3
25	..	..	15.3	1.0160	1.0160		...
26	D.	E.	15.3	1.0178	1.0178	1.1	1.1
27	D.	E.	15.9	1.0172	1.0173	1.2	1.0
28	D.	W.	17.6	1.0144	1.0148	.2	.2
29	B.	W.	19.5	1.0130	1.0137	.05	.05
30	B.	W.	18.0	1.0152	1.0156	.05	.05
July 1	B.	W.	18.2	1.0156	1.0161	.02	.02
2	B.	W.	18.0	1.0162	1.0166	.02	.02
3	B.	W.	17.6	1.0182	1.0186	.02	.02
4	B.	W.	17.6	1.0176	1.0180	0.0	.05
5	B.	E.	17.3	1.0183	1.0186	.05	.05
6	B.	W.	18.0	1.0191	1.0195	.07	.06
7	B.	C.	18.8	1.0191	1.0195	.2	.5
8	B.	C.	20.5	1.0102	1.0110	.03	.03
9	B.	E.	20.5	1.0112	1.0122	.02	.02

TABLE II—*Cont.*

Date	Weather	Wind	Water temp. °C.	Specific gravity as read	Specific gravity to 15°C.	Diatoms CC. of residue	
						Surface	Depth
1920							
July 10	B.	E.	19.5	1.0125	1.0133	.3	1.4
11	R.	C.	17.9	1.0182	1.0186	.5	1.4
12	D.	C.	15.1	1.0194	1.0194	1.6	1.3
13	D.	W.	14.7	1.0208	1.0208	.5	.8
14	B.	E.	17.2	1.0091	1.0094	.05	.1
15	B.	W.	19.7	1.0092	1.0100	0.0	0.0
16	B.	W.	19.9	1.0088	1.0097	0.0	0.0
17	D.	C.	21.0	1.0122	1.0133	.05	.1
18	D.	E.	19.9	1.0132	1.0141	.25	.3
19	B.	E.	17.0	1.0185	1.0188	.15	.3
20	D.	E.	17.3	1.0194	1.0197	.2	.2
21	D.	W.	17.1	1.0192	1.0195	.03	.03
22	D.	E.	18.5	1.0082	1.0087	.03	.03
23	D.	E.	17.4	1.0111	1.0115	.05	.15
24	D.	E.	16.1	1.0148	1.0150	.5	.6
25	D.	E.	17.0	1.0139	1.0142	.5	.9
26	B.	W.	18.2	1.0114	1.0119	.35	.25
27	B.	W.	19.3	1.0098	1.0105	0.0	0.0
28	D.	C.	17.8	1.0102	1.0106	*.1	*4.5
29	B.	E.	18.7	1.0113	1.0119	*.4	*4.0
30	D.	E.	17.5	1.0145	1.0149	*2.0	*17.5
31	D.	E.	17.0	1.0178	1.0181	*1.2	*3.0
Aug. 1	B.	W.	18.2	1.0167	1.0172	*2.0	*1.2
2	B.	E.	19.1	1.0090	1.0097	*6.0	*3.0
3	B.	W.	18.3	1.0131	1.0136	*1.5	*1.1
4	B.	W.	17.8	1.0136	1.0141	*1.5	*1.4
5	B.	W.	19.0	1.0134	1.0141	*3.0	*1.5

TABLE III

1921							
June 8	D.	E.	14.1	1.0210	1.0209	.6	1.5
9	D.	E.	14.3	1.0203	1.0202	.4	2.5
10	D.	B.	13.5	1.0208	1.0206	2.0	.4
11	D.	E.	14.0	1.0204	1.0203	1.0	1.3
12	B.	B.	14.0	1.0201	1.0200	1.0	.5
13	R.	E.	15.8	1.0128	1.0129	.5	.1
14	R.	E.	14.0	1.0173	1.0172	.1	0.0
15	D.	C.	13.5	1.0198	1.0196	....	....
16	D.	E.	13.8	1.0217	1.0216	....	....
17	B.	E.	14.3	1.0143	1.0142	0.0	.5
18	D.	E.	14.7	1.0157	1.0157	.5	.5
19	D.	E.	14.0	1.0180	1.0179	0.0	0.0
20	R.	E.	12.9	1.0193	1.0190	0.0	0.0
21	B.	E.	11.7	1.0222	1.0218	0.0	0.0
22	B.	C.	13.1	1.0157	1.0154	0.0	0.0
23	D.	W.	15.0	1.0113	1.0113	0.0	0.0
24	R.	C.	15.2	1.0119	1.0119	0.0	0.0

TABLE III—*Cont.*

Date	Weather	Wind	Water temp. °C.	Specific gravity as read	Specific gravity to 15°C.	Diatoms CC. of residue	
						Surface	Depth
1921							
June 25	D.	E.	16.3	1.0146	1.0147	0.0	0.0
26	R.	E.	14.5	1.0176	1.0176	0.0	0.0
27	D.	E.	14.7	1.0179	1.0179	0.0	.1
28	B.	E.	14.6	1.0206	1.0206	.2	.05
29	R.	E.	17.0	1.0135	1.0138	0.0	0.0
30	B.	E.	18.2	1.0138	1.0143	0.0	.3
July 1	B.	W.	15.7	1.0146	1.0147	0.0	0.0
2	B.	B.	15.1	1.0141	1.0141	0.0	0.0
3	B.	E.	15.8	1.0149	1.0150	0.0	0.0
4	D.	W.	15.2	1.0171	1.0171	0.0	0.0
5	B.	W.	15.3	1.0193	1.0193	0.0	0.0
6	B.	E.	15.2	1.0166	1.0166	0.0	0.0
7	D.	C.	15.2	1.0192	1.0192	0.0	.1
8	B.	E.	13.8	1.0211	1.0210	0.0	0.0
9	B.	W.	15.3	1.0198	1.0198	.05	.05
10	B.	W.	15.8	1.0152	1.0153	0.0	0.0
11	B.	W.	16.3	1.0154	1.0154	0.0	0.0
12	B.	W.	17.3	1.0153	1.0156	0.0	0.0
13	B.	W.	16.8	1.0158	1.0161	0.0	0.0
14	B.	E.	17.3	1.0169	1.0172	0.0	0.0
15	D.	E.	17.5	1.0176	1.0180	.01	.01
16	B.	W.	15.1	1.0198	1.0198	*.5	*.4
17	B.	W.	17.2	1.0174	1.0177	0.0	0.0
18	B.	E.	17.5	1.0177	1.0181	0.0	0.0
19	D.	E.	18.1	1.0162	1.0167	0.0	0.0
20	D.	C.	18.6	1.0162	1.0168	0.0	0.0
21	B.	E.	17.9	1.0168	1.0173	0.0	0.0
22	D.	E.	17.1	1.0189	1.0192	0.0	0.0
23	B.	W.	16.7	1.0195	1.0197	0.0	0.0
24	B.	W.	18.8	1.0160	1.0167	0.0	0.0
25	D.	E.	19.3	1.0146	1.0153	0.0	0.0
26	D.	E.	18.6	1.0148	1.0154	0.0	0.0
27	B.	E.	18.0	1.0172	1.0177	0.0	*.35

DISCUSSION

From the Tables given above it is apparent, I think, that in each year the period of lowest specific gravity is also the period when few or no diatoms are obtained in surface samples. This relationship between specific gravity and diatoms in Departure Bay waters is shown more clearly when the actual daily specific gravity readings and the amount of diatoms in surface samples are plotted. The two curves (Fig. 1) will be seen to approximate one another fairly closely, especially when it is remembered that the relatively large amounts of diatoms recorded for May and August, 1920, were due to the presence of *Chaetoceras* forms. It was also noted, at the time when these collections were made, that a prevailing west wind caused a decrease in the number of diatoms in surface tows. The reason for this is not clear but, as a reference to Table II will show, this fact explains several of the sudden drops in the diatom curve given, *e.g.*, on May 19 and 27, which drops cannot be explained simply by the theory of the influence of specific gravity on diatoms at Departure Bay.

The curves for 1920 are presented because the records for that year extend over a longer period than those for either 1919 or 1921, and are practically a continuous series. The curves for the other two years, however, also show this relationship between specific gravity and diatoms, although somewhat less clearly. The method employed during the summer of 1919 to determine the amount of diatoms was less accurate than that used during the two succeeding summers, and therefore the actual measurements of diatoms present are less reliable. Nevertheless, the records definitely show the absence of diatoms during the period of low specific gravity, *i.e.*, during the first three weeks of July. For the summer of 1921, owing to the loss of two nets in succession, the series of observations on the amount of diatoms is incomplete and extends over a relatively short period.

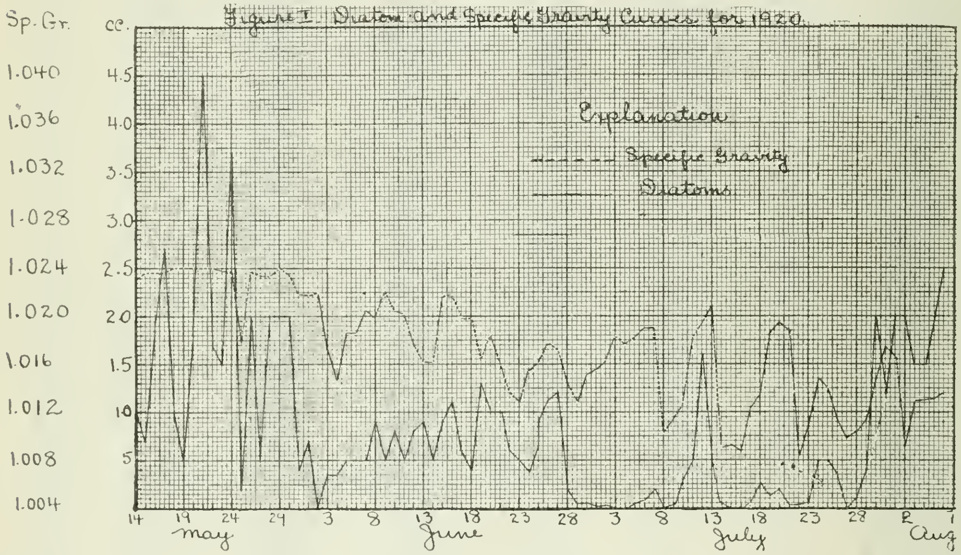


FIG. 1.

In adopting the conclusion that sudden decreases in specific gravity affect the amount of diatoms in the surface waters of Departure Bay one must take into consideration: (1) the many possible sources of error in methods, and (2) the influence of certain factors other than specific gravity. Allen (2) has drawn up a long list of possible sources of error in such plankton methods as are in general use and, although they refer primarily to vertical hauls under ocean conditions, many of them are applicable as well to surface tows in inside waters. In making collections at Departure Bay the difficulties experienced in locating the station and the errors resulting from a rough sea are negligible; there still remain, however, the variations in the amount of water passing through the net due to the influence of wind, tide and currents; errors due to the leaking and clogging of the net and the presence in the samples of organisms other than diatoms; and errors in diluting, measuring and recording. It must be admitted, therefore, that the records presented in this paper are, at most, only approximately correct. To give a more accurate account it would be necessary to make a more exact estimation of the numbers of the various species present in the sample. Such a proceeding would, doubtless, yield very interesting results, and would make it possible also to discuss the important question of the seasonal succession of forms and their relative frequency at different periods of the year.

The effect of a prevailing west wind has already been mentioned, but there still remain several influences, other than specific gravity, that, without doubt, are responsible for many of the variations in the number of diatoms in the surface waters of Departure Bay. Chief among these influences, perhaps, is seasonal variation both in the numbers and in the forms of diatoms that appear. Allen (2) has found that for the San Diego region, California, "there is a strong indication that annual maxima for both diatoms and dinoflagellates occur in the period from April to early June," and that "there is an indication that the minimum diatom production for the year comes in August or September." As has been indicated, no detailed study of the collections has yet been made; but, if the periods of maximum and minimum diatom production for Departure Bay corresponded to those in San Diego waters, this seasonal variation would still not wholly account for the annual disappearance of diatoms from the surface waters of Departure Bay when they can be obtained a few fathoms below the surface. With regard to the distribution of various forms throughout the year, the general observation has been made that here, just as in St. Andrews waters, (6) the solid compact forms which predominate in the early spring soon give place to such forms as *Chaetoceras* and *Thalassiosira* in the summer. The errors in measurement caused by the prevalence of these forms has already been mentioned.

Then, too, cultural studies (1, 7) have shown that strong direct sunlight and high temperatures are detrimental to the rapid growth of diatoms. Cameron (3) has pointed out that in Departure Bay waters ". . . there is a marked relationship between the curves for temperature and specific gravity, any marked rise in the one corresponding to a fall in the other, and *vice versa*. Any rise in temperature obviously takes place under steady good weather conditions, where there is an optimum chance that the Fraser River can exert its maximum effect to produce a fall in specific gravity." It has already been noted that a decrease or total disappearance of diatoms from the surface waters of Departure Bay occurs with a low specific gravity. From the foregoing quotation it is evident that this low specific gravity is accompanied by a relatively high temperature and fine weather; in other words, in these waters the period of minimum diatom production is also a period of prevailing high temperature and fine weather. In how far these factors are responsible for the disappearance of the diatoms it is impossible even to estimate at present.

With regard to the hydrogen-ion concentration of sea-water it is almost certain that the relation between specific gravity and distribution of diatoms at Departure Bay is connected with the change in P_H which the specific gravity change connotes. It has been shown (3) that in this vicinity a high specific gravity is accompanied by a relatively low P_H and *vice versa*, the figures, however, always remaining on the alkaline side. It would appear, therefore, from the results shown in Tables I-III that one of the chief factors causing the presence of diatoms in marked amounts in surface waters of Departure Bay is a lowering of the P_H in these waters. This actually means a surface water more nearly approximating in concentration ocean water.

The complexity of conditions which exist at Departure Bay with regard to the effect of winds, the influx of fresh water from the Fraser River, currents, and the comparatively high temperature which prevails has been fully dealt with by Cameron and Fraser (3, 4, 5). It is sufficient, therefore, to have pointed out the effect of this complexity of conditions upon one phase of marine life, namely, the variation in the amount of diatoms in the surface waters of the bay. Taking all these factors into consideration it is not surprising that somewhat different results with regard to phytoplankton have been obtained off the coast of California, near San Diego (8). There "upwelling" causes a reduction in temperature *and* salinity and an increase in the amount of phytoplankton. A similar mixture of surface and depth waters in Departure Bay, however, causes a sudden lowering of temperature and an increase in specific gravity (3) which may or may not be accompanied by an increase in phytoplankton, at least for that period of the year during which observations were made; but, as has been shown, a marked decrease in salinity would be accompanied by a decrease or total disappearance of diatoms.

In conclusion, I wish to thank Professor A. H. Hutchinson for his permission to publish data which were obtained while making the daily diatom collections for him, and also Professor A. T. Cameron for his assistance and advice.

CONCLUSIONS

1. It will be seen from the foregoing that a large number of factors influence the appearance and distribution of diatoms in the plankton of Departure Bay waters. Nevertheless, from measurements made during the last three summers and from the close correspondence of the curves it is justifiable to conclude that *a marked decrease in specific gravity is accompanied by a decrease or total disappearance of diatoms.* Thus it has been shown that one of these important factors is the variations in specific gravity.

2. From this it has been deduced that one of the chief factors causing the appearance of diatoms in large amounts in Departure Bay waters is a lowering of the P_H or, in other words, the approximation of the surface water more nearly to ocean water in concentration.

3. Whereas in San Diego waters a decrease in salinity is accompanied by an increase in phytoplankton; in Departure Bay waters a decrease in salinity is accompanied by a decrease in phytoplankton.

REFERENCES

(1) Allen, E. J. and Nelson, E. W. On Artificial Culture of Marine Plankton Organisms. *Jour. Marine Bio. Assoc.*, New Series, Vol. VIII, No. 5, 1920.

(2) Allen, W. E. Preliminary Statistical Studies of Marine Phytoplankton of the San Diego Region, California. *Special Publications of Bernice P. Bishop Museum*, No. 7, 1921.

(3) Cameron, A. T. Some Physical and Chemical Factors Influencing the Distribution of Marine Flora and Fauna in the Strait of Georgia and Adjacent Waters. *Contr. to Canadian Biol.* N.S. Vol. I, 1922.

(4) Fraser, C. M. and Cameron, A. T. Variations in Density and Temperature in the Coastal Waters of British Columbia. *Contr. to Canadian Biol. for* 1914-1915, 1916.

(5) Fraser, C. M. Temperature and Specific Gravity Variations in the Surface Waters of Departure Bay, B.C. *Contr. to Canadian Biol. for* 1918-1920, 1921.

(6) Fritz, Clara W. Plankton Diatoms, their Distribution and Bathymetric Range in St. Andrews Waters. *Contr. to Canadian Biol. for* 1918-1920. 1921.

(7) Fritz, Clara W. Experimental Cultures of Diatoms occurring near St. Andrews, N.B. *Contr. to Canadian Biol. for* 1918-1920, 1921.

(8) Michael, Ellis L. Effect of Upwelling Water upon the Organic Fertility of the Sea in the Region of Southern California. *Special Publications of the Bernice P. Bishop Museum*, No. 7, 1921.

No. 7

A NEW HYDRACTINIA AND OTHER WEST COAST HYDROIDS

BY

C. McLEAN FRASER
Marine Biological Station, Nanaimo, B.C.

A New Hydractinia and other West Coast Hydroids

By C. McLean Fraser
Marine Biological Station, Nanaimo, B.C.

Hydractinia lævispina *new species*

Plate I, figs. 1-6

Trophosome.—As the colonies were growing on a barnacle shell the basal cœnosarc is separated into parallel masses by the ridges of the shell, with apparently little connection over the ridges. The nutritive zooids appear in successive stages of growth from the one side of the colony to the other, the largest reaching a length of 2.5 mm. Even in the largest zooids the tentacles are few in number as compared with *H. aggregata*, eight being the common number. The ridges of the barnacle shell give a certain amount of protection and this may account for the fact that there are very few basal spines and those that are present are smooth, not jagged, as in other species. They taper gradually to a rather blunt point and they are very slightly curved. They are about 0.5 mm. in length.

Gonosome.—Sporosacs begin to develop on the generative zooids when they are small; on these zooids there are three or four tentacles that persist although they remain of small size. A mouth is present. The sporosacs, commonly four in number, appear at about one-third of the distance from the tentacles to the base. The female sporosacs are small, with one ovum in each; the male considerably larger; both spherical.

Other Zooids.—Scattered about the outer portion of the colony are numerous long, slender, tentacular filaments or "tentaculozooids." They are only about one-fourth the diameter of the extended nutritive zooids and may be twice as long. They are well provided with nematocysts but have neither mouth nor tentacles.

Colour.—General colour light pink; the spadix of the male sporosac and the basal portion of the female sporosac are of a much darker pink and in many of the female generative zooids there is a patch of similar shade just below the base of the tentacles.

Distribution.—On barnacles in 7 to 10 fathoms, at the western end of Gabriola Pass.

Two fine colonies of this species were discovered by Dr. C. H. O'Donoghue, in looking over the shells of the barnacle, *Balanus aquilla*, for polyzoa, one on the outside of the main shell or parapet and the other on the surface of the scuta. Fortunately the one was a male colony and the other a female and as both were in good condition they gave all the data necessary. They were obtained June 29, 1921.

Eudendrium irregulare *new species*

Plate I, fig. 7

Trophosome.—Stolons irregular, straggling over such other hydroids as *Lafoëa gracillima*, not forming a regular network but, in places, adhering to form a loose fascicle. There are no definite stems as there are in most of the species of this genus. Most commonly the pedicels grow singly from the stolon; they are more or less sinuous and they vary greatly in length, the longest about 4 mm. Probably because the stolons grow over more or less erect hydroids, these pedicels pass out from the stolon in all directions and at various angles. Neither the stolons nor the pedicels are annulated, although the perisarc may be slightly and irregularly wrinkled. Hydranths with few tentacles, 8 to 10.

Gonmosoe.—There were no gonophores present in any of the colonies examined.

Colour.—Perisarc, light horn colour; hydranths, gray.

Distribution.—Northumberland channel, 15 fathoms.

Colonies of this species have been dredged on numerous occasions and in different localities, but the hydranths disintegrate so soon after the colony is dislodged that it has never been possible until now to get anything to examine but the stolons and the perisarcal stumps. Even in this instance, the cœnosarcal structures had disappeared in many cases, but there were several well preserved hydranths, enough to serve for diagnosis when taken in connection with the unusual habitus of the colony. Now that this much has been observed it may be possible later to get specimens with gonophores. There were none present on these colonies, collected July 14.

CAMPANULINA FORSKALEA (Peron et Lesueur)

Plate II, fig. 8

In a paper "On the development of Aequorea forskalea"[1] the development of this medusa was traced from the stage in which four complete perradial canals and four partial interradials were developed, and attention was called to the likelihood that a hydroid found in the vicinity, of the genus *Campanulina,* was the hydroid belonging to the species, although no convincing evidence was available at that time.

Shortly after the paper was written, on May 17 of that year, 1916, a fine hydroid colony was obtained on a Pinnixid from the mantle cavity of a specimen of *Mya arenaria*, obtained at Taylor Bay, Gabriola Island, and with it a partially developed medusa-bud. On May 22, another colony was found on a Pinnixid from a *Mya* obtained at Snake Island and this time there was a fully developed medusa-bud with the medusa nearly ready to escape. This showed unmistakable similarity to the very young medusa of *Aequorea forskalea* obtainable in the sea in the spring. It has been stated that the hydroid is very small as compared with the large size of the medusa and the lack of proportion is plainly evident even when the medusa is only a bud, as it towers above the little zooid which gives it support and is of so much greater diameter that it puts the whole colony out of balance.

The pedicel of the gonosome is attached to the pedicel of the nutritive zooid just below the hydrotheca. The total length of the pedicel and bud is 1.25 mm. while the length of the nutritive zooid is but 0.9 mm. Its greatest diameter is 0.4 mm., more than twice as great as the diameter of the hydrotheca.

The pedicel has one shallow annulation near the base; it increases in dia-

---

[1] Trans. Roy. Soc. Can., Ser. III, Vol. X, Sec. IV, 1916, pp. 97-104.

meter distally until it passes into the gonangium without any definite constriction. There is only one medusa-bud developed in the gonangium; its height from the base of the tentacles is approximately the same as its greatest width. Four radial canals and four tentacle bulbs, each giving rise to a tentacle, are already present.

PLUMULARIA LAGENIFERA Allman

Plate II, fig. 9

Colonies of this species are not uncommon in the Vancouver Island region but during the past summer one was picked up by the plankton net, with some unusual features that are interesting because they are similar to those observed in an entirely different species, *Obelia geniculata*, collected under somewhat similar conditions off the coast of Massachusetts.[1]

Normally the colonies are very regular, the hydrocladia are simple and regularly alternate; the internodes are definitely arranged and the nematophores are definitely placed.[2] In this colony the main internodes vary in length and while some of them have the single nematophore besides the two in the axil, several have two; in one instance two hydrocladia come off in succession from the same side instead of regularly alternating. In the hydrocladia there is much greater variation. In all cases there is a short non-hydrothecate internode followed by a longer hydrothecate internode as in the normal colonies, but there the similarity ceases in every hydrocladium but the basal one on the one side, in which the second pair of internodes is also normal. Elsewhere, the remaining internodes with the exception of the terminal one, more nearly resemble the stem internodes except that they are longer and more slender, each with from 1 to 3 nematophores besides those in the axil, and each giving off a secondary hydrocladium. The arrangement is very irregular, however, as there may be two or three given off in succession on the same side. The terminal internode is of the frustule type, such as is often found late in the season in such forms as *Obelia longissima*, *Campanularia angulata*, etc., a condition supposed by Kramp and others to be due to a lack of nourishment. On this internode there are one or two nematophores. The secondary hydrocladia have the two internodes at the base similarly to those of the primary hydrocladia, with a terminal internode similar to the primary terminal, with or without an intermediate internode.

The colony was obtained at or near the surface near Berry point, which is the northeast point of Gabriola Island, in an area where much of the time there are cross currents and eddies. In all probability these would bring a supply of food to the hydroids, but there may not have been enough for normal development of the colony which, in any case, was fully alive when the collection was made, with the hydranths in good condition.

The relative scarcity of the hydranths, the attenuation and irregularity of growth of the hydrocladia and the formation of terminal frustules or tendrils, may be an indication of starvation. These were the abnormal characteristics of the specimens of *Obelia geniculata*, found floating off the Massachusetts

---

[1] Bull. Mus. Comp. Zool. Harvard, Vol. LIX, No. 4, 1915, pp. 311-314.

[2] Hydroids of the Vancouver island region, 1914, p. 207.

coast, to which reference has been made above. In *Obelia* the gonangia were irregularly arranged as well but there were no gonangia on the Plumularian colony.

HYDRA VIRIDIS Linn

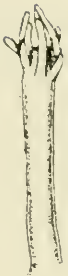
Although it is quite probable that *Hydra* is to be found throughout the province of British Columbia there does not seem to be any record of its occurrence. On May 25, 1919, some fine specimens of *Hydra viridis* were obtained in a small pool near the top of the hill immediately southwest of Hammond Bay and about a mile from the Biological station. Since that time others have been found in the same pool and in pools at other points in the vicinity of the station.

HYDRA VULGARIS Pallas?

While looking over some material collected from a stream about half a mile from the Biological station on September 8, 1921, Mrs. C. H. O'Donoghue observed a gray *Hydra*. Other material from the same locality was examined but no other specimens were obtained. It was smaller than the usual size of *Hydra vulgaris* and had only six tentacles. There was no indication of a spermary or ovary.

On account of this immaturity it is not possible to be sure of the identity of the species but it probably belongs to the gray type of *Hydra vulgaris*. In any case it seems better to place it here until the examination of mature specimens makes it possible to settle the question.

PLATE I.



1

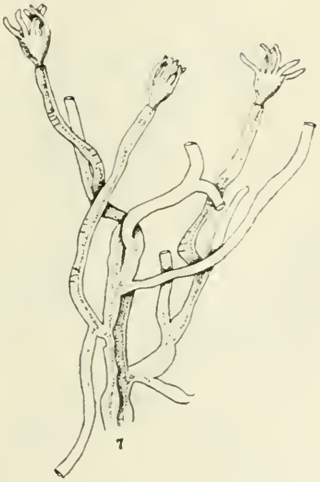
2

3

4

5

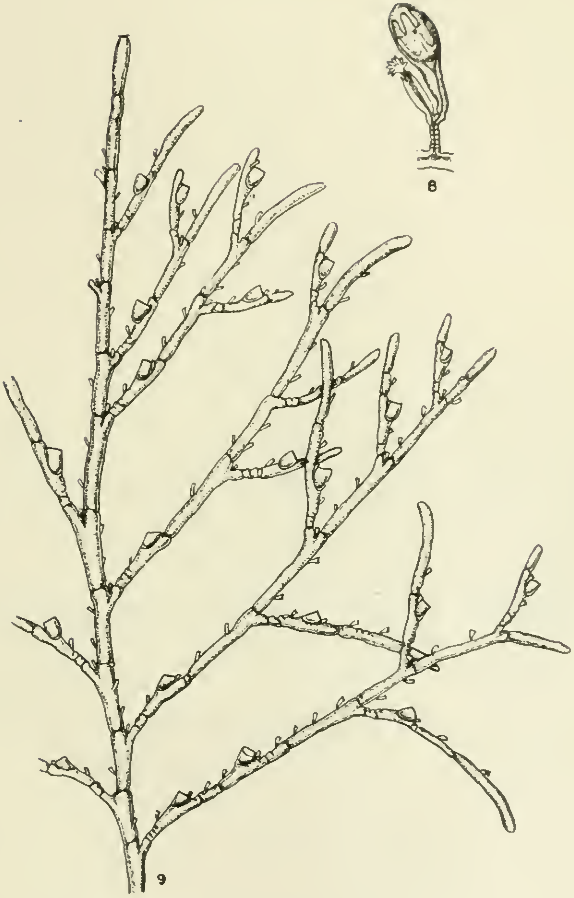
6



7

Figs. 1-6. *Hydractinia laevispina.*
1, 2. Nutritive zooids.
3. Generative zooid, male.
4. Generative zooid, female.
5. Tentaculozooid.
6. Spine.
Fig. 7. *Eudendrium irregulare.*
Portion of colony showing irregular habitus.
Magnification in each case 12 diameters.
Drawings by Clara A. Fraser.

PLATE II.


8

9

Fig. 8. *Campanulina forskalea.*
Colony showing medusa bud.
Fig. 9. *Plumularia lagenifera.*
Portion of colony showing unusual growth features.
Magnification in each case 12 diameters.
Drawings by Clara A. Fraser.

No. 8

THE CIRCULATION OF THE WATER IN THE BAY OF FUNDY

PART I

INTRODUCTION AND DRIFT BOTTLE EXPERIMENTS

BY

JAMES W. MAVOR

The Circulation of the Water in the Bay of Fundy

Part I

Introduction and Drift Bottle Experiments

By James W. Mavor

CONTENTS

1. INTRODUCTION

The object of the present series of investigations has been to determine what, if any, general movement of the water other than the tides occurs in the Bay of Fundy. The movement of sea-water made evident in the tides is always of the nature of an oscillation, whether it be the rise and fall seen on all shores, or the flow to and fro seen in tidal streams. Such an oscillatory movement does not produce a constant flow in one direction and does not lead to any continuous translation of the water. It may often be in fact that the flow and ebb of the tidal streams in a given region obscure a slower but continuous movement of the water in one direction not due to the tidal force. The importance of such continuous movements in any consideration of the life history of marine organisms is obvious; eggs, larvae or post-larval stages may be transported far from the place of breeding to waters either suited or unsuited to their survival.

2. PHYSICAL FEATURES OF THE BAY OF FUNDY

The Bay of Fundy extends in a north-easterly direction from the northern side of the Gulf of Maine and forms with the southern coast of Nova Scotia the northern boundary of the Gulf. The western boundary of the Gulf is formed by the coast of the United States from Canada to Cape Cod and the southern and eastern boundaries by Nantucket shoals, Georges Bank and Brown Bank, which reach to from 20 to 30 fathoms (36 to 55 meters) of the surface. The 50 fathom (91 meter) contour line enters the Gulf of Maine south of Nova Scotia, following the coast line at a distance of 20 to 30 miles. Entering the Bay of Fundy only 5 miles from the coast, and enclosing a large basin forming most of the lower half of the Bay, it leaves to the southeast of Grand Manan (see bathymetric chart, Plate I). From the Bay of Fundy this contour line follows at a distance seldom over 10 miles the coast of the United States and the outlines of the banks, leaving the Gulf some 60 miles to the south of where it entered. Between the 50 fathom contour line, as it enters and as it leaves the Gulf, is the Eastern Channel, the only deep passage between the Gulf and the Atlantic. The entrance to the Bay of Fundy is funnel-shaped, the narrow part of the funnel being placed between Grand Manan and Brier Island. All of the upper part of the Bay, that is the part above a line joining St. John and Digby, is under 50 fathoms in depth.

Opening into the lower part of the Bay of Fundy on its north-western side is Passamaquoddy Bay, a large enclosed bay averaging 15 to 20 fathoms (27 to 36 meters) in depth and communicating with the Bay of Fundy by two narrow and irregular channels, Head Harbour Passage and Letite Passage. On the south-eastern side of the mouth of the Bay of Fundy is St. Mary Bay, a long and narrow bay, widest where it opens into the Gulf of Maine and connected with the Bay of Fundy only by two narrow passages, Grand Passage and Petite Passage. The depth of St. Mary Bay gradually decreases from about 20 fathoms (36 meters) at its mouth to the shallow upper end. Passing farther up the Bay of Fundy on the north-western shore we find St. John Harbour, and across the Bay at about the same level Annapolis Basin with its narrow outlet, Digby Gut. At its upper end the Bay of Fundy divides into two arms. To the north-east is Chignecto Channel, a long bay extending to the north-east with a depth of about 20 fathoms, decreasing to 8 or 10 fathoms (15 to 18 meters) at its upper end. To the east is Minas Channel, connected by a narrow passage with Minas Basin. The depth of Minas Channel is 20 to 30 fathoms (36 to 55 meters), that of the Basin 10 to 5 fathoms (18 to 9 meters).

The north-western shore of the Bay of Fundy is somewhat shallower than the south-eastern. The shore line from St. John to Maine is strikingly irregular, as is also the corresponding shore of Grand Manan, a condition for which the prevailing south-west winds may be largely responsible.

The bottom of the Bay is covered with mud and sand, with rocks and gravel appearing in places (see chart, figure 1). Mud alone is found in the Chignecto

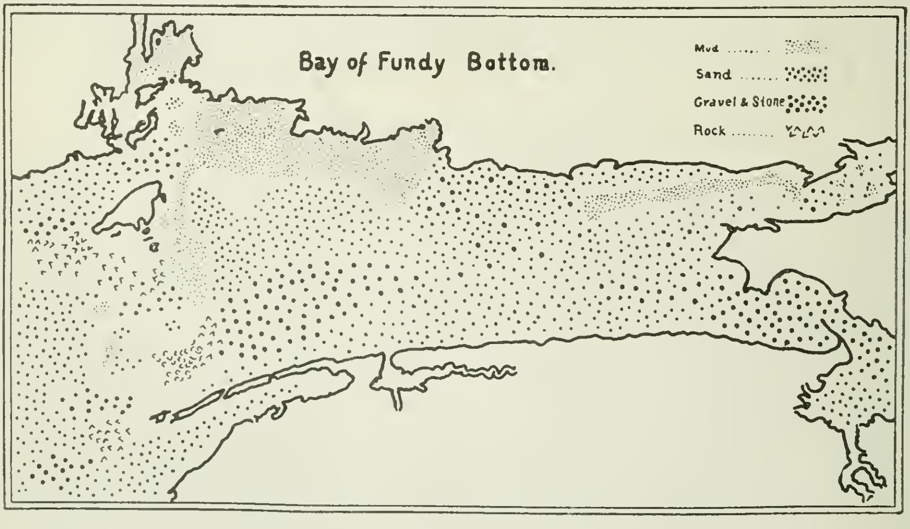


Fig. 1. Bottom deposits in the Bay of Fundy.

Channel, and on the north-west shore to Quaco Head, about half way to St. John and from St. John to near Passamaquoddy Bay and north and east of Grand Manan. The latter area of mud is of importance in the discussion of the flow of fresh water from the River St. John into the Bay.

Fresh water enters the Bay of Fundy from five important rivers: the St. Croix draining into Passamaquoddy Bay, the St. John opening directly on the north-west shore of the Bay, the Petitcodiac leading into Chignecto Channel, the Shubenacadie opening into the Basin of Minas, and the Annapolis draining into Annapolis Basin. The area drained is approximately 26,000 square miles. Considerably more than half of this area is drained by the St. John River (see chart of drainage areas, figure 2).

Fig. 2. River basins draining into the Bay of Fundy.

With these physical features in mind we are prepared to approach the problem of the movement of the water in the Bay.

3. METHODS OF INVESTIGATING CURRENTS

The problem of the general movement of any large body of sea-water may be approached by three quite different physical methods. The most direct method is to measure the actual movement of the water with a current meter. The observations must extend over at least one complete tidal period. The determinations are then treated so as to separate the general movement of the water from the tidal oscillation. Such measurements with current meters require the service of a large vessel anchored for days at a time; it is, therefore, rarely that simultaneous, or even approximately simultaneous, measurements can be made at different places. A second method is to record the drift of objects floating in the water. By comparing numerous records of this kind where the drift has occurred between different places and under different conditions of wind and tide a picture of the movement of the surface water can be obtained. The third method may be called the hydrodynamic method since it involves the calculation of the movement of the water from a determination of the position and contour of the surfaces of equal buoyancy in it, or, in other words, from the hydrodynamic forces which such surfaces can be shown to express. Since observations of temperature and salinity can be made with considerable rapidity, it being possible with the proper equipment to take a whole series from the surface to a depth of 100 fathoms (182 meters) in less than an hour, it is possible for a single vessel to make observations over a large area which are practically simultaneous, so far as the comparatively slow changes in the sea are concerned. All three of these methods have been applied to the Bay of Fundy, and there is a striking agreement with regard to the general movement of the water as determined by the three different methods.

4. MEASUREMENTS WITH CURRENT METERS

During the summers of 1904 and 1907 W. Bell Dawson made an extensive series of accurate observations on the tidal currents in the Bay of Fundy, using the surveying steamer *Gulnare* and anchoring at 19 different stations in the Bay and its approaches. Current meters working at a depth of 3 fathoms, or slightly under 5 meters, were used and records of the direction and velocity of the current were taken half hourly throughout the period spent at each station, which varied from two days to one week. The results of these observations are published in "Tables of Hourly Direction and Velocity of Currents and Time of Slack Water in the Bay of Fundy and its Approaches." The actual velocities found at the different stations are reduced in the tables to mean velocities for each hour, the mean being the average for the lunar period calculated from the recorded observations by comparing the range of tide at each station with the range of tide at St. John, N.B. Observations with the current meter were made also at greater depths since Dr. Dawson states: "Almost everywhere the current is as strong down to a depth of 30 fathoms as it is at the surface, and at most places it turns in direction on the surface and below at practically the same time. This has an important bearing on wind disturbance, as it shows that the current will soon regain its normal direction and strength after a storm moderates." From a consideration of the direction and velocity of the water determined at the different stations, Dawson concludes: "There is no general movement of the water in any one direction in this region which is at all well marked, nor did the temperature of the water give any definite indication of this."

As it is planned to submit Dawson's tables to a simple dynamic treatment one of these tables is here reproduced.

Let us imagine a drop of water moving with the current at the depth, velocity and direction stated in this table, and construct a diagram of the path which it would take. Such a diagram is shown in figure 3 on a scale of ½ inch to the nautical mile. Starting just after high water at the point *a* in the diagram, we find from the table the average velocity of 0.60 nautical miles per hour in a

TABLE I

Station A from Dawson's Tables.
Station A. 13½ miles S 26°W from Cape Spencer Light. Depth, 55 fathoms.

No. of line in figure representing Velocities[1]	Tide at St. John N.B.	Direction and Velocity of Current	No. of line in figure representing velocities[1]	Tide at St. John N.B.	Direction and Velocity of Current
..	At H.W.	NE bN 0.76		......	...
1	1 h. after	N b W 0.60	7	5 h. before	N b E 0.64
2	2 h. "	W b N 0.97	8	4 h. "	E N E 1.39
3	3 h. "	W 1.42	9	3 h. "	E N E 1.69
4	4 h. "	W 1.60	10	2 h. "	E N E 1.61
5	5 h. "	W 1.05	11	1 h. "	NE b N 1.29
6	6 h. "	W 1.10			

Time.—The state of the current is here referred to the time of High Water at St. John, N.B., to be found in the Tide Tables published by the Survey.

Direction and Velocity.—The directions indicate the point towards which the current sets. They are magnetic throughout, the average variation in these regions being 18°W. The velocities are in knots, tenths and hundredths. They correspond with the average range of 21 feet at St. John, and will be stronger or weaker as the range varies from springs to neaps.

direction north by west. The line marked *1* will represent in magnitude and direction this velocity. Since the velocities and directions given in the table are the averages of half hourly determinations made during a number of different tidal periods, we may assume that to a first approximation the drop of water moves with a uniform velocity equal to that of the table and in the direction given. At the end of the first hour it will then have arrived at the end of the line marked *1*, and will have approximately followed the course of that line. In the same way we draw the line marked *2* to represent the course which the drop takes during the second hour. Similarly for the lines *3* to *11* and *H. W.* In this way we have traced the movement of the drop to the point *b*. Only twelve hours have been represented, the extra 25 minutes in the tidal interval would be represented by a very short line between west and north when the current is turning 6 hours after high water. It is thus seen that the drop of water, instead of returning to the point *a* which it would have done if it moved only in the equal oscillations of the tidal stream, has been moved to the point *b*. The result of this movement is the same as if the drop had moved in the direction of the straight line *ab* for a distance equal to *ab*. The line *ab* may, therefore, be said to represent in magnitude and direction a resultant velocity which, in this case, is 5.10 nautical miles per tidal period of approximately 12½ hours. This is the same as a velocity of 0.41 knots and is in the direction N ½ W. In this discussion we have started with the drop of water at the end of high water, and followed it till the next high water, but it is easily seen that the same resultant velocity in the same direction would have been obtained had we started with the drop at any other time and followed it through a complete tidal period since a line joining, for example, the ends of the lines marked *3* in the diagram would be equal in length and parallel to the line *ab*. This method of treating the

---

[1] These two columns are inserted by the writer and refer to his figure 3.

velocities and directions given for Station A in Bell Dawson's "Tables of hourly direction and velocity of the currents and time of slack water in the Bay of Fundy and its approaches" has, therefore, shown that there is a general movement of the water in the Bay at this point in a direction toward one half point West of North at a rate of 0.4 knots.

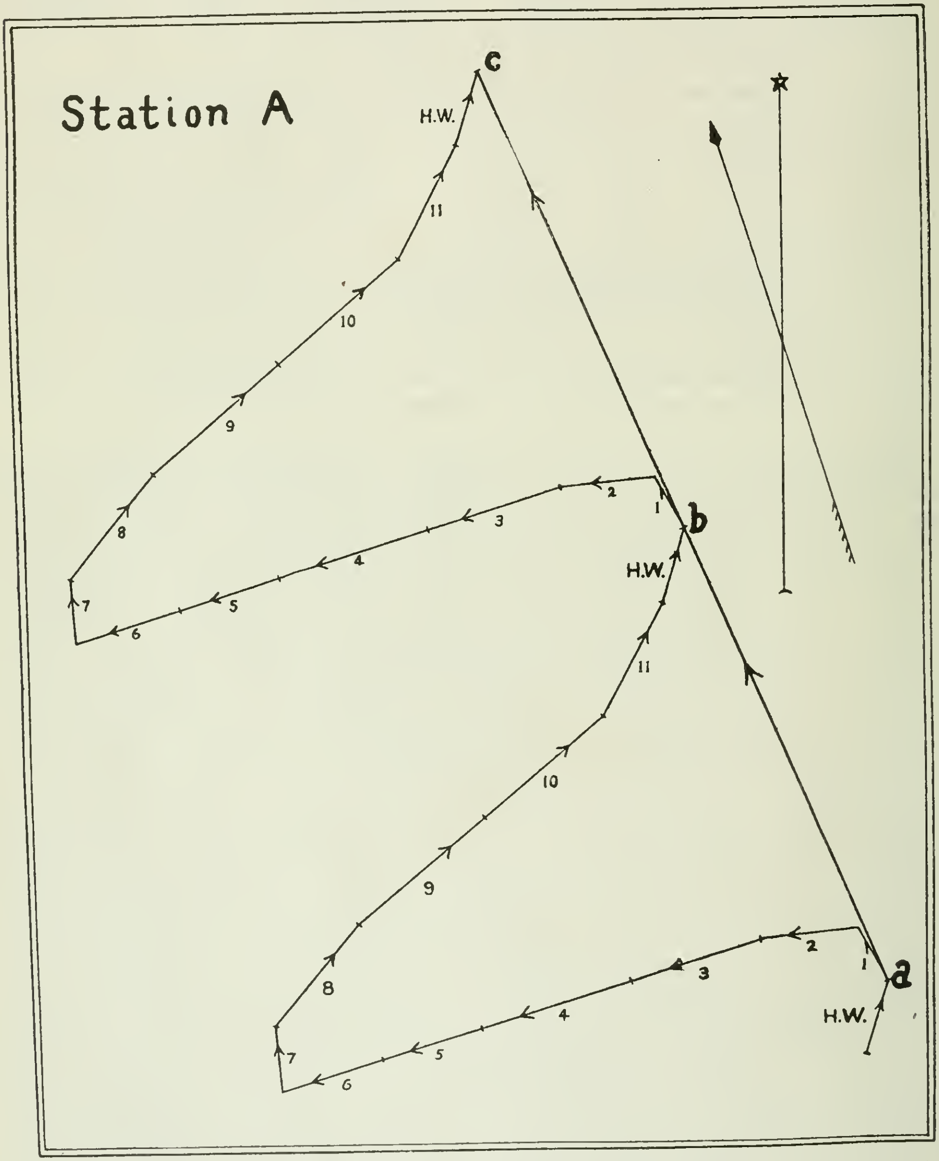


Fig. 3. Method of calculating resultant velocities from Dawson's current measurements.

When this method is applied to the figures for the other stations in the tables similar resultant velocities are obtained for these stations. The graphical constructions for the other stations in Dawson's tables are shown on a reduced scale in Plates II and III, and the positions of the stations are on the chart in Plate IV. At stations *A* and *B*, which are well within the Bay, the general movement is across that of the tidal stream. Here, as might be expected, the direction as recorded by the current meter at the time of the turn of the tidal stream (Station *A*, *H.W.*, *1* and *7*; Station *B*, *H.W.*, *1* and *11*) is not far from that of the general movement. In Table II are given the directions and velocities of the resultant movement of the water for stations *A* to *M*. The velocities and directions given in this table are shown graphically in the chart (Plate IV) where the arrows at the different stations show the direction of the resultant or general velocity and are drawn of such a length that they represent to the scale of the chart the distance which the general movement of the water carries it in two tidal periods, or approximately one day.

TABLE II

Resultant Velocities determined by the method of graphic summation from Bell Dawson's "Table of hourly direction and velocity of the currents and time of slack water in the Bay of Fundy and its approaches."

Station (see Chart, Plate IV)	Velocity in nautical miles per tidal period	Velocity in knots	Direction referred to Magnetic North
A	5.10	0.41	N ½ W
B	3.88	0.31	N b E
C	2.34	0.19	E b S
D	3.35	0.27	N E
E	6.53	0.52	W S W
F	4.72	0.38	N E b N
G	1.04	0.08	N
H	1.62	0.13	N N E
J	1.98	0.16	E S E
K	4.46	0.36	E N E
L	3.75	0.30	N N W
M	3.77	0.30	E N E

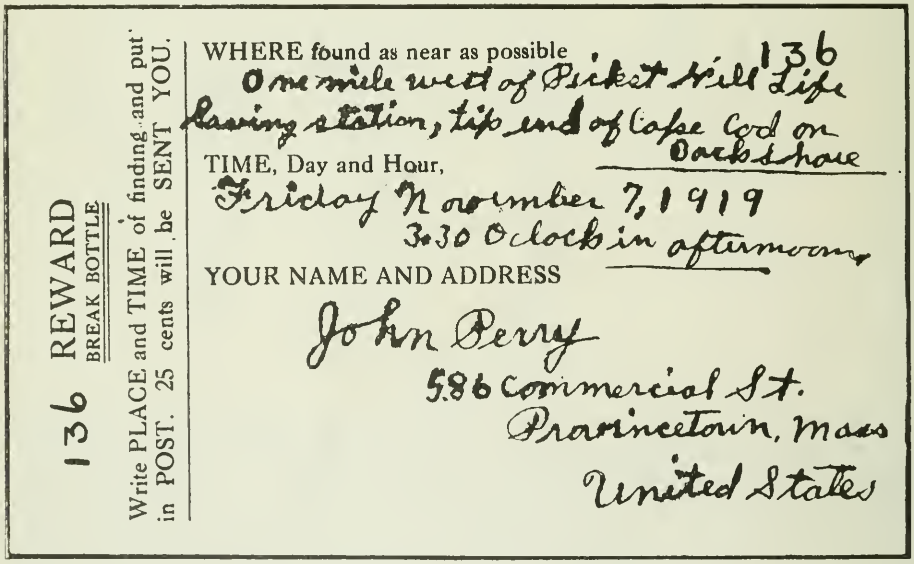
Although not made in the Bay of Fundy but at the entrance to the Gulf of Maine certain measurements made by Bigelow ('17, p. 203) on July 27 to 28 in 1914 are of interest for comparison with Bell Dawson's. He worked at the same depth (3 fathoms), but used an Ekman current-meter, while Dawson used an electric current meter. Bigelow's station is not far from Dawson's station *T*. He found that "the general movement of water for the whole tide was about four miles toward the south-west." A direct comparison of this with Dawson's figures for station *T* is not possible, as he found the direction too variable to record, but Bigelow's determination agrees in direction and rate with the general movement as determined at Dawson's other stations.

The conclusion to be drawn from these observations and calculations is that there is a general movement of the water in the Bay of Fundy which may be described as follows: Water from the North Atlantic enters the Gulf of Maine on the north, passes round the southern end of Nova Scotia and into the Bay on its eastern side. The water then moves along the Nova Scotia coast, crosses the Bay from the Nova Scotia to the New Brunswick side and flows out of the Bay to the east of Grand Manan. In the Grand Manan Channel there is a movement inward.

5. DRIFT-BOTTLES

A. Bottles picked up in the Bay of Fundy.

During the summer of 1919 three hundred and ninety-six drift-bottles were set out by the staff of the Atlantic Biological Station of the Biological Board of Canada in the Bay of Fundy. These bottles were put out in sets and spaced on lines crossing the Bay. Two types of drift-bottle were used; one kind consisted of simply a bottle with either a rubber or a paraffined cork stopper; the other, designed to be less affected by the wind and the wind-driven water at the surface, had attached to it to hang usually at a depth of 3 fathoms (5.5 meters), a drag made from a square of galvanized iron 5 inches on a side cut into at the middle of two opposite sides, and bent so as to oppose about a half of its surface to any lateral movement. These drags were hung by 3 pound cod line (about 1.5 mm. in diameter) and the line was tied to the bottles so that they floated with the neck out of the water.



136 REWARD
BREAK BOTTLE

Write PLACE and TIME of finding and put in POST. 25 cents will be SENT YOU.

WHERE found as near as possible 136
One mile west of Picket Hill Life Saving station, tip end of Cape Cod on Back shore

TIME, Day and Hour,
Friday November 7, 1919
3.30 Oclock in afternoon

YOUR NAME AND ADDRESS
John Perry
586 Commercial St.
Provincetown, Mass
United States

Fig. 4. Post card from drift bottle number 136.

Each of these bottles contained rolled up inside of it an ordinary post card (Figure 4) on which was printed on one side the address of the Biological Station and on the other side the offer of a small reward (twenty-five cents) which would be sent to the finder who wrote in the spaces provided on the card, the answers to the three questions: "Where found? When found? By whom found?" and returned it.

The station cruiser, *Prince*, crossed the lower part of the Bay of Fundy during the summer and the bottles were thrown overboard from her, being spaced in some cases a mile and in other cases half a mile apart. When the experiment was started it was thought that very few of the post cards would ever be seen again. As a matter of fact seventy-three out of the three hundred and ninety-six cards set out had been found and returned through the post by December 1, 1919. The post mark gives a very convenient way of verifying the statements on the cards regarding the time and place of finding, for in all cases the cards seem to have been posted near where they are said to have been found. Almost all the bottles were found on the sea shore where they had been left by the tide, although some were picked up at sea. The finders were mostly fisher folk, lighthouse keepers, coast guardsmen and others, whose callings make them keen observers of the sea and the sea shore. The accuracy with which these people have answered the questions is quite noticeable. Many of them have asked about the experiment and where the bottle was sent adrift. One card found during a north-east storm on Cape Cod has this note attached: "Never mind the 25 cents, but send details of your experiment which has to do, I judge, with ocean currents."

The first set consisted of ten 8 oz. bottles with rubber corks and having attached to them by a cod line a galvanized iron drag to hang at a depth of 3 fathoms. They were spaced in a line between Flag Cove, Grand Manan and Petite Passage, Nova Scotia, on June 18. Two of these cards have been returned.[1]

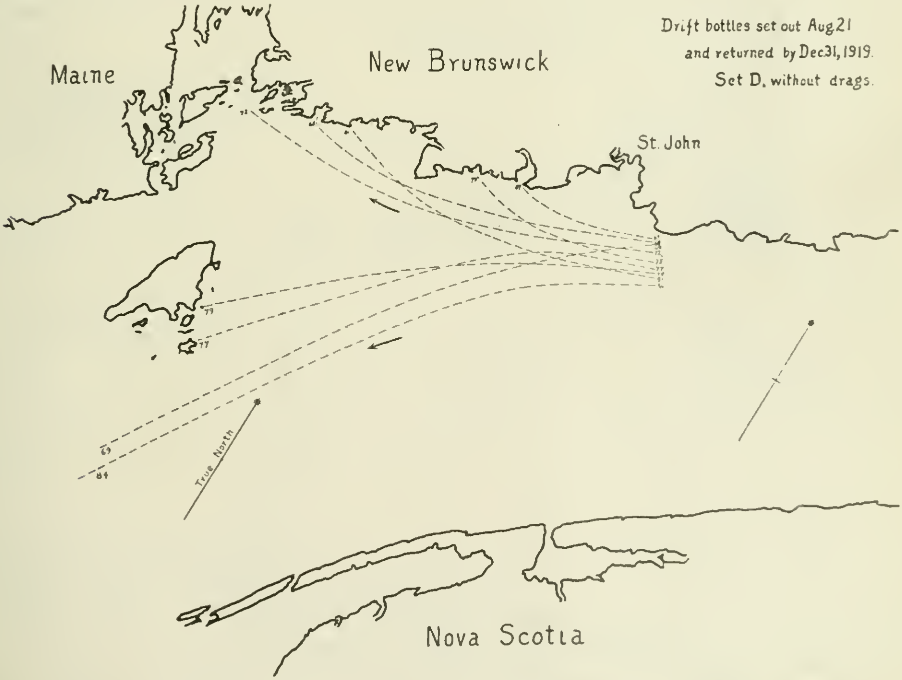


Fig. 5. Drift bottles of set D. Chart showing where bottles set out on the northwestern side of the Bay of Fundy were found.

---

[1] The present description refers only to drift bottles post cards from which were received by December 31, 1919.

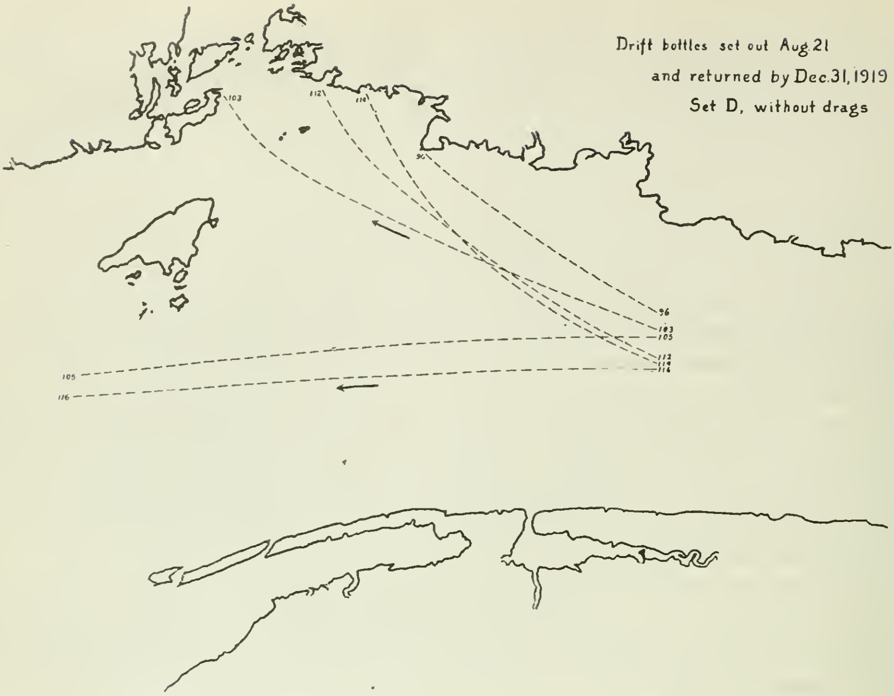


Fig. 6. Drift bottles of set D. Chart showing where bottles set out in the middle of the Bay of Fundy were found.

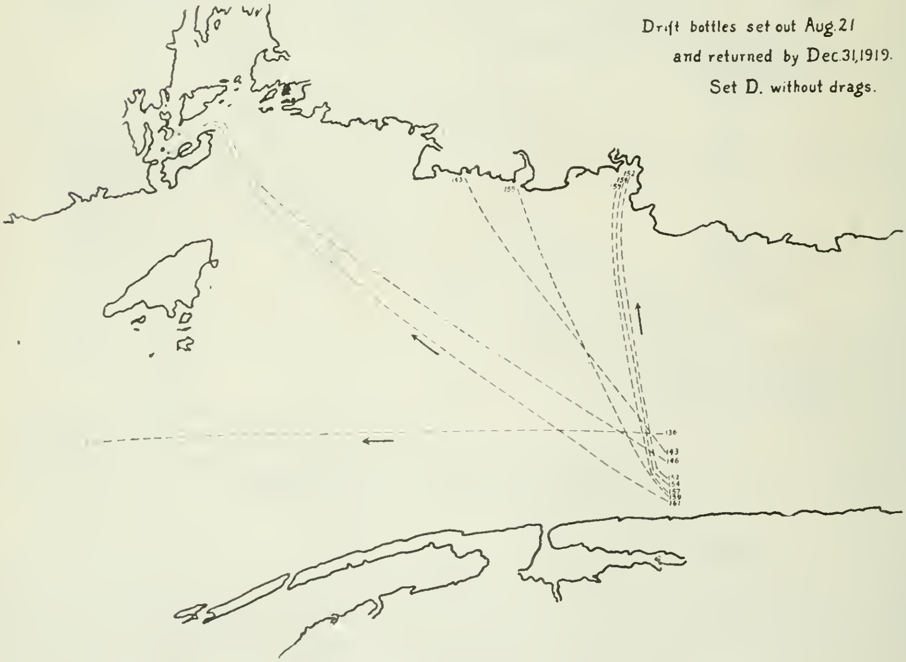


Fig. 7. Drift bottles of Set D. Chart showing where bottles set out on the southeastern side of the Bay of Fundy were found.

Both were found on the coast of Maine (Figure 14). The next set from which returns were received, Set D, consisted of 100 2 oz bottles with paraffined cork stoppers and without drags. They were spaced evenly between Cape Spencer and Parker's Cove on August 21. Of these twenty were found within the Bay, all on the coast of New Brunswick west of Cape Spencer, those set out on the Nova Scotia side tending to come across the Bay. Figures 5, 6 and 7 show the positions where these bottles were set out and found. The interrupted lines in the figures are drawn merely to join the place of finding with that of setting out, and are not intended to show a course which the bottle may have taken. Five out of the eight bottles represented were returned by September 4 or within two weeks. The prevailing and strongest winds during the latter part of August as determined by the Meteorological Station at Pt. Lepreaux were south to south-east; the maximum velocity was 33 miles per hour and occurred before the bottles were put out. Thus the wind could not have been responsible for the drift of the bottles westward. Three of these bottles were found so soon after they were set out that their rate of travel is significant as establishing a minimum rate for the current in which they were carried. Bottle 67, which was set out near Cape Spencer on August 21, was found three days later in Musquash Harbour, a distance of about 15 nautical miles per day. Bottle 75, which was set out at about the same time and further from shore, was found four days and six hours later at a distance of about 20 nautical miles, giving a rate of a little less than 5 nautical miles per day. Bottle 96, set out also on the same day about a third of the way across from Cape Spencer to Parker's Cove, was found six days later at Little Lepreaux, near Point Lepreaux, a distance of about 30 nautical miles, giving again a rate of about 5 nautical miles per day. Bottle 72, put out on the same day near Bottle 75, was found eleven days later in Letite Passage, a distance of about 46 nautical miles, giving a rate of about 4 nautical miles per day. The finding of these bottles, therefore, indicates the presence of a current running along the New Brunswick shore from east to west at a rate of at least 5 nautical miles per day. The places of finding of the rest of the bottles of set D are shown in the two charts, figures 6 and 7. Bottles set out on the Nova Scotia side of the Bay have all come across. Three from near Nova Scotia, Numbers 152, 154 and 157, were found in St. John Harbour on the same day by different people. They were found 8 days after being set out. The distance in a straight line from the place of setting out to that of finding is about 30 nautical miles. This gives about four nautical miles per day as a minimum rate for crossing the Bay. The south to south-east wind may have helped these bottles to cross the Bay.

Another set, H, of 50 bottles similar to those of the set just considered, were put out on September 13 by Dr. Philip Cox from the passenger steamer plying from St. John to Digby. Twelve post cards from these bottles were received by December 31, 1919, nine from the New Brunswick coast west of St. John, one a few miles to the east, and two from the Nova Scotia coast (Figures 8 and 9). The drift of these bottles has, then, in the main repeated that of the previous set put out on a line slightly to the east of them.

Another set, G, consisting of 100 bottles of the same kind, 2 oz bottles without drags, were set out to the west of these on a line from Point Lepreaux, N.B.,

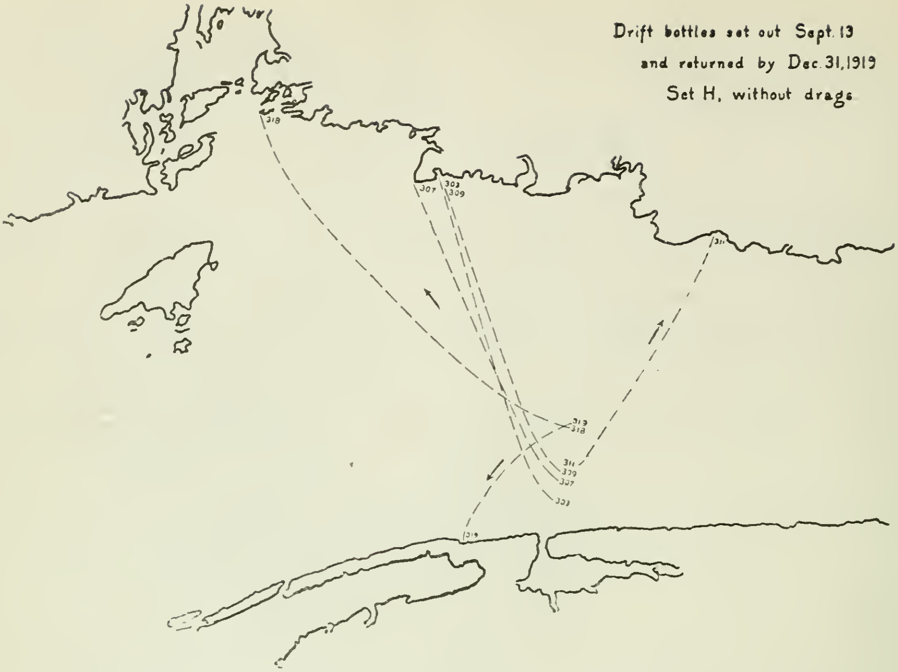


Fig. 8. Drift bottles of Set H. Chart showing where bottles set out on the southeastern side of the Bay of Fundy were found.

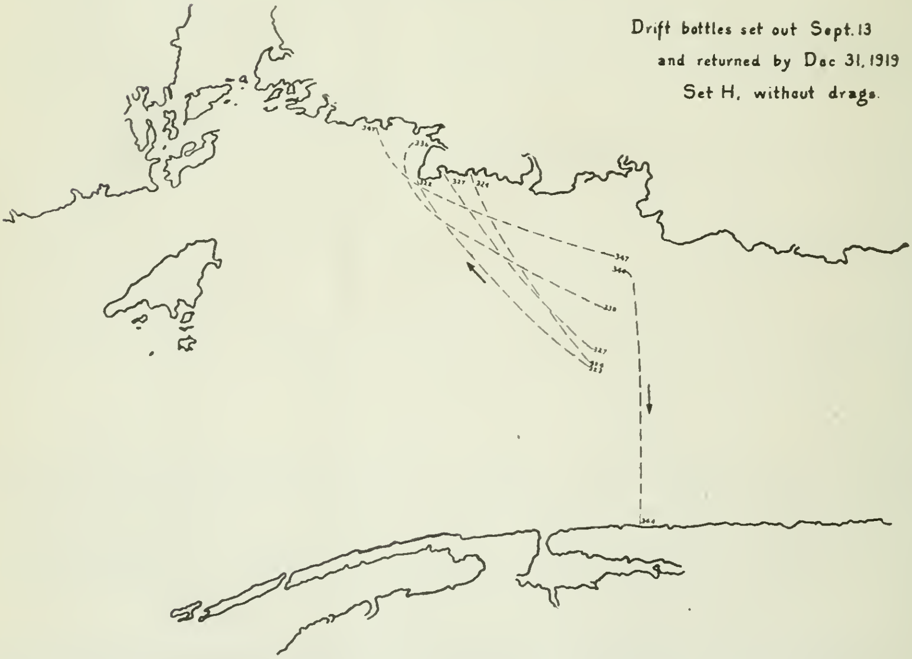


Fig. 9. Drift bottles of Set H. Chart showing where bottles set on the northwestern side of the Bay of Fundy were found.

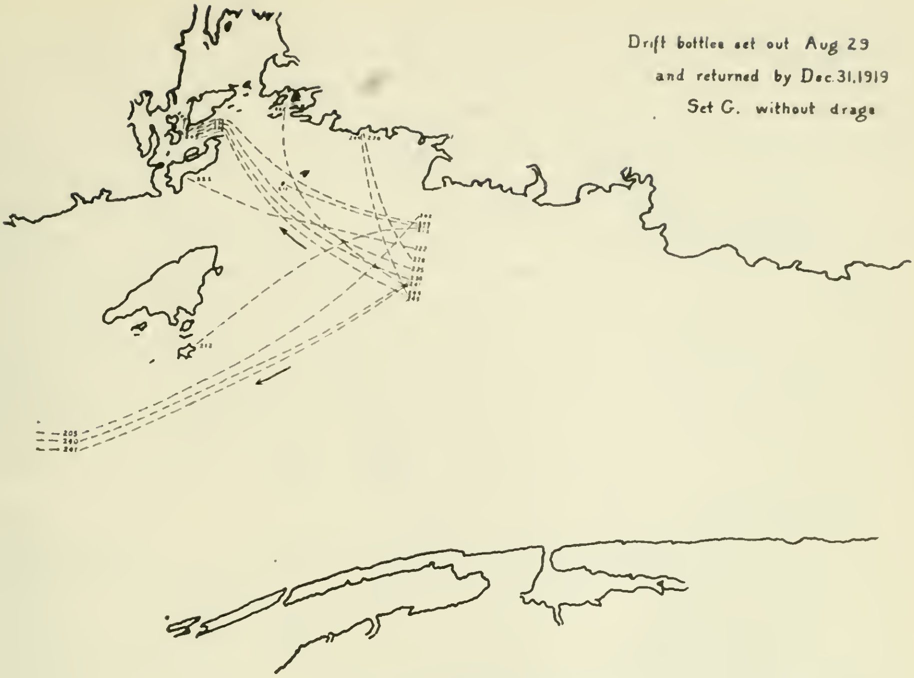


Fig. 10. Drift bottles of Set G. Chart showing where bottles set out on the northwestern side of the Bay of Fundy were found.

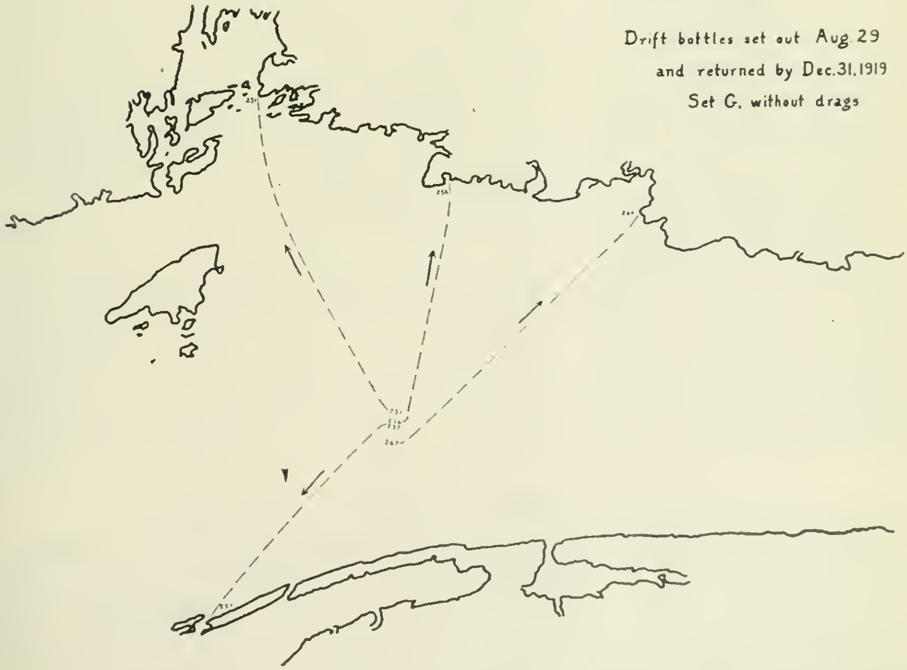


Fig. 11. Drift bottles of Set G. Chart showing where bottles set out in the middle of the Bay of Fundy were found.

to Petite Passage, N.S., on August 27. By the end of the year 27 post cards had been received from these. The drift of the bottles of this set (Figures 10, 11 and 12) also confirms the presence of a current westward along the New Brunswick shore, and indicates a current across the Bay. Four of the bottles, Numbers 251, 256, 257 and 267, shown in Figure 11, were set out close together about two-thirds of the way across from the New Brunswick to the Nova Scotia coast. They were picked up at widely separated points on both sides of the Bay, a considerable time after they were set out. This would seem to indicate that they were put out near the boundary between currents running in different directions. It is also noticeable that some of the bottles set out on the Nova Scotia side, Numbers 267, 281 and 293, were picked up to the north-east of Point Lepreaux, indicating that they may have drifted up the Bay on the Nova Scotia side before crossing. The fact that the bottles set out on the Nova Scotia side were found in the Bay on the average after a much longer time (25 to 93 days) indicates also that they may have taken a longer route going up on the Nova Scotia side and down on the New Brunswick side.

Set E consisted of bottles similar to those of set A with iron drags attached. They were set out on the same day and spaced evenly along the same line as set D. None of these have been reported from the Bay, but four were found in the Gulf of Maine (Figure 14), indicating that being less affected by the wind than the bottles without drags, they were carried out of the Bay by the westward current on the New Brunswick side.

Turning now to another series of 50 bottles, 25 small without drags, set J, and 25 large with drags, set I, which were set out on a line N.W. by N. from North Point, Brier Island, N.S., extending for 10 nautical miles, we find that five of these (Figure 13) had been reported from before the end of the year, and that they were all found on the Nova Scotia coast in the Bay of Fundy to the east of Brier Island, three of them reaching as far as Port George near the head of the Bay, a distance of 70 nautical miles. One of the bottles, 387, was found at Port George, only 17 days after it was set out, giving a minimum rate for the drift along the Nova Scotia shore of over 4 nautical miles per day.

From the drift of these bottles it seems clear that during the summer of 1919 there was a general movement of the water in the Bay of Fundy of the same general nature as that shown to be the case in 1904 and 1907 from Bell Dawson's tables. This movement is into the Bay along the Nova Scotia coast across the Bay, along the New Brunswick shore and out (Figure 15). The times of finding of certain of the drift-bottles show that the rate of this movement is probably not less than five nautical miles per day. This rate is not quite as great as that deduced from the current measurements, but is of the same order of magnitude.

B. Drift-Bottles Picked up in the Gulf of Maine.

All the drift-bottles which have been recorded from outside the Bay of Fundy were picked up in the Gulf of Maine.[1] Table III shows the number of bottles found outside of the Bay. Figure 14 shows the places of setting out and finding of the bottles of set A of June 18, and sets D and E of August 21. There seems no doubt that during the times these bottles were at sea there was a general drift of the water in the north-west part of the Gulf of

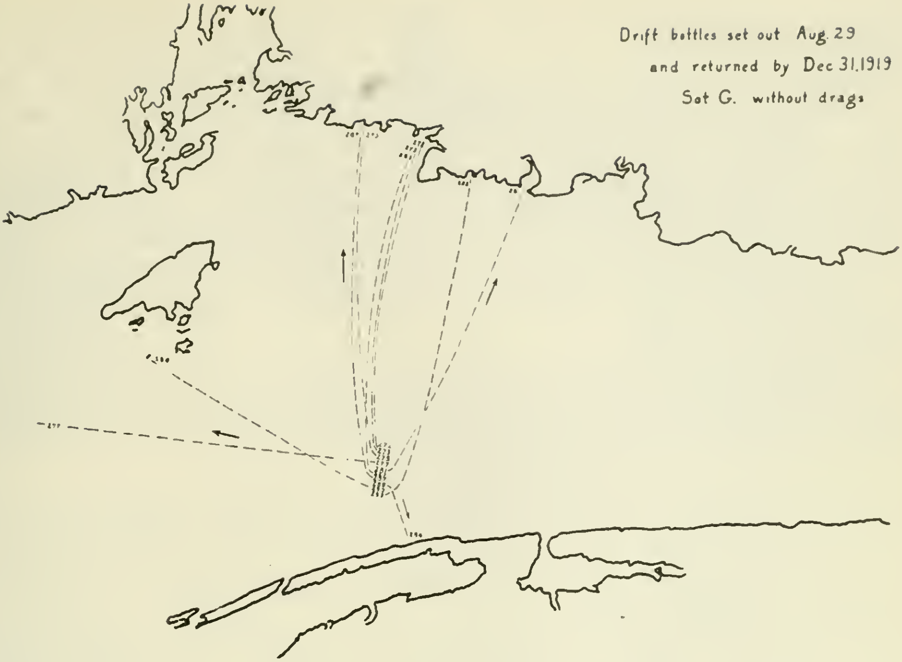


Fig. 12. Drift bottles of Set G. Chart showing where bottles set out on the southeastern side of the Bay of Fundy were found.

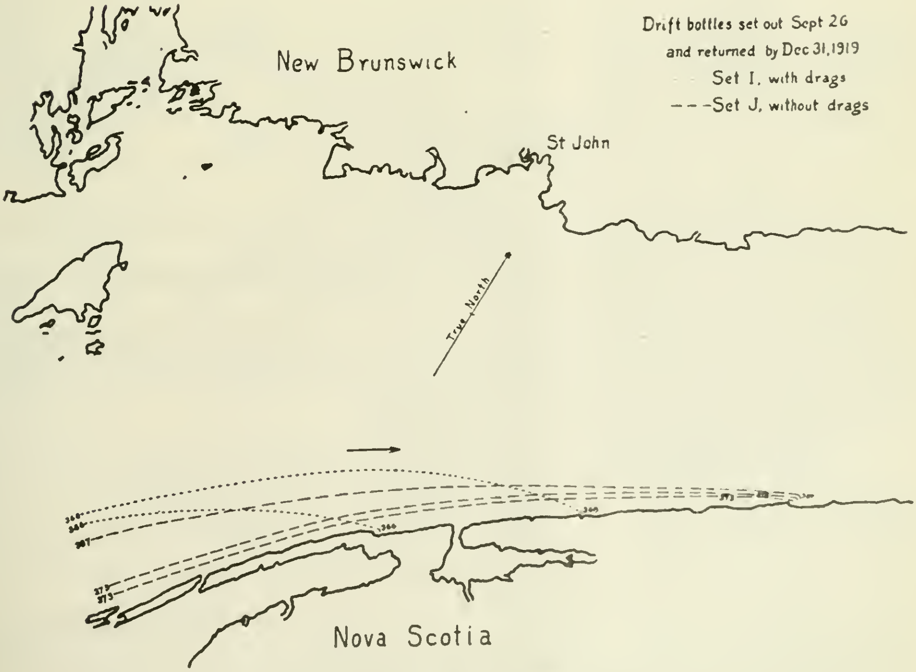


Fig. 13. Drift bottles of Sets I and J.

Maine in a south-westerly direction toward Cape Cod. A chart showing the distribution of the bottles of set G of August 29, which were found in the Gulf of Maine, would show the same general drift. Of the bottles with drags three were picked up on the Cape Cod peninsula, the other three on the coast of Maine. Of the bottles without drags eight were picked up on the Cape Cod peninsula and two on the coast of Maine. Here again the times of finding are significant. Seven out of the eleven bottles which went to Cape Cod or its vicinity were found between 70 and 80 days after being put out, the shortest time being 73 days. The distance in a straight line from the Bay of Fundy is about 300 nautical miles. The rate of the drift was, therefore, about four nautical miles per day.

The drift of these bottles, set out at various times during the summer indicates a surface movement of the water from the Bay of Fundy, through the north-western part of the Gulf of Maine and striking Cape Cod, the rate of this drift being about four nautical miles per day.

TABLE III

Drift bottles found and reported by Dec. 31, 1919, complete records.

	Set No.	Date set out	No. set out	Found in Bay		Found outside Bay		Total found	
				No.	%	No.	%	No.	%
With drags	A	June 18	10	0	0	2	20	2	20
	E	Aug. 21	20	0	0	4	20	4	20
	I	Sept. 26	25	2	8	0	0	2	8
Without drags	D	Aug. 21	100	19	19	5	5	23	23
	G	Aug. 24	100	23	23	4	4	27	27
	H	Sept. 13	50	12	24	0	0	12	24
	J	Sept. 26	25	3	12	0	0	3	12
	All sets[1]	......	330	59	18	15	5	73	22

TABLE IV

Drift bottles set out during 1919 and returned by the end of that year.

SET A. DRIFT BOTTLES NOS. 1-10

Put overboard on a line between *Flag Cove*, Grand Manan, and *Boar's Head*, Petite Passage, N.S., on June 18, 1919, by the *Prince*.

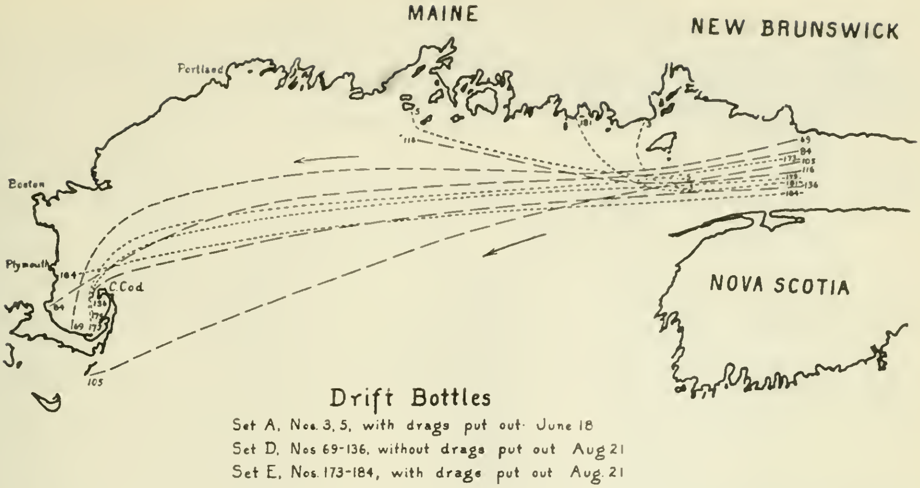
Eight oz. medicine bottles with rubber stoppers and zinc drags made by bending a galvanized iron square 5″ on a side and attaching it with 3 lb. cod line to hang at a depth of 3 fathoms. Bottles contained Canadian Post Cards with usual legend stamped with rubber stamp. Probably legend bleached out after one or two months in sunlight.

2 returned by Dec. 31, 1919.

Number on card	Distance from Flag Cove	Set out Aug. 21, 1919	Time found	No. of days out	Where found
3	14 mi.	8.53 a.m.	July 23, 7.30 a.m.	35	*Bailey's Mistake*, Me.
5	18 mi.	9.27 a.m.	Sept. 2, 2.00 p.m.	76	Penobscot Bay, ½ mi. S. of Heron Neck Light.

---

[1] Sets B, C and F from which no returns were received are omitted from this table.



Drift Bottles
Set A, Nos. 3, 5, with drags put out June 18
Set D, Nos 69-136, without drags put out Aug 21
Set E, Nos. 173-184, with drags put out Aug. 21

Fig. 14. Drift bottles. Chart showing where those found outside of the Bay of Fundy were found.

Fig. 15. Chart showing circulation of water in the Bay of Fundy as shown by drift bottle experiments.

SET D. DRIFT BOTTLES NOS. 66-165

Set out on a line between *Cape Spencer* and *Parker's Cove* on Aug. 21, 1919, by the *Prince*. Eight oz. flat-sided medicine bottles without drag, with rubber stoppers, containing Canadian Post Cards with usual legend printed.

23 returned by Dec. 31, 1919.

Number on card	Distance from Cape Spencer naut. mi.	Set out Aug. 21, 1919	Time found	No. of days out	Where found
67	1.3	9.38 a.m.	Aug. 24, 12.05 a.m.	3	*Musquash Harbour*, Near Narrows.
68	1.7	9.40½ a.m.	Sept. 9, 9.00 a.m.	19	*Beaver Harbour*, Eastern Wolfpool Cove.
69	2.	9.42½ a.m.	Dec. 6, 1.00 p.m.	107	*Scorton Beach*, East Sandwich, *Cape Cod*, Mass.
72	2.7	9.49 a.m.	Sept. 1, 2.30 p.m.	11	*Letite Passage*, 300 yds. below Green's Point.
75	3.5	9.55½ a.m.	Aug. 25, 3.45 p.m.	4	*Chance Harbour*, 100 yds. S. of Light house.
77	4.	10.00 a.m.	Oct. 5, 12.00 N.	45	*Grand Manan*, Gull Cove, White Head.
79	4.5	10.04 a.m.	Sept. 9, 4. 30 p.m.	19	*Grand Manan*, Nantucket I.
81	5.	10.08½ a.m.	Sept. 2, 9.00 a.m.	12	*Seeley's Head*, 2 mi. S. (at sea?)
34	5.7	10.15 a.m.	Nov. 8, 7.00 a.m.	79	*Cape Cod*, Mass., Sagamore Beach.
96	9.	11.03 a.m.	Aug. 28, 9.45 a.m.	7	*Little Lepreaux.*
103	10.7	11.18 a.m.	Sept. 11, 2.00 p.m.	21	*Campobello Island*, Head Harbour, "landed."
105	11.2	11.22½ a.m.	Nov. 2, 2.30 p.m.	73	*Chatham*, Mass. (on C. Cod), Monomoy Point.
112	12.7	11.37½ a.m.	Oct. 11, 2.00 p.m.	51	*Mace Bay*, Pocologan, Char. Co.
114	13.2	11.42 a.m.	Sept. 14, 4.00 p.m.	24	*Seeley's Basin*, on Beach.
116	13.7	12.09 p.m.	Oct. 10, 5.00 p.m.	50	*Penobscot Bay*, Wooden Ball Isl. Knox Co., Maine.
136	19.	12.53 p.m.	Nov. 7, 3.30 p.m.	78	*Cape Cod.* "Back shore," 1 mi. W. of Picket Hill Life-Saving Station.
143	20.7	1.31 p.m.	Sept. 11, 4.00 p.m.	21	*Chance Harbour*, Little Dipper Harbour.
146	21.6	1.37½ p.m.	Sept. 4, 12.45 p.m.	14	*Campobello Isl.*, Wilson's Beach.
152	23.2	1.50½ p.m.	Aug. 29, 8.30 a.m.	8	*St. John*, Red Head Beach.
154	23.7	1.56 p.m.	Aug. 29, 7.30 p.m.	8	*St. John*, Red Head Bank.
157	24.5	2.08 p.m.	Aug. 29, 11.00 a.m.	8	*St. John*, Red Head.
159	25.	2.16 p.m.	Aug. 29, 6.00 p.m.	8	*Musquash Harbour*, Frenchman's Creek.
161	25.6	2.24 p.m.	Sept. 12	22	Eastport, Me., Gondy's Point, in weir.

SET E. DRIFT BOTTLES NOS. 166-185

Set out on a line between *Cape Spencer* and *Parker's Cove* on Aug. 21, 1919, by the *Prince*.

Eight oz. medicine bottles with galvanized iron drag made by bending piece 5 inches square tied with 3 lb. cod line to hang 3 fathoms below bottle. Bottles contained Canadian Post Card with usual legend printed.

4 returned by Dec. 31, 1919.

Number on card	Distance from Cape Spencer	Set out Aug. 21, 1919	Time found	No. of days out	Where found
173	11 mi.	11.21 a.m.	Nov. 9, 3.30 p.m.	80	*Cape Cod.* South Wellfleet, Marconi Wireless Sta. on beach.
179	17 mi.	12.37 p.m.	Nov. 5, 2.05 p.m.	76	*Cape Cod.* Pamet River, Truro, Mass. 500 ft. N. of Watch House Station 37, U.S. Coast Guards.
181	19 mi.	12.54 p.m.	Sept. 22, 7.15 a.m.	32	*Jonesport,* Me. 300 yds. S.W. from Norton's Island, 100 yds. N. from Bush Ledge, West End.
184	22 mi.	1.40 p.m.	Nov. 9, 8.00 a.m.	80	*Plymouth,* Mass. White Horse Beach, after heavy storm.

SET G. DRIFT BOTTLES NOS. 198-297

Set out between *Point Lepreaux* and *Gulliver Hole* on Aug. 29, 1919, by the *Prince*.

Two oz. plankton bottles with paraffined corks, no drags, and containing Canadian Post Cards with usual legend printed.

28 returned by Dec. 31, 1919.

Number on card	Distance from Pt. Lepreaux, naut. mi.	Set out Aug. 29, 1919	Time found	No. of days out	Where found
205	2.4	11.10½ a.m.	Dec. 22, 9.30 a.m.	115	*Cape Cod,* Sagamore Highlands, Mass.
209	3.2	11.16½ a.m.	Sept. 14, 9.30 a.m.	16	*Deer Island,* Cumming's Cove Wharf.
211	3.6	11.19½ a.m.	Sept. 10,	12	*South Wolf Island.*
212	3.8	11.21 a.m.	Nov. 6? 2.00 p.m.	69	*Grand Manan,* North Pond Beach.
222	5.8	11.36 a.m.	Sept. 13, 3.00 p.m.	15	*Campobello Island,* Southern Head Herring Cove.
228	7.	11.45 a.m.	Sept. 28, 3.00 p.m.	30	Below *Seeley's Head.*
235	8.4	11.55½ a.m.	Sept. 20, 11.00 a.m.	22	Near *Deer Island,* Indian Cove, Indian Island.
238	9	12.00 N.	Sept. 5, 10.30 a.m.	7	Near *Deer Island,* Indian Island.
240	9.4	12.03 p.m.	Dec. 10, 9.30 a.m.	103	*Schoodic,* Maine.
241	9.6	12.04½ p.m.	Nov. 18, 2.00 p.m.	81	7½ mi. from *Provincetown Harbour* Beach at N. Truro.
242	9.8	12.06 p.m.	Oct. 20, 11.00 p.m.	52	*Letang River,* Char. Co.

SET G. DRIFT BOTTLES NOS. 198-297—*Cont.*

Number on card	Distance from Pt. Lepreaux naut. mi.	Set out Aug. 29, 1919	Time found	No. of days out	Where found
244	10.2	12.09 p.m.	Sept. 4, 4.00 p.m.	6	*Seeley's Basin*; Beach.
245	10.4	12.10½ p.m.	Sept. 10, 6.00 a.m.	12	*Eastport, Me.*, on beach below Dog Island Light.
251	22.6	1.54½ p.m.	Oct. 8, 9.00 a.m.	40	*Muscabin Point*, Letite Passage.
256	23.6	2 02 p.m.	Nov. 8, 10.30 a.m.	71	*Mace Bay*, 2 mi. N. by W. from Point Lepreaux.
257	23 8	2.03½ p.m.	Nov. 4, 3.00 p.m.	67	*Freeport*, Digby Co., N.S. Beautiful Cove.
267	25.8	2 18½ p.m.	Oct. 5, 11.00 a.m.	37	*Mispec*, 2 mi. north of Cape Spencer.
272	26.8	2.26 p.m.	Nov. 30, 11.00 a.m.	93	*Lepreaux Harbour.*
273	27	2.27½ p.m.	Oct. 8, 10.00 a.m.	40	*Lepreaux Harbour.*
275	27.4	2.30½ p.m.	Sept. 26, 10.00 a.m.	28	*Seeley's Cove.*
277	27 8	2.33½ p.m.	Dec. 2, 9.00 a.m.	95	*Cape Cod*, between Wood End Light and Race Point Light.
281	28.6	2.39½ p.m.	Sept. 23, 11.45 a.m.	25	*Little Musquash*, Maguire's Beach.
283	29	2.42½ p.m.	Dec. 10, 4.00 p.m.	103	*Lepreaux Harbour.*
287	29 8	2 48½ p.m.	Sept. 25, 6.00 p.m.	27	*Seeley's Cove.*
288	30	2 50 p.m.	Nov. 7, 11 00 a.m.	70	1 mi. N.E. of *Centreville*, Digby Co.
290	30.4	2.53 p.m.	Oct. 16, 10.00 a.m.	48	*Grand Manan*, Lower Green Island.
293	31	2.57½ p.m.	Sept. 29, 4.00 p.m.	31	*Dipper Harbour.*

SET II. DRIFT BOTTLES NOS. 298-347

Set out between *Digby* and *St. John* on Sept. 13, 1919, by Dr. Philip Cox on the passenger steamer running from Digby to St. John.

Two oz. plankton bottles with paraffined corks, and without drags, containing Canadian Post Cards with usual legend printed.

12 returned by Dec. 31, 1919.

Number on card	Distance from Whistle Buoy off Digby Gut, naut. mi.	Set out Sept. 13, 1919	Time found	No. of days out	Where found
303	2.4	3.08 p.m.	Oct. 11, 9.00 a.m.	28	*Dipper Harbour* East.
307	4.2	3.16 p.m.	Sept. 28, 9.00 a.m.	15	*Point Lepreaux*, Mace Bay, 2 mi. below Pt. Lepreaux, low water; shore.
309	5.2	3.20 p.m.	Sept. 22, 11 00 a.m.	9	*Dipper Harbour.*
311	6.1	3.24 p.m.	Oct. 5?, 3.00 p.m.	22	On *Black River* Beach, St. John Co.
318	9.4	3.38 p.m.	Oct. 10, 11.00 a.m.	27	*Bliss Harbour*, near Howard Island.
319	9.9	3.40 p.m.	Oct. 30, 1 00 a.m.	47	*Gulliver's Cove.*
323	15.7	4.05 p.m.	Sept. 22, 8.00 a.m.	9	*Pt. Lepreaux* Beach, 25 yds west of whistle house.
324	16.2	4.07 p.m.	Sept. 22, 9.00 a.m.	9	*Little Dipper Harbour*, Ledges.
327	17 6	4 13 p.m.	Oct. 8, 7.00 a.m.	25	*Dipper Harbour.*
336	21.8	4.31 p.m.	Sept. 28, 10.45 a.m.	15	*Little Lepreaux.*
344	25.6	4.47 p.m.	Oct. 31, 11.00 a.m.	48	*Litchfield Cove.*
347	27.1	4.53 p.m.	Sept. 27, 4.00 p.m.	14	*Red Head Cove*, Char. Co. (near Seely's Cove, N.W. Pt. Lepreaux).

SET I. DRIFT BOTTLES 347A-371

Set out on a line running N.W. by N. from *North Point of Brier Island* on Sept. 26, 1919, by the *Prince*.

Eight oz medicine bottles with galvanized iron drags made from strips 7″ x 3½″ and attached with cotton twine so as to hang at a depth of 5 meters.

2 returned by Dec. 31, 1919.

Number on card	Distance from Brier Island naut. mi.	Set out Sept. 26, 1919	Time found	No. of days out	Where found
366	8.8	5.58½ p.m.	Nov. 10, 5.00 p.m.	45	*Gulliver's Cove*, Digby Neck.
368	9.6	6.04½ p.m.	Oct. 18, 10.30 a.m.	22	*12 miles below Digby* on the Bay of Fundy shore.

SET J. DRIFT BOTTLES NOS. 372-396

Set out on a line running N.W. by N. from *North Point of Brier Island* on Sept. 26, 1919, by the *Prince*.

Two oz. plankton bottles without drags with corks paraffined, containing Canadian Post Cards with usual legend printed.

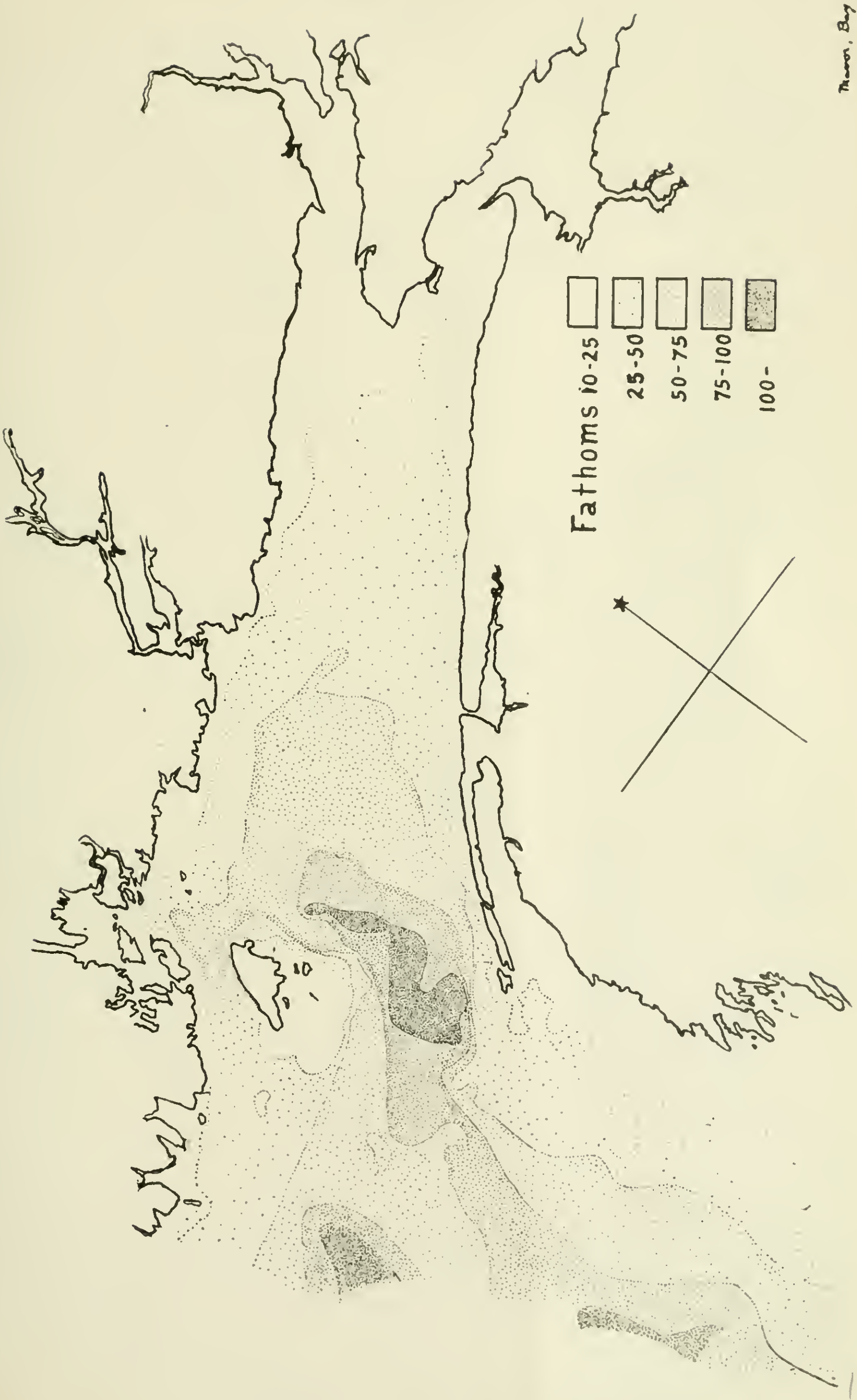
3 returned by Dec. 31, 1919.

Number on card	Distance from north. point of Brier Isl. naut. mi.	Set out Sept. 26, 1919	Time found	No. of days out	Where found
373	1	5.03 p.m.	Nov. 3, 10.00 a.m.	38	*Port George*, 35 mi. East of Digby Gut, Annapolis Co., N.S.
375	2	5.09 p.m.	Oct. 19, 5.00 p.m.	23	*Port George.*
387	7	5.45 p.m.	Oct. 13, 7.00 a.m.	17	*Port George.*

A bibliography will be published in the concluding part of this paper.

PLATE I.

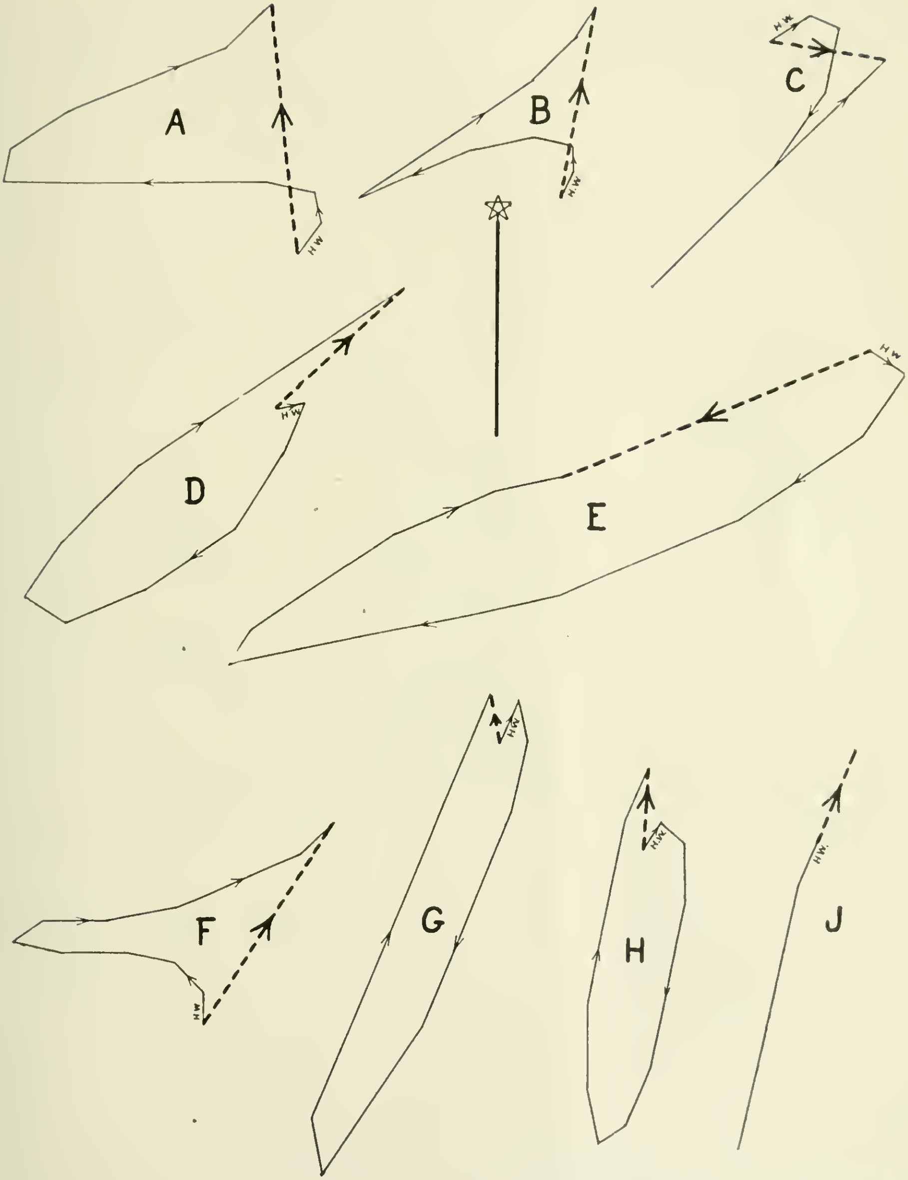
Mem., Bay of Fundy



124

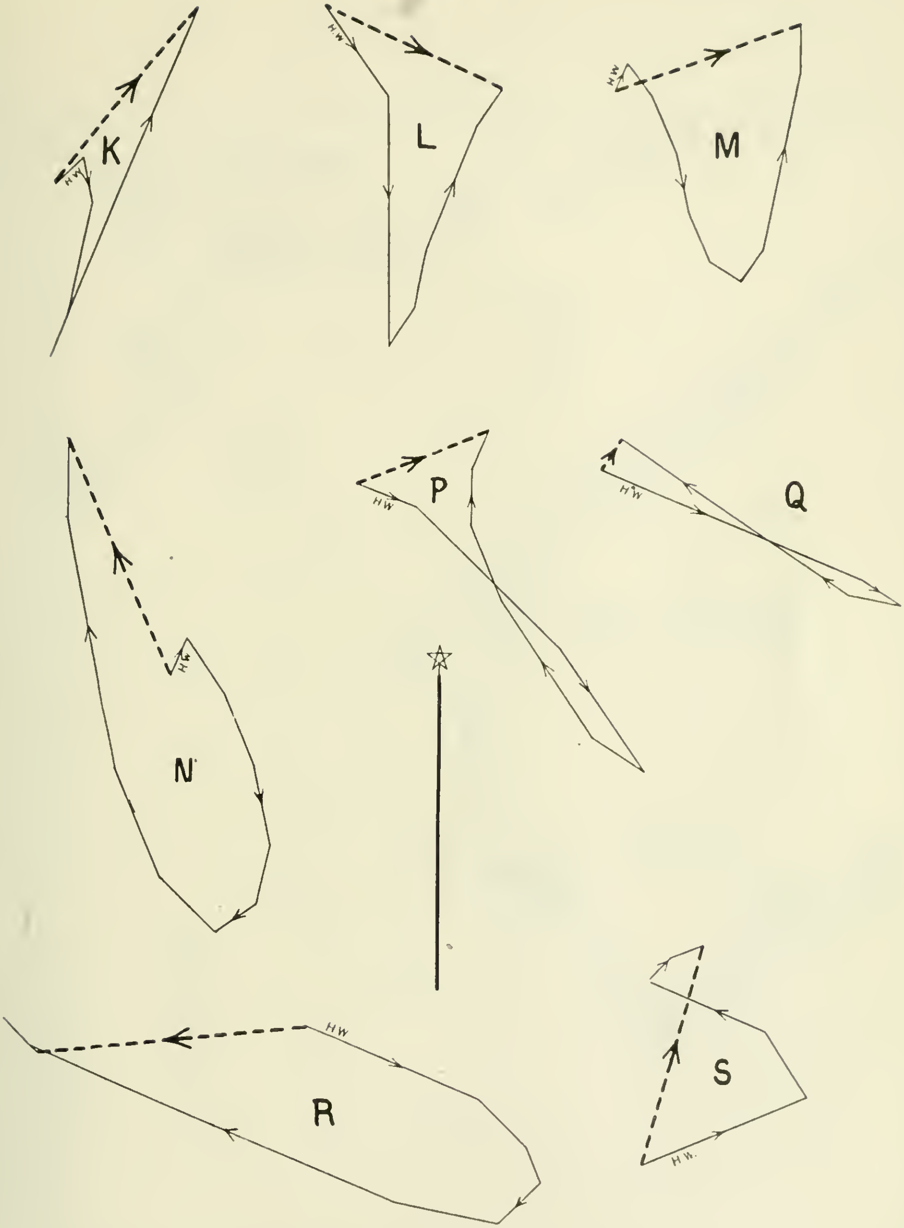
I. Bathymetric chart of the Bay of Fundy.

Plate II.



Velocity diagrams for Dawson's stations A-J.

PLATE III.



Velocity diagrams for Dawson's stations K-S

In making Plates II and III the average velocity at high water (*H.W.*) was plotted first and then the average velocity for each hour after that until the next high water. The resultant, general velocity, of the water is shown by the heavy dotted line. For the method of finding this see text-figure 3. All the diagrams are drawn to the same scale and oriented alike. The direction of true north is indicated on each plate.

Plate IV.

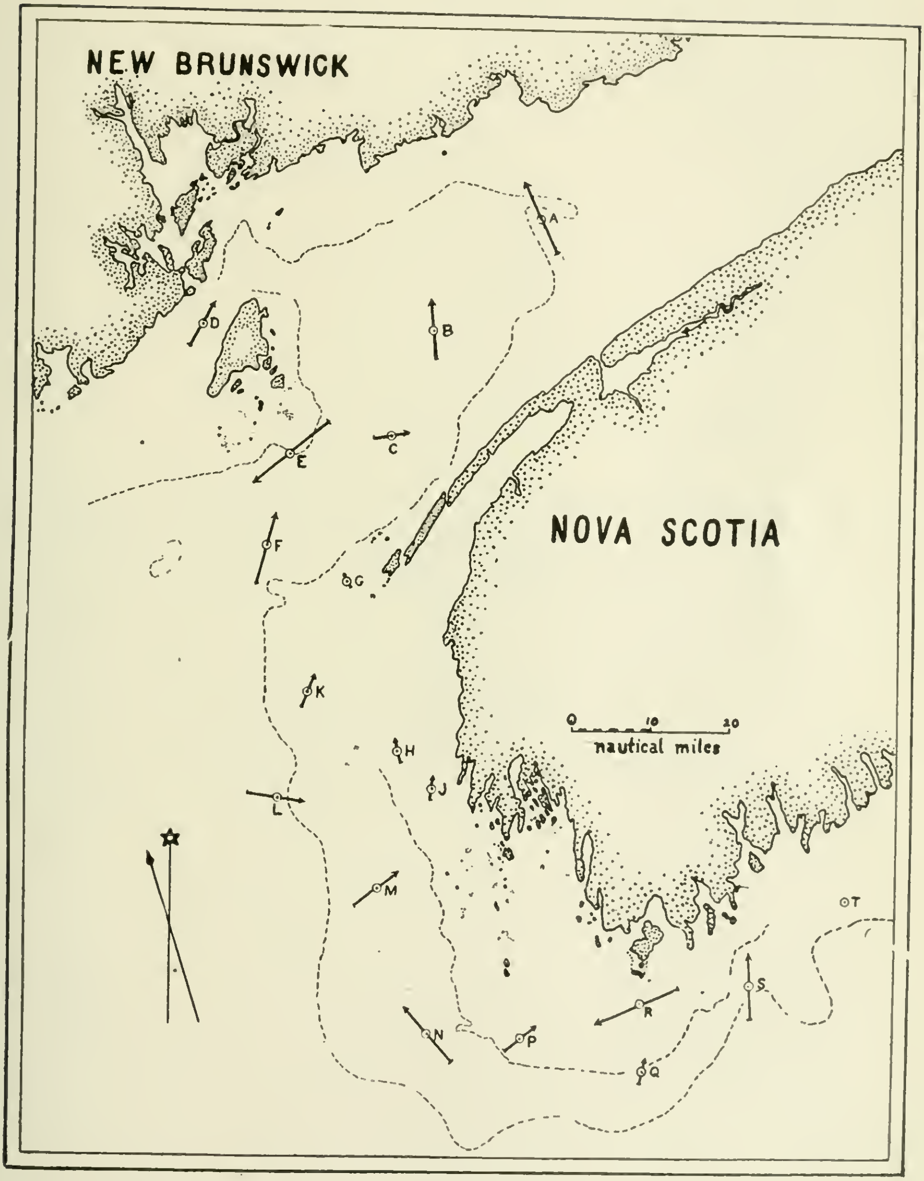


Chart showing resultant velocities at stations A-S as calculated from Dawson's tables.

154

No. 9

THE QUILL LAKES OF SASKATCHEWAN AND THEIR FISHERY POSSIBILITIES

BY

A. G. HUNTSMAN

Biologist to the Biological Board of Canada

The Quill Lakes of Saskatchewan and their Fishery Possibilities

By A. G. Huntsman

INTRODUCTION

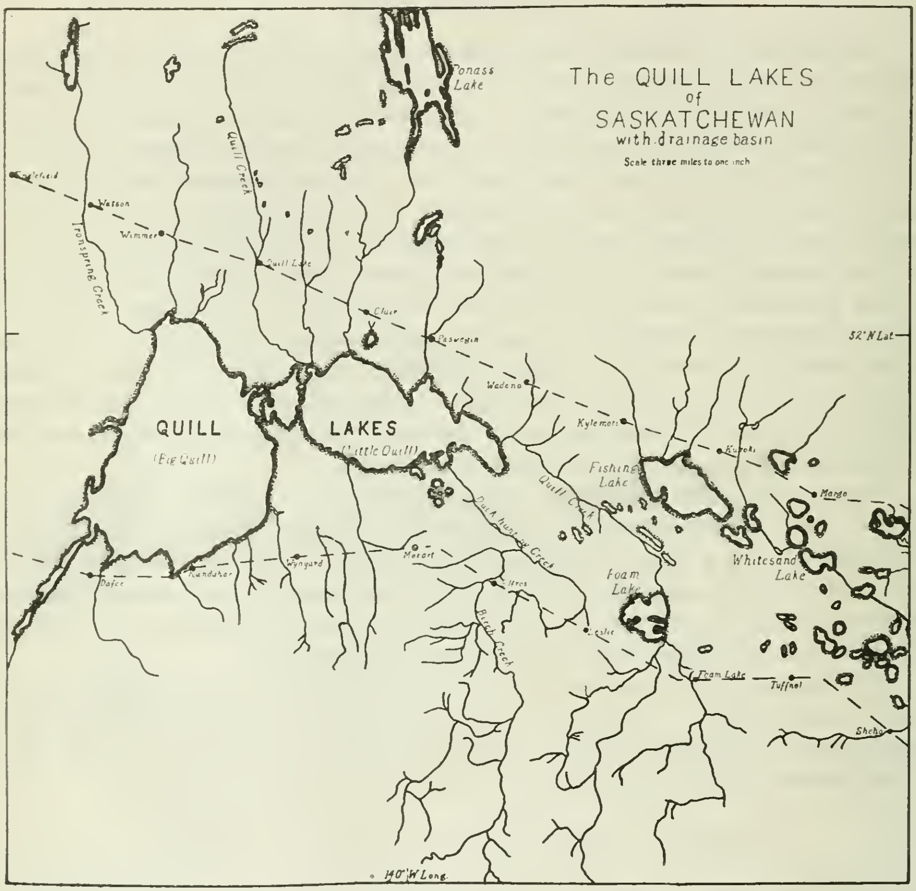
No part of our country is more poorly supplied with fish than is the prairie that makes up the settled portions of the provinces of Alberta and Saskatchewan, and also in part that of Manitoba. This prairie country is most distant from the sea coast, and at the same time it is poorly provided with large deep lakes. As a result of this situation there have been repeated requests for an improvement in the fish production of the lakes that exist in that region. The relatively small amount of moisture precipitated in many parts of this prairie country has not only caused a dearth of large bodies of water, but has also been responsible for the production of bodies of salt or alkaline water. This has occurred in places where the evaporation is much in excess of the precipitation, and where at the same time there are no deep channels to carry away the water rapidly. The various salts are leached from the soil by rains and carried into the lakes or ponds occupying the depressions in the land, and there they are concentrated by evaporation and more or less constant addition.

Among the most important of these saline lakes are the connected Quill lakes of central Saskatchewan. Requests have repeatedly been made for their examination with a view to stocking them with fish. In the spring of 1920 an opportunity presented itself for me to visit these lakes in the course of a journey to Vancouver, B.C., and in this investigation I was so fortunate as to have the collaboration of Professor A. Willey of McGill University.

We were able to spend at the end of May two days at Little Quill lake and one at Big Quill lake. In our work we received great assistance from Mr. B. D. Branscombe of Wynyard, Mr. J. J. Stefansson of Little Quill lake, and Mr. J. G. Stephanson of Kandahar, to all of whom we are greatly indebted.

EXTENT AND RELATION OF THE LAKES

Together these bodies of water cover an area of over 230 square miles. The actual extent will vary to some degree with the level of the water in the lakes. From the maps furnished by the Department of the Interior the following have been calculated. Little Quill lake has an area of 70 square miles, with a length (nearly east and west) of 15 miles, and a breadth at the widest point of 6 miles. Big Quill lake has an area of 162 square miles, with a length (nearly north and south) of 18 miles and a breadth at the widest point of 11 miles. The area of the basin that is drained into these lakes is nearly 3,000 square miles. They have no outlet to the sea, and, therefore, the salts leached from the soil of the basin have been for a very long period drained into these lakes and concentrated there by evaporation of the water. If there has been at any time drainage out of the basin, it has doubtless passed from the south-western end of Big Quill lake through Saline creek into Last Mountain lake. Evidence in favour of this as the natural exit for the water is afforded in the first place by the levels in this region which decrease in the direction indicated, and in the second place by the presence of alkali-encrusted flats along this course, and by the name (Saline) given to the creek at the Last Mountain lake end of the course. These facts indicate that such drainage as has taken place along this course has consisted of saline water from the Quill lakes.



The two lakes are connected by a runway, an expansion of which, known as Mud lake, is so near the Little Quill as to be considered part of it. The three lakes form in fact one system with a common level. The drainage or chief movement of the water is from the Little Quill to the Big Quill, as will be seen from the following facts. The drainage basin of the Little Quill comprises some 1,900 square miles, while that of the Big Quill is scarcely 900 square miles in extent. The larger lake must, therefore, be supplied with a considerable portion of its water through the smaller one. This is corroborated by the finding of a greater percentage of salts in the larger lake. The runway permits of a certain amount of interchange of water in both directions when the wind acts upon the lakes, and thus prevents the development of any very great difference in salt content.

DEPTHS AND CHANGES OF LEVEL IN THE LAKES

There was no opportunity for determining the maximum depths in the lakes. In harmony with the flat character of the surrounding land they are very shallow. According to Mr. J. J. Stefansson, who has fished all over it, the Little Quill is on the whole about ten feet deep, with perhaps fourteen feet as the greatest depth. Mr. J. G. Stephanson informed me that the Big Quill is about twenty feet deep with about forty (or perhaps even fifty) feet as the greatest depth. The shores of the Little Quill are low, and where examined consist of stones, gravel or sand, with very little mud or marsh. In the Big Quill on the northern side the land is very low, the shores in places marshy and the water shallow, while on the southern side the land is rather high, the shore for the most part sandy and stony, and the water deepening rapidly. The lack of outlet from the lakes is owing to the fact that on the whole the evaporation of water from the district is greater than the precipitation. For this reason the level of the lakes rarely, if ever, rises so high that the water can flow over the barriers between the Quill Lake basin and the neighbouring basins draining into the sea. As the level of these lakes is not controlled by an outlet, it will change from year to year and reflect the varying climatic conditions. According to Mr. Stefansson the level of the water in Little Quill a number of years ago rose about four feet and killed a poplar that was estimated to be about twenty years old. In recent years the level has gone down and is still lowering.

TRIBUTARIES

The streams or creeks which empty into these lakes are not very large, and are apt to run dry during the summer. By the action of storms the mouths of many of these creeks are blocked by bars of coarse sand or gravel through which the water filters.

The creeks that empty into Big Quill, and the areas of their drainage basins as calculated are as follows:

"Wimmer" creek	122	sq. miles
Ironspring creek	179	" "
"Dafoe" "	63	" "
"Kandahar" creek	38	" "
Unnamed	21	" "
Unnamed	10	" "
"Wynyard" creek	42	" "
Total	475	" "

The creeks of the Little Quill with the areas of their drainage basins are as follows:

"Mozart" creek	125	sq. miles
Duck-hunting or Birch creek	443	" "
Quill (from Foam lake) creek	577	" "
"Paswegin" creek	130	" "
"Clair" creek	274	" "
Quill (from Wetasta valley) creek	252	" "
Total	1801	" "

From these figures it will be seen that the streams flowing into Big Quill must be insignificant compared with those of Little Quill. The two largest flowing into the latter, which are called Birch and Quill creeks, enter the small lake at its eastern end, the point farthest removed from the large lake. We were not able to investigate these larger streams. They empty into shallow bays protected from wave action by projecting points of land or islands, depending upon the level of the water.

In estimating the drainage area for Quill creek, which empties into the easternmost end of Little Quill lake, we have not included Fishing lake and its drainage basin. The latter lake is said to contain suckers, pike, and perch in abundance, and the appearance of these fish in the Quill lakes in recent years has been attributed to transference from Fishing lake. This lake is not shown with a definite outlet on the available maps of the region. From its position and the observed levels of the district it would seem as likely to drain into Quill creek as through Stony and Whitesand lakes eastward into Whitesand river, and the former drainage may have existed during the period of heavy precipitation when the level in the Quill lakes rose, as has been already mentioned.

NATURE OF THE WATER

Professor A. Vachon of Laval University, Quebec, undertook a chemical examination of samples of water from the two lakes, and has furnished the analyses which follow:

Results of analyses of water samples for radicles and salts, in grams per million cubic centimetres or parts per million.

Radicles	Little Quill Lake		Big Quill Lake
	Surface	11 feet deep	Surface
K'	120.47	.....	162.80
CO_3''	219.00	.....	235.80
Na'	1802.00	.....	2537.00
Mg''	825.77	.....	1169.08
SO_4''	5676.00	.....	8368.00
Ca''	180.70	.....	502.00
SiO_2	7.40	.....	10.40
Cl'	1197.50	1216.00	1937.00
Other salts and organic matter	821.16	.....	1627.92
Total solids	10850.00	11110.00	16550.00
Alkalinity			
OH'	121.72	123.00	133.62

These show the following: (1) A salt content nearly half that of the ocean, which is considered to be 3½%; (2) nearly 50% more salt in the big lake than in the little one; (3) a stratification of the water, the water at the surface containing less salt than that of a sample from a depth of 11 metres (36 feet); (4) a large amount of sulphate in the water (as opposed to a large amount of chloride in sea-water); (5) the relative amounts of the chief radicles (sodium, magnesium, sulphuric acid, chlorine, silica and potassium) practically the same in the two lakes; (6) significantly large differences in the relative amounts (per total salt) of calcium and carbonic acid in the two lakes, the smaller one having more carbonic acid and less calcium; and (7) the high degree of alkalinity of the water from both lakes (possibly rather different in the lakes themselves). Those living near the lakes have noted the scouring or purgative action of the water on cattle, which would be due to the large amount of sulphate present.

It is interesting to note that Devil's lake in North Dakota presents very similar conditions. Its history is known for a much longer period than is the case for the Quill lakes, and it has been repeatedly investigated. The total solids have varied much, having been as low as 0.85% in 1906 (Pope, 1908, p. 14) and as high as 1.9% about 1912 (Brannon, 1913, p. 30). This range includes what we have found to obtain in the Quill lakes. The total solids in Big Quill lake water about 1911 (Prince, 1912, p. 39) was apparently about 1.6%, that is, almost exactly the same as in 1920.

The percentage composition of the total solids is almost identical for the two Quill lakes, and for Devil's lake it is very similar, as appears in the following table:

	Little Quill Lake	Big Quill Lake	Devil's Lake	
			Pope, 1908	Brannon, 1913
K	1.10	0.98	2.11	4.02
Na	16.61	15.33	22.60	17.36
Mg	7.61	7.07	5.58	4.58
SO_4	52.30	50.60	52.7	53.10
Ca	1.66	3.06	0.21	1.26
SiO_2	0.07	0.06	0.24	0.15
Cl	11.20	11.71	9.68	9.50

The percentages have been calculated from the data given above for the Quill lakes and published by Pope and Brannon for Devil's lake.

The temperatures of the water in the lakes were as follows:

Little Quill lake.

Near mouth of "Mozart" creek, at surface, May 28, 1920, 10 a.m., 15°C.

East of mouth of "Mozart" creek and off shore in 11 feet of water, May 29, 1920. Surface, 12 noon, 10.4°C.; 11 feet deep, 11.35 a.m., 10.5°C.

Big Quill lake.

Opposite Kandahar, at surface, May 31, 1920, 7.00 a.m., 7.4°C.

We were informed that on May 14 Big Quill lake was still covered with ice. The ice disappeared first from the smaller lake, which accounts for the marked difference between the two lakes in temperature, which existed at the time of our visit.

MOLLUSCA

Rather large quantities of gastropod shells were found on the beaches of the two lakes, where in some places they formed an almost continuous coating over the sand or mud. Living *Limnaea palustris* were found in "Mozart" creek, but no living gastropods were found in either of the lakes. This may have been due to our examination of the lakes not having been thorough enough, but it is more probable that these forms are unable to live in the lakes, and that all that are carried there by the creeks during freshets die and leave their shells to be driven by the wind, and to be cast up on the beaches by the waves.

To Mr. Bryant Walker of Detroit, I am indebted for the identifications which follow:

Beach of Little Quill lake:

Succinea grosvenori Lea; *Limnaea palustris* Müller; *L. caperata* Say; *L. vahlii* Müller; *L. vahlii arctica* Lea; *L. dalli* Baker; *Planorbis trivolvis* Say; *P. similaris* Baker; *Aplexa hypnorum* L.; *A. hypnorum tryoni* Currier.

"Mozart" creek:

Limnaea palustris Müller (living); *L. caperata* Say.

Beach of Big Quill lake:

Limnaea obrussa decampi Streng.; *L. palustris* Müller.

CRUSTACEA.

The largest form encountered was the Amphipod *Hyalella knickerbockeri.* This was very abundant in weed along the shores of both lakes. It should prove of considerable importance as fish food.

The group of small crustacea or entomostraca was represented by Copepods, Ostracods and Cladocera. Professor Willey, who is reporting fully elsewhere on the material collected, has furnished the following account of those that were to be found in large quantities in a tow made with a No. 5 net near the surface in Little Quill lake on May 29.

Percentage of Entomostraca in the plankton.

Diaptomus sicilis	55
Cyclops parcus	30
Daphnia longispina	15

In addition there was a new species of the Harpacticoid genus *Laophonte*, proposed to be called *Laophonte calamorum*, scattered in important numbers through the gathering, but not enough to appear in the percentage count.

Daphnia pulex with summer eggs in the brood-pouch was present.

Ostracod valves, including that of *Limnicythere reticulata* Sharpe, were present.

Cyclops parcus showed frequent variations in the armature of the swimming feet.

The lake, therefore, supports a very abundant and somewhat varied entomostracan fauna in the open water, sufficient to provide a large amount of food for such fish as live upon plankton forms.

INSECTA.

The only forms found swimming freely in the water so as to be taken in the plankton nets were Notonectids or water boatmen, belonging apparently to two species. Many of these were taken in Little Quill lake two to three feet below the surface in water from eight to eleven feet deep, with a coarse plankton net. and they were also found in Big Quill lake in abundance along the exposed beach at Kandahar.

The nymph of a damsel fly was found in small numbers in Little Quill and in large numbers in Big Quill lake, under stones and among vegetable debris in shallow water along the more precipitous beaches. Dr. E. M. Walker has examined these and informs me that they are probably the nymphs of *Enallagma calverti* Morse, but they may be those of *E. clausum* Morse, a related species which has not yet been reared from the nymph stage. The nymphs are mostly full grown, but some are in the penultimate and earlier stages.

As only a single haul was made with the dredge, very little knowledge was obtained concerning the forms on the bottom. Two Chironomids or midge larvae were taken in the haul (Little Quill lake) and others were found in the vegetable debris floating near shore in Big Quill. These larvae are doubtless very abundant on suitable bottom.

A few larvae of Caddis-flies were obtained and these were sent to Professor Cornelius Betten of Cornell University, who informs me that a species occurring in weed along the shore of Big Quill lake is *Phryganea interrupta*, and others from the shore of Little Quill and in "Mozart" creek are Limnophilids. No large numbers of these were seen.

FISHES

The most abundant fish in the lakes and tributary streams is the nine-spined stickleback (*Pygosteus pungitius*), which is known locally as a minnow. It was found plentifully in "Mozart" creek and also along shore in both lakes in the masses of pondweed kept in motion by the waves. Twenty were taken in a 15-minute tow taken with a 30 in. plankton net, which would indicate that they are extraordinarily abundant. Five (that is one-quarter) of this lot were infested with large tapeworms in the coelome, and appeared swollen in consequence. Of those captured in the creek nearly one-quarter were affected in the same way. Quite a number of these sticklebacks were found dead cast up on the beach, and only part of these were infested with the tapeworm. These facts would indicate that they have not enough enemies in the form of large fish to dispose even of as many as are weakened by old age or disease. The sticklebacks seem to have been the only fish that were to be found in the lakes when the district was first settled. Mr. Stephanson, who lives near Kandahar, and who came to the district about 12 years ago, said the "minnows" were present in Big Quill from the time he first knew the lake.

The only abundant commercial fish in the lakes is the sucker (*Catostomus commersonii*). Mr. Stefansson, who came to the district in 1905, stated that at that time and subsequently the lakes were considered to have no fish and to be incapable of supporting them, although some of the older Indians living in the region related that formerly there were many fish in the lakes, but in recent years none. He, himself, believed that fish would be found in the lakes and tried systematically with nets to catch them. He first succeeded in 1908 in catching some suckers, from one to nine in a net all over the lake, and they were small. In 1909 they were more plentiful and they have become more numerous and larger since then, except that the last two years there has been no change. Some are obtained in the summer, but most are taken during the winter from the end of November on. The fishery is done through holes in the ice in the deepest water. Gill nets of from 3½ to 4½ inch mesh are used. Three men operating about 1000 yards of net may take up to nearly a ton of fish a day. They are used fresh, and also salted or even canned for local use. Considerable quantities are shipped in boxes to many neighbouring stations on the railway lines.

For the Big Quill lake Mr. Stephanson gave the information that there were no suckers to be found when he first came to the district. The first were got in 1910 and they were small. They have become larger and more abundant since. Suckers have been seen and caught running up the creeks of both lakes in the spring. The mouths of the two creeks, which we examined, were blocked with sand or gravel so that it was impossible for the suckers to have ascended as they were then. No evidence could be found of suckers having ascended these creeks to spawn. It is probable that only the larger streams, possibly only those at the eastern end of the smaller lake, are regularly open for the ascent and spawning of the suckers.

The abundance of the suckers was evidenced by the fact that the beach of Little Quill lake was strewn wherever we went with specimens that had been cast ashore. Professor Willey counted 300 in less than half a mile. Some were found on the beach of Big Quill, but they were said to have been much fewer than usual on the shore near Kandahar, owing to the wind having been in the wrong quarter after the breaking up of the ice. The explanation given of the abundance of these dead suckers was that they were the fish lost or discarded from the nets in stormy weather and washed ashore when the ice broke up. No net marks could be seen on any of the fish, so that it is more likely that they had died during the spring spawning season, not having been able to ascend the creeks. The striking thing in these lakes as compared with others is that both suckers and sticklebacks have not sufficient enemies to capture and devour the weakened and dying individuals. Nor are there sufficient animals such as crayfishes or other crustacea to dispose rapidly of the dead fishes.

Mr. J. J. Stefansson informed us that almost from the first appearance of suckers in Little Quill lake there has been a small proportion of "white" suckers, which are thin and deep, with large easily loosened scales, but with the typical sucker mouth. We have had no opportunity of examining and identifying specimens of this fish.

Another fish that is now found regularly in these lakes is the pike (doubtless *Esox lucius* Linn.), of which, however, we were unable to examine any specimens. According to Mr. J. J. Stefansson, the first one was caught in Little Quill lake between 1910 and 1913, and a year passed before a second was seen. They have been rather steadily increasing in numbers, but even in 1920 they were not numerous. Their food consists of suckers. The pike occur also in Big Quill lake, but are much less abundant there.

The only other fish reported as having been found in the lake was the perch, a single large specimen (nearly a foot long) of which was said to have been taken in Big Quill lake near Kandahar about the year 1918.

The evidence shows that there are very few species of fishes in the lakes, the only regular inhabitant being the small stickleback. Of the other four kinds that have appeared in recent years, three only are to be found generally. The origin of these fishes is uncertain, but it is probable that they came from the east through Quill creek, and possibly from Fishing lake, where they are said to be abundant.

DIATOMS.

Professor L. W. Bailey, of Fredericton, N.B., has examined and reported upon the species of diatoms occurring in our material from these lakes (Bailey, 1922). He has listed 63 kinds, of which 3 are considered to be new. Six species of these are usually regarded as wholly marine, that is, not occurring in fresh water. Certain species were extremely abundant in the tows taken with No. 20 bolting cloth plankton net, particularly in those from Little Quill lake. Miss C. W. Fritz of the University of Toronto has given me the following counts, showing the relative numbers of individuals of certain genera and species in two samples, one from each lake. The numbers are comparable *only within* each sample.

Diatom	Big Quill Lake	Little Quill Lake
Navicula	10,776	288
Amphiprora a	144	9
" b	128	333
Pleurosigma a	120	....
" b	...	18
Synedra	64	126
Surirella striatula	904	873
" ovalis	56	243
Campylodiscus	8	....
Nitzschia	56	126
Thalassiothrix	448	48,690
Chaetoceras	....	11,394
Melosira	....	1,296

The striking feature is the great predominance of the marine genera *Thalassiothrix* and *Chaetoceras*. In fact with the exception of *Navicula* and *Melosira* (which contain both fresh-water and marine species), all the most abundant forms are exclusively marine. The amount of plankton obtained in Big Quill lake was very small compared with that from Little Quill. The differences between the two lakes in quantity and kinds of diatoms may be due in part to the season (as shown by the temperature) not being so far advanced in the larger lake.

OTHER ALGAE.

Professor A. B. Klugh of Queen's University has very kindly identified the Algae (exclusive of the diatoms), all from Little Quill lake.

With No. 20 silk net at surface.

Enteromorpha prolifera tubulosa	scarce
Cladophora crispata	common
Nodularia spumigena	abundant
Pediastrum boryànum	abundant

On stones along shore:

Enteromorpha prolifera tubulosa	both abundant
Cladophora canalicularis	

"Mozart" creek:

Cladophora crispata	common
Oscillatoria formosa	scarce
O. tenuis	scarce

While the number of species is so small some of these are extremely abundant and furnish a very large amount of food for the animals of the lake.

Higher plants.

The only one of the higher plants occurring in the lakes is a pondweed which grows very abundantly at moderate depths as the fishermen testify. Large masses of this weed are rolled up by the waves on the beaches of both lakes. Professor R. B. Thomson of the University of Toronto has diagnosed it (from such fragments as were available at that time of the year) as *Potamogeton pectinatus* L., the fennel-leaved pondweed, widely distributed and occurring in fresh, brackish or salt water.

COMPARISON WITH DEVIL'S LAKE, NORTH DAKOTA

We have already shown how the physical and chemical conditions of the water in the Quill lakes greatly resemble those that obtain in Devil's lake, North Dakota. One would expect that the animals and plants found therein would be very similar, and to a certain extent this is the case, as will be seen from the following summary of the life of Devil's Lake.

Pike (called pickerel) formerly abounded in the lake, but disappeared when certain tributary bodies of fresh water were cut off by a series of dry years. In 1907 a minnow (*Pimephales promelas*) was abundant (Pope, 1908, p. 17), but seems to have disappeared since then. In 1917 the only remaining fish was the stickleback, *Eucalia inconstans* (Young, 1917, p. 506). Among insects backswimmers (*Notonecta* sp.) (Pope, p. 18) and midge larvae (*Chironomus* sp.) (Young, 1917, p. 506) are the most notable. The crustacea include an Amphipod (Pope, p. 18) (*Hyalella?*), the copepods *Cyclops viridis* and *Diaptomus sicilis* (Moberg, 1918, p. 246, etc.), and the Cladoceran *Moina* (Moberg, 1918, p. 243, etc.). There are a few extinct mollusks (Young, 1917, p. 506).

A single species of higher plant (*Ruppia maritima*) grows abundantly in the shallower water (Pope, p. 18, and Young, 1917, p. 506). Among the diatoms the genus *Chaetoceras* is prominent (Moberg), and of the other algae we may mention the genera *Oscillatoria*, *Nodularia*, *Pediastrum*, *Enteromorpha* and *Cladophora*, all abundant (Moore, 1917).

While there is general resemblance in the life of the two lakes or sets of lakes (in each case there is more or less subdivision of the water), a number of differences are manifest. Whether or not these are the result of such differences in the physical conditions as occur, we are of course unable to state, but it may well be that they are the result of more or less insignificant factors, and that forms occurring in only one of the two lakes could be successfully introduced into the other.

DISCUSSION OF PROBLEM

The problem under consideration is that of conserving and improving the fish production of the Quill lakes. The basis for fish production is plant growth. The minute floating plants such as diatoms and other algae are extremely abundant in Little Quill lake (and probably also in Big Quill lake at the proper season), and are in such variety as to be almost certain to ensure suitable food for the animals that live on these minute forms. Other algae grow in abundance on suitable shores and on the bottom. The single larger plant, the pondweed, though growing luxuriantly might well be supplemented by introducing the water-weed (*Ruppia*) that is so abundant in Devil's lake. Even without this the plant growth is sufficient to support a large population of fish.

Among the animals that serve as intermediaries in making the food from the plants available for the fishes, no group is more important than that of the Crustacea. Small species of this group occur in abundance and a somewhat larger form is to be found among the plants of the bottom. There is a lack, however, of large open-water forms and of large scavengers to make use of the dead fish. For the former need it might be advisable to introduce the shrimp *Mysis relicta*, that lives not only in fresh-water lakes, but also in brackish water along the sea coast. Crayfishes would be suitable as scavengers if they proved to be able to live in such saline waters, and an attempt should be made to introduce the species (*Cambarus virilis*) that lives in Last Mountain lake.

Of small fishes to serve as food for the larger ones there is only the stickleback. Its sharp spines make it rather unsuitable. It would be a distinct advantage to introduce the minnow (*Pimephales*) that formerly flourished in Devil's lake.

The larger fishes are of importance for direct use by man, and to keep up and increase their numbers is our final object. One resident of the district expressed the opinion that the suckers which are now abundant are all that is needed, and that the introduction of other species would not be an improvement. In support of this view is the fact that from the standpoint of the production of a large quantity of fish from the plants, that form the ultimate food source, suckers rate higher than such predatory fishes as bass, pike-perch, pike, perch and trout or salmon. The pike that now occur in these lakes are harmful and a nuisance in the view of those who are wanting suckers. If these latter fish are considered the most important what are the measures that should be adopted to maintain and increase the present supply?

The most important matter is to ensure that the suckers have access to suitable spawning grounds in the larger streams. Those emptying into the eastern end of Little Quill lake are probably the most constant and important, but all that offer proper spawning conditions, even if only in occasional years, should be brought into service. For each of these every spring before the time of the spawning run a passage should, if necessary, be cleared at the mouth so that the fish may be able to enter. In the fall a passage downward for the young should be assured. When these streams empty into sloughs or bays more or less perfectly barred off from the lake, it would be a very distinct advantage to retain the bar, or, if not too costly, even to build a permanent tight dam, with an opening just large enough to permit the fish to enter and the surplus water to escape. If there is not a constant flow of water out, the passage should be long and tortuous so as to prevent as far as possible the mixing of the water in the bay with that in the lake. Such bays, containing comparatively fresh water, would provide suitable spawning grounds for many fishes and also suitable feeding grounds for the fry and young until such time as they are able to endure the conditions in the lake. Similarly a dam and narrow passage at some point in the channel connecting the two lakes would keep the Little Quill in a better, that is, a less salt condition, such as makes it even now more productive than the larger lake. The flow, being from the small to the large lake, would, in the course of time, freshen the smaller lake, particularly if all possibility of a back-flow were prevented.

These measures that have been advocated for the improvement of conditions for the suckers are equally necessary for the majority of other fishes that it might conceivably be desirable to introduce. The fishes that live in water of varying salinity almost invariably spawn in fresh water, and fresh-water spawning grounds suitable for them must be available if there is to be a prospect of permanent success in their introduction into the Quill lakes. What fishes are most desirable and at the same time most likely to succeed in these waters? Opinions differ so much in regard to desirability that we can scarcely do more or less than to consider all those that find a market in our country at the present time. Two factors must be kept in view in selecting the kinds that are likely to succeed, and these are the food that is available and the salinity of the water.

What kinds of fish are likely to endure the salinity of the Quill lakes? We know that pike and suckers, and probably also perch, can do so. The United States Bureau of Fisheries and the North Dakota Biological Station have tested the resistance of a number of kinds of fish to the waters of Devil's lake by keeping them in tanks, the conditions admittedly not being ideal. Pike and suckers did not survive very long, but this may have been due not to the salinity, but to the confinement. Yellow perch, black bass, catfish, pike-perch, rainbow trout, and steel-head trout survived in good condition. It is remarkable that there was failure only for the two kinds that have succeeded naturally in the Quill lakes. Professor Prince (Report of Alberta and Saskatchewan Fishery Commission, p. 40) has suggested that the Atlantic brackish-water fishes, the tom-cod and the striped bass, might be successful, and a trial of these deserves to be made. Other species of fishes that have been found to occur in waters having a wide range in salinity are the following: eel, alewife or gaspereau, shad, smelt, whitefish, cisco (lake herring), white perch (*Morone*) and several trouts and salmons.

Eels could be planted with the practical certainty of their doing well. As they breed only in the open oceans there would be no danger of them becoming a permanent nuisance, if for any reason they were found to be undesirable. On the other hand, it would be necessary to restock regularly, at least every few years, and the young eels or elvers would have to be brought from the Atlantic coast It should be understood that this method of stocking inland bodies of water with elvers brought from the sea coast is regularly followed in many parts of Europe.

So far as our knowledge goes there is not at present much food of the right kind for yellow perch, black bass, pike-perch, steel-head trout, smelt, white perch, tom-cod, striped bass and salmon, although the introduction of large crustacea and small varieties of fish would doubtless remedy this condition.

The temperature reached by the water during the summer is probably so high as to be fatal to some of these fishes, but we have not yet sufficient information for a definite conclusion on this question.

There is plenty of suitable food for young fishes, and for the adults of such species as the alewife, whitefish and cisco. These fishes are very desirable from the standpoint of quantity production, and would almost certainly endure the salinity well. The only question is whether there would be suitable water for the spawning of the eggs and the rearing of the fry.

In any attempt to stock these lakes it should be arranged to plant the fish in the streams or bays at the eastern end of Little Quill lake. This would permit the fish to pass gradually into water of higher and higher salinity.

It is important to ensure protection of the fish from freezing during the winter. Both lakes are deep enough not to freeze to the bottom; but, if bays or sloughs are dammed off at the mouths of creeks a part of each should be made deep enough (for example, 8 to 12 feet) to provide a safe retreat for the fish that might remain in it over winter.

SUMMARY

The Quill lakes together form a connected body of saline water with an area of over 230 square miles and with depths ranging for the most part between 10 and 50 feet. As the evaporation is greater than the inflow from precipitation over the drainage area, there is rarely if ever, any outflow of water. The level of the water, consequently, has varied and will vary markedly from year to year depending upon the weather conditions. The drainage and the increase in salinity is from east to west as a result of the drainage area decreasing in the same direction, and of the natural outlet and the greatest depression for storing the water being at the west. The salinity of the water is from 1% to 1.65%, and the chief salts present are Magnesium sulphate (Epsom salt), Sodium sulphate (Glauber's salt), and Sodium chloride (common salt).

There are many kinds of plants and animals in the lakes, but these are chiefly microscopic in size. The minute floating plants found in Little Quill lake were so abundant that a short tow with a fine-meshed net gave a bottle full of material of the consistency and appearance of pea-soup. Of larger plants there is a pond-weed growing in abundance at moderate depths and several simpler weeds coating the surfaces of boulders and other firm objects washed by the waves. Minute shrimps are found floating in the water in great abundance, as also a kind of insect known as a back-swimmer A shrimp of medium size and the larva of a damsel fly are common along shore. A small fish, known as a stickleback, is abundant almost everywhere. A sucker is the commonest large fish, but another sucker and the pike are said to occur regularly in smaller numbers. The lakes are tenanted by large numbers of aquatic birds, such as phalaropes, snipes, sand-pipers, terns, gulls, cormorants, ducks, geese and pelicans. These afford further evidence of the food-producing possibilities of these lakes.

There is every reason to believe that these waters could produce a much larger quantity and greater variety of fish than they do at the present time. To keep up and increase the fish production the most essential thing is to ensure fresh water conditions for the eggs and for the young fish, either in the streams or at their mouths, and at the same time to provide an avenue of access to these grounds for the adult fish at the proper season. If bays are dammed off for this purpose, part of each should be deep enough to serve as a retreat for the fish from the superficial layers that freeze during winter. Little Quill lake should be not only protected from an increase in salinity, but also given an opportunity to decrease in salinity, by the erection of a dam at a convenient point in the channel connecting the two lakes, a passage-way being kept open for fishes for a part of the year at least.

Attempts should be made to introduce other plants and animals to provide a greater variety of food for the fishes. If desired, other commercial fishes could be planted in the lake, and a number of kinds offer a good prospect of becoming permanently established providing suitable breeding grounds are available. Perhaps those most likely to succeed would be yellow perch, pike perch, alewife, smelt, whitefish and cisco. The eel would be very suitable for continuous planting.

We have not dealt with the use of artificial measures in keeping up the stock of fish in these lakes. Of the kinds of fish mentioned many could be hatched and some could be reared in much larger numbers by more or less artificial means than naturally, when the fresh water supply is limited. Such a course would, it is evident, not be advisable at the present time, but should be kept in view for the future.

LITERATURE

BAILEY, L. W.

1922. Diatoms from the Quill lakes, Saskatchewan, and from Airdrie, Alberta. Contr. Canad. Biol. 1921, No. 11, pp. 155-166

BRANNON, M. A.

1913. Second and third annual reports of the Biological Station to the Governor of North Dakota, pp. 1-36.

MOBERG, E. J.

1918. Variation in the horizontal distribution of plankton in Devil's lake, North Dakota. Trans. Amer. Micr. Soc., Vol. XXXVII, pp. 239-267.

MOORE, G. T.

1917. Algological Notes. II. Preliminary list of algae in Devil's lake, North Dakota. Ann. Miss. Bot. Garden, Vol. IV, pp. 293-303.

POPE, T. E. B.

1908. Devil's lake, North Dakota. A study of physical and biological conditions, with a view to the acclimatization of fish. Bur. Fish. Doc. No. 634, pp. 1-22.

PRINCE, E. E.

1912. Dominion Alberta and Saskatchewan Fisheries Commission, 1910-11. Report and recommendations, pp. 1-71.

YOUNG, R. T.

1917. The work of the North Dakota Biological Station at Devil's lake. Scient. Monthly, Vol. V, pp. 497-508.

No. 10

A PRELIMINARY LIST OF BRYOZOA (POLYZOA) FROM THE VANCOUVER ISLAND REGION

BY

CHAS. H. O'DONOGHUE, D.SC., F.Z.S., F.R.S.C.
University of Manitoba

AND

ELSIE O'DONOGHUE, B.A.

A Preliminary List of Bryozoa (Polyzoa) from the Vancouver Island Region.

By Chas. H. O'Donoghue, D.Sc., F.Z.S., F.R.S.C.
Professor of Zoology, University of Manitoba

and

Elsie O'Donoghue, B.A.

The specimens recorded in the following list were all obtained while at the Biological Station, Nanaimo, British Columbia, and most of them were collected within an area of about 20 miles from the laboratory. A considerable amount of material had been accumulated by the Director, Dr. C. MacLean Fraser, and much of this Mr. Cyril Berkeley, of the Biological Station, had sorted out. Mr. Berkeley had identified a number of these forms and started a very useful index card list of them; his other work prevented him carrying on this investigation and he handed the material and list to us. All the specimens have been re-identified quite independently, but this sorting of materials and the list were of considerable use to us.

Besides that just mentioned there were also jars containing material from points wider afield; some collected by the former curator, Rev. G. W. Taylor, and others by Professor J. P. McMurrich further North. Mrs. Berkeley brought a few species from Barclay Sound and one of us (C. H. O'D.) obtained a few from Friday Harbour, Puget Sound, U.S.A., during a short visit.

The whole of this material was carefully gone through and sorted out, and in addition we collected assiduously ourselves for over four months and succeeded in finding more than 80 per cent. of the species already in the collections just mentioned, and in addition a large number not previously represented. In all we examined and identified many thousands of specimens.

Our knowledge of the Bryozoa of the Pacific Coast of North America is practically limited to the works of two authors, the Rev. T. Hincks and Dr. Alice Robertson. The former author, in a series of papers in the Annals and Magazine of Natural History for 1882, 1883, and 1884, described the material collected by Dr. G. M. Dawson from the Queen Charlotte Islands in 1878. These three papers were re-issued together by the Geological Survey of Canada in 1884 and contain a list of 96 species, of which 36 were new to science and, in addition, 5 varieties.

Dr. Alice Robertson's contributions comprise a series of useful publications from 1900-1910. The material included was obtained from Alaska (Harriman Expedition), Puget Sound (a small amount) and California, and in the papers to date 115 species have been described, 31 of which were new, and also 2 subspecies were recognized.

The following list includes 173 different species, and in addition distinct varieties of some of them amounting in all to 22. Thus it is a more extensive list than has been given previously from the Pacific Coast of North America, and it is from an area from which we have no records as yet. A number of the forms, 39 in all, we have not found described in any of the literature so far studied and they are here listed, provisionally at any rate, as new species. For the determination of these new forms one of us (C. H. O'D.) is responsible.

In view of the large amount of material, it was deemed advisable to publish this preliminary list with records of local distribution so that the information might be available to other workers and it is hoped that a fuller treatment with descriptions, notes, etc., will be given later.

We should like to express our thanks to Dr. C. McLean Fraser for placing the material at the Station at our disposal and for his generous assistance in collecting. We also wish to thank Mr. Cyril Berkeley for handing over to us the material he sorted and the list he had made, and to all the other workers at the Station who brought us in specimens wherever and whenever they collected.

The main outline of the classification here adopted is taken from the excellent article on this group by Sir Sidney F. Harmer, F.R.S., in the Cambridge Natural History, to which reference may be made for detailed information.

No bibliography is given as it is thought that this would be more fittingly included in a more detailed paper. In addition to the papers by Hincks and Robertson already noted references are made for purposes of comparison to the very useful list of "The Bryozoa of the Woods Hole Region" (1912), by R. C. Osburn, and to the classical "British Marine Polyzoa" (1880) by Hincks. The reference is not to the first description of the species, but to a readily available description or to one of the papers mentioned above, and in a few cases it has been found desirable to include a brief synonymy to clear up certain points. Whenever the species has been recorded previously from the Pacific Coast of North America this is noted by placing "Pacific N.A." after the reference. When the word "Atlantic" or "England" is placed after the reference it means that the reference is to a description of the species from that region, but that it has not previously been recorded from the Pacific Coast of North America. Whenever possible also the bathymetric range is indicated in fathoms.

In drawing up such a list as the following, one is faced from the outset by the difficulty of deciding what forms shall be included within the limits of a single species. Since this is frequently a matter of opinion and there is no absolute criterion by means of which a case in dispute can be settled, it will always remain a subject for discussion. Two opposing tendencies are noticeable. The one extreme is encountered when all noticeable varieties of a form are raised to the rank of different species, a proceeding that accentuates the differences at the expense of the resemblances. The other extreme is to group all such varieties together under one specific name without further comment and this is apt to mislead just as badly, since it does not indicate sufficiently the extremes of variation that the author admits within the species. It has been our endeavour to steer between these extremes and, while keeping the bounds of the species as wide as possible so that a number of forms fall under the same specific name, the striking variations are pointed out as varieties of the main type. In this we are only following the example of so good an authority as Hincks.

The Bryozoa are a group in which this making of varieties is necessary to a greater degree than in some other groups, because small changes, in themselves of no great significance, may considerably affect the appearance of the colony. Thus, for example, in such a species as *Microporella ciliata* the replacement of the ordinary type of avicularia by ones of a vibraculoid type considerably alters the appearance of the zooecium and yet, while this certainly deserves notice, it is hardly sufficient to call for the creation of a separate species.

CLASS **BRYOZOA** (Ehrenberg) **POLYZOA** (J. V. Thompson).

Sub-class ENTOPROCTA Nitsche, 1869.

Order *PEDICELLINEAE* Hincks, 1880.

Family Loxosomidae Hincks, 1880.

Genus LOXOSOMA Keferstein, 1863.

Loxosoma davenporti Nickerson.
Reference. Osburn (15, p. 212, Pl. XVIII), Atlantic.
Distribution. Hammond Bay Lagoon. Low tide.

Family Pedicellinidae Hincks, 1880.

Genus MYOSOMA Robertson, 1900.

Myosoma spinosa Robertson.
Reference. Robertson (17, p. 324, Pl. XVI), Pacific N.A.
Distribution. Northumberland Channel; Nanoose Bay; Thetis Island. 8-25 fms.

Genus GONYPODARIA Ehlers.

Robertson (17, p. 337) in dealing with *Gonypodaria ramosa* states: "A comparison of the colonies from these four localities leads one to suspect that there may be more than one species among them. They differ markedly in size and robustness of calyx and stalk and especially in the number of branches. However, until more material can be obtained and further investigation made, they will all be placed under one species."

This is true also of the material at present under review, but, in addition to a certain amount of variation, three quite distinct types can be made out which do not apparently intergrade. The first is here listed as *G. nodosa* Lomas, with which it is in close agreement. The second is identified as *G. ramosa* Robertson, and the third has been treated, provisionally at any rate, as a new species with the name *G. parva*.

Gonypodaria nodosa Lomas (Pl. I, Fig. 1*c*).
Reference. Lomas (14, p. 190, Pl. III), England.
Distribution. Off Brandon Island; Northumberland Channel; Thetis Island; China Hat; Burrard Inlet; off Protection Gap; North West Bay; Departure Bay; Gabriola Pass. 8-25 fms.

This is apparently very close to the *G. nodosa* Lomas with which it is here identified.

Gonypodaria ramosa Robertson.
Reference. Robertson (17, p. 337), Pacific N.A.
Distribution. Gabriola Pass; Nanoose Bay. 8-20 fms.

Robertson (17, p. 337) points out that the two species, *G. ramosa* and *G. nodosa*, differ in the number of muscular expansions on the stalk. The latter has not more than three, while the former has frequently four, five or more. This in itself is not an important difference since in a colony of *G. ramosa* individuals resembling *G. nodosa* may be found, but the branching is peculiar to this form and warrants the formation of a new species.

Gonypodaria parva sp. nov. (Pl. I, Figs. 1*a*-*b*).

The general form of the colony approaches most nearly to that of *G. nodosa* in that there is no branching as in *G. ramosa*, each stalk coming off separately from the stolon. It is at once distinguishable from *G. nodosa* by its much smaller size, more slender build, and by the fact that the muscular swellings on the stalk are relatively less marked. The whole colony is thus much smaller and of a far more slender appearance. The name gracilis suggested itself, but as the original name of *G. nodosa* was *Pedicellina gracilis* var. *nodosa* it was feared that confusion might result from its use, so the name *parva* is here proposed.

The stolon, like the stalk, is slender and of a pale yellow colour and, so far as observed, it is closely adherent to the substratum. The stolon gives off branches which may be fairly close together but no sign of anastomosing was noticed and, as in *G. ramosa*, the branches occur near the base of a polyp stalk.

In common with the other members of this genus, the stalk lies at right angles to the stolon or nearly so, and commences with a muscular dilatation. While in young forms this may be the only dilatation, in fully grown stalks a second occurs about half-way along the stalk, and a third usually less noticeable just beneath the calyx. Thus the stalk is divided into two portions, termed phalanges, and in the specimens examined never more than two were present, while in *G. ramosa*, in addition to the branching habit, four or five phalanges may be developed.

It seems to be characteristic of the genus that the calyx is first produced upon a stalk that has only the basal swelling and the other swellings are added subsequently, but the stalk is of the same diameter from the beginning. In one specimen, where colonies of *G. nodosa* and *G. parva* overlap, a young stalk of the former occurs in close proximity to older stalks of the latter, and it is immediately noticeable as being coarser, much larger and considerably deeper in colour than the latter.

The calyx is, in general, similar to that of other members of the Pedicellinidae. It is somewhat ovoid but relatively longer and narrower than in either *G. nodosa* or *G. ramosa*, and noticeably smaller.

The polyp is much like that of the other two species, but, unfortunately, in no case did the preservation permit of determining accurately the number of tentacles.

Distribution. Nanoose Bay; Northumberland Channel. 8-20 fms.

Genus BARENTIA Hincks, 1880.

Barentia major Hincks.
Reference. Hincks (12, p. 226), Osburn (15, p. 213, Pl. XVIII), Atlantic.
Distribution. Bull Passage; Cape Ebenshaw. 15-25 fms.

Sub-class ECTOPROCTA Nitsche, 1869.

Order *GYMNOLAEMATA* Allman, 1856.

Sub-order *CYCLOSTOMATA* Busk, 1852.

Division A, ARTICULATA.

Family CRISIIDAE Busk, 1875.

Genus CRISIA Lamouroux (pars), 1812.

Some of the following Crisiidae resemble one another closely and are practically only separable by the position or shape of the ooeciostome. Forms resembling those described and figured by Robertson have been found and they are here listed under the specific names of that author.

Crisia cornuta Linnaeus.
References. Hincks (7, p. 49, Pl. LVI). England (11*b*, p. 32), Pacific N.A.
Distribution. Cape Ebenshaw; Banks Island. 15 fms.

Crisia franciscana Robertson.
Reference. Robertson (21, p. 233, Pl. 18), Pacific N.A.
Distribution. Banks Island; Round Island; off Masset. 7-25 fms.

Crisia geniculata Milne-Edwards.
Reference. Robertson (21, p. 235, Pls. 18 and 19), Pacific N.A.
Distribution. Bull Channel; Ballenac Islands; Northumberland Channel; Cape Ebenshaw. 15-25 fms.

Crisia occidentalis Trask.
Reference. Robertson (21, p. 239, Pl. 19), Pacific N.A.
Distribution. Banks Island.

Crisia operculata Robertson.
Reference. Robertson (21, p. 240, Pl. 19), Pacific N.A.
Distribution. Houston Passage. 15 fms.

Crisia pacifica Robertson.
Reference. Robertson (21, p. 242, Pl. 20), Pacific N.A.
Distribution. Departure Bay; Gabriola Pass; Bull Channel; Nanoose Bay; off Hammond Bay; Northwest Bay; Swiftsure Shoal; Banks Island; off Protection Island; entrance to Departure Bay; West Rocks. 8-40 fms.

Crisia maxima Robertson.
Reference. Robertson (21, p. 243, Pl. 20), Pacific N.A.
Distribution. Bull Passage; Departure Bay. 12-25 fms.

Crisia pugeti Robertson.

Reference. Robertson (21, p. 244, Pl. 20), Pacific N.A.

Distribution. Off Gabriola Island; Departure Bay; entrance to Departure Bay. 12-25 fms.

Division B, INARTICULATA.

Family TUBULIPORIDAE Johnston, 1838.

Genus TUBULIPORA Lamarck (pars), 1816.

Tubulipora flabellaris Fabricius.

Reference. Osburn (15, p. 218, Pl. XX), Atlantic; Robertson (21, p. 247, Pl. 21), Pacific N.A.

Distribution. Between Jesse and Newcastle Islands. 15-20 fms.

This form, while not unmistakably identical with those described by either Osburn or Robertson, is so near them that it is here included as the same species.

Tubulipora fasciculifera Hincks.

Reference. Hincks (11*b*, p. 35, Pl. IX), Pacific N.A.

Distribution. Between Jesse and Newcastle Islands; Northumberland Channel; West Rocks; Friday Harbour. 8-25 fms.

As Hincks pointed out, the fasciculate arrangement of the zoœcia is characteristic. The oœcium is an inflation near the margin and the oœcial tube apparently much like a zoœcium.

Tubulipora pacifica Robertson.

Reference. Robertson (21, p. 248, Pl. 22), Pacific N.A.

Distribution. Gabriola Pass; False Narrows; Ballenac Islands; Round Island; Bull Passage; off Snake Island; Stuart Channel; Nanoose Bay. Low tide, 25 fms.

In some respects this species recalls *T. flabellaris*, but it has the same oœciopore as that described by Robertson for *T. pacifica* and, like it, is often found in large numbers upon a frond of kelp (*Nereocystis luetkiana*).

Tubulipora occidentalis Robertson.

Reference. Robertson (21, p. 249, Pl. 22), Pacific N.A.

Distribution. Entrance to Departure Bay; off North Shore of Brandon Island; Gabriola Pass; off Protection Gap; Round Island. Low tide—15 fms.

Tubulipora pulchra MacGillivray.

Reference. Robertson (21, p. 250, Pl. 23), Pacific N.A.

Distribution. Entrance to Departure Bay; Bull Passage; off Snake Island. 15-35 fms.

These were fairly young colonies in which the characteristic lobed appearance of the older colonies had not been fully assumed.

Tubulipora serpens Linnaeus var. *radiata* Hincks.

Reference. Hincks (7, p. 453, Pls. LXI and LX), England; Osburn (15, p. 218, Pl. XX), Atlantic.

Distribution. Bull Passage; Nanoose Bay; Round Island; off Protection Gap; Swiftsure Shoal; off Snake Island; Banks Island; Cape Ebenshaw; West Rocks; Strait of Georgia. Low tide—25 fms.

There is a certain amount of uncertainty about this species. It is described and figured by Hincks (7, p. 453, Pl. LXI and LX), and the specimens obtained in the Vancouver Island Region are all of them very like the form there described as *Idmonea serpens* var. *radiata*, save that there are more zoœcia in a row. Hincks remarks that in their early stage the Idmoneæ resemble the Tubuliporæ, citing *I. serpens*. Harmer (5, p. 90) goes into this matter in some detail and points out that *I. serpens* is really a Tubulipora. Osburn (15, p. 218, Pl. XX) also adopts this view and gives *I. serpens* as a synonym of *T. liliacea*. For these reasons the form is here listed as *T. serpens* var. *radiata*. It is included in the genus Tubulipora, but all the specimens are quite unlike the *T. liliacea* figured by Osburn, and so the specific name *serpens* var. *radiata* is retained in order to indicate that it is most probably identical with the form figured and described by Hincks under this name (vide infra).

Tubulipora striata sp. nov. (Pl. I, Fig. 2).

Zoarium adnate and of a fairly regular fan-shape or oval in old colonies, the largest observed measuring 7.25 x 6 mm. The margin is intact and regular. The whole texture of the colony is more opaque than in certain other allied species. The surface of many species of this genus shows a shallow wrinkling or striation, which is more pronounced in the present species than generally, and here also the surface is minutely punctate, which is very apparent in places. The zoœcia are sub-erect and for the most part entirely free, only here and there near the margin are they to be found connate in pairs. In this respect it differs from *T. flabellaris*, *T. fasciculifera*, *T. pacifica* and *T. occidentalis*, where there is a tendency, very marked in some species, for the zoœcia to run together in bundles. In the middle region of the colony the single tubes are arranged in a very regular manner. The oœcium is an inflation involving the bases of 8-14 zoœcia, fairly regular in outline and not lobed. Both the oœciostome and the oœciopore are of the same size, oval in shape and with their long diameter at least twice that of a zoœcium. The walls of the oœcial tube are parallel and not more than half as high as a zoœcium. Thus the form of the oœcial tube separates it from *T. pulchra*, *T. pacifica*, *T. occidentalis* and *T. flabellaris*.

As far as can be found it does not agree with any previously described form, and it is proposed to place it under the name *Tubulipora striata* to call attention to the fact that the surface of the zoarium is more striated than in allied species. Distribution. Gabriola Pass; Banks Island. 8-? fms.

Tubulipora labiata sp. nov. (Pl. II, Figs. 3*a-b*).

The zoarium is adnate, typical of a number of members of the genus, and its outline is more irregular than in *T. striata*. The largest colony measured 11 x 7.5 mm. The surface is more faintly wrinkled than in the preceding species. The zoœcia are sub-erect and for the most part free. The central region of the colony is much like that of *T. striata*, save that the zoœcial tubes are not quite so long and they are somewhat more closely set. Towards the edge, however, there is a greater tendency for the tubes to lie in connate bundles of two, three or more rarely four. The margin of the colony also is not so regular and is sinuous, although this is hardly sufficiently marked to justify the colony being described as lobed, save where its growth is interfered with by extraneous bodies. It is of a bright white colour, easily distinguishable from the grey of *T. occidentalis* which it most nearly approaches in the structure of the oœciostome.

The oœcium is a not very conspicuous inflation of the surface of the colony, involving the bases of from 10-24 zoœcia. The aperture of the oœcium, however, is most striking and is, so far as we are aware, unlike any other that has been described. The oœciostome always lies at the base of a zoœcium and wraps nearly half round it in the form of a thin crescent-shaped slit; its long diameter is thus greater than that of the zoœcium, but its transverse diameter much less. The long diameter does not appear to bear any fixed relation to the radial axes of the colony; it may be parallel with them, at right angles, or set obliquely. The oœcial tube varies in length; it is often very short, sometimes longer, but never as long as the zoœcium it adjoins, and it is asymmetrically developed. The oœciopore is also crescentic and slightly larger than the oœciostome, but its most striking characteristic is that its margin is only developed on one side. The free edge is higher in the middle than at the ends. In effect the wall of the zoœcium against which it lies forms one wall of the oœcial tube, and so the actual wall of the latter is not developed on this side. The striking asymmetrical development of the oœcial tube and its margin is apparently peculiar to this species, and as it results in the formation of a very distinct lip it is proposed to give this species the name *Tubulipora labiata*.
Distribution. Gabriola Pass. 15 fms.

Tubulipora intermedia sp. nov. (Pl. I, Fig. 4).

The zoarium commences as a fairly typical tubuliporan colony and passes along the substratum for a distance of 2-3 mm., becoming 3 or 4 cells wide. It then becomes erect for a similar length and then broadens out into an oval expansion about 3 mm. long and 2 mm. wide. The zoœcia are sub-erect, free for a considerable length and disposed singly and irregularly, but never in pairs or rows. Their aperture is circular with a suggestion of a turned-out lip. They open upon one side of the stem and expansion only. The oœcium is a noticeable dilation towards the middle of the blade-like portion. The oœciopore is a circular aperture much smaller in diameter than a zoœcium; the oœcial tube has always been found attached to a zoœcium with the oœciostome of the same diameter as the oœciopore and opening at the same level as the zoœcium.
Distribution. On sponge beds outside Departure Bay. Entrance to Departure Bay. 15-20 fms.

The present species is an interesting one from several points of view. At first sight it appears almost like an *Entalophora* allied to *E. capitata*, although the free parts of the tubes are longer. This genus is ruled out by the fact that in the present species the tubes open on one side only, whereas in *Entalophora*, of course, they open on all sides. It also presents some points of likeness to *Idmonea*, but there is not the slightest indication of the zoœcia being regularly arranged in rows and there is also no branching, no production of relatively long branches and no sign of anastomosing. The result is, of course, a solitary colony, not a compound network as in most of the *Idmoneæ*. On the whole, its type of zoœcium, oœcium, oœcial tube and, in particular, the basal part of the colony ally it clearly with *Tubulipora*. It does not appear to have been described and the name *T. intermedia* is suggested to call attention to the fact that in some respects it is intermediate between this and other genera.

Genus STOMATOPORA Bronn, 1825.

This genus apparently has not been previously recorded from the Pacific Coast of North America. In the material we have examined no fewer than 7 types were found, six of them seemingly referable to previously known species, but one, a very flattened form, is here listed as new.

Stomatopora granulata Hincks.
Reference. Hincks (7, p. 425, Pl. VII), England.
Distribution. Northumberland Channel; off Protection Gap; Bull Passage. 15-25 fms.

Stomatopora major Johnston.
Reference. Hincks (7, p. 427, Pl. LVIII), England; (11*b*, p. 33), Pacific N.A.
Distribution. West of Gabriola; Northumberland Channel. 15-40 fms.

Stomatopora johnstoni Heller.
Reference. Hincks (7, p. 430, Pls. LX and LIX), England.
Distribution. Off Newcastle Island, off Protection Gap. 15-25 fms.

Stomatopora expansa Hincks.
Reference. Hincks (7, p. 432, Pl. LXII), England.
Distribution. Banks Island.

Stomatopora diastoporides Norman.
Reference. Hincks (7, p. 434, Pl. LXII), England; Osburn (15, p. 218, Pl. XVIII), Atlantic; Hincks (11*b*, p. 33), Pacific N.A.
Distribution. Northumberland Channel. 15-18 fms.

Stomatopora incrassata Smitt.
Reference. Hincks (7, p. 436, Pl. LIX), England.
Distribution. Northumberland Channel; Bull Passage. 15-25 fms.

Stomatopora depressa sp. nov. (Pl. I, Fig. 5).

The zoarium is completely adnate, very much flattened and, compared with most species of the genus, broadly expanded and little branched. Thus it forms a more than usually compact colony. The surface is minutely granular, making it a little rough, and it is faintly striated. The zoœcia are almost completely immersed, their basal portions indistinguishable and only a small portion of the end is free and slightly raised. They do not appear to be arranged regularly either in longitudinal or transverse series. The oœcium is apparently an almost imperceptible low swelling, situated towards the end of a broad branch and the oœciostome an aperture much like a zoœcial opening, but smaller and lower, so that we cannot apply the term oœciopore or oœcial tube.

It appears to be undescribed and the name *S. depressa* is suggested to call attention to its flattened adnate form.

Distribution. Northumberland Channel. 15-18 fms.

Genus IDMONEA Lamouroux, 1821.

The separation of this genus from *Tubulipora* is largely based upon its erect habit of growth, and Harmer, as pointed out above, has shown that one species included in *Idmonea* by Hincks is really a tubuliporan. In this matter, however, we find ourselves inclined to the opinion given by Robertson (21, p. 253), viz.: "I recognize the difficulty, as I have said before, of establishing a genus on mere habit of growth, and yet I hesitate to ignore the genus *Idmonea*, since the species here regarded as *Idmonea* is so distinctly different from those forms identified as *Tubulipora*." There is indeed this difference and for the present, at any rate, we think it advisable to retain the genus to indicate this distinct difference in the appearance of the well-grown colonies, but it is obvious that the two genera are closely related and nowhere is this more clearly shown than in the case of *Tubulipora intermedia*, which in some respects bridges the gap between them.

Idmonea atlantica Forbes.

Reference. Hincks (7, p. 451, Pl. LXV), England.

Distribution. Off Maude Island; outside Departure Bay; Northumberland Channel; Goose Island. 15-40 fms.

Idmonea californica d'Orbigny.

Reference. Robertson (21, p. 253, Pl. 23), Pacific N.A.

Distribution. Trincomali Channel; Banks Island; Clan-innick; Nawhitte Bar; Brotchie Ledge (Victoria). 13-16 fms.

The specimens from Brotchie Ledge, now in the Provincial Museum at Victoria, are fine specimens of this form which can grow into complex colonies knit together by means of anastomosing branches.

Idmonea palmata sp. nov. (Pl. I, Fig. 6).

This species is a somewhat difficult one to place satisfactorily. In using the key given by Robertson it falls between the genera *Idmonea* and *Entalophora*, while from Harmer's key it comes most nearly between *Idmonea* and *Hornera*. However, as from both keys it has certain characters of the genus *Idmonea*, and it most nearly approaches *I. californica* d'Orbigny, it is thought better to include it in that genus rather than set up a new one for it.

The zoarium is erect and composed of numerous dichotomously branched stems. The stems are not so upright as in *I. californica*, but bend over; they are broader and shorter, attaining a width of 5 or 6 mm. and of about the same length. The branches do not anastomose so freely, with the result that a much lower and more expanding type of colony is produced. All the zoœcia open upon the ventral surfaces of the branches, which are covered with a smooth minutely punctate surface. The dorsal surface is also minutely punctate and marked by a series of low transverse striations. In colour the colony is yellowish white or umber, not the grey of *I. californica*. The zoœcia are immersed for the most part with their bases hidden and only their short free extremity projects upwards from the surface at right angles, in the form of a small tube. In other members of the genus the zoœcia are arranged in parallel transverse or oblique lines on each side of a median line. In the present species, however, this regularity of arrangement has been lost. While here and there we find lines of from 2-4 zoœcia this is not the rule, and sometimes 3 or 4 may be in a small group. For the most part, however, they are irregularly scattered over the ventral side of the branch and well separated. There is a certain amount of irregularity in this respect in *I. atlantica* and more in *I. californica*, but in the present species it is much more marked and regular rows are decidedly more the exception than the rule.

The oœcium is a low inconspicuous inflation of the ventral surface often lying near the base of two branches. The oœciostome is circular and slightly larger than a zoœcial aperture. The oœcial tube is a little longer than the zoœcial tubes around it and expands slightly as it passes upwards, so that the oœciopore is larger than the oœciostome.

This form does not appear to have been described previously and is here given the name *I. palmata* to call attention to the relatively broad palmate nature of the branches.

Distribution. Gabriola Pass; Black Rock; Porlier Pass. 8-18 fms.

Genus ENTALOPHORA Lamouroux, 1821.

Entalophora clavata Busk.

Reference. Hincks (7, p. 456, Pl. LXV), England.

Distribution. Between Jesse and Newcastle Islands; Gabriola Pass; off Snake Island; Cape Ebenshaw; off Protection Gap; Houston Passage. 15-35 fms.

While differing in certain minor points this is very like *E. clavata*, with which it is here identified. The zoœcia are joined and the stalk and tubular portions minutely punctate as in this form.

Entalophora raripora d'Orbigny, 1847.

Reference. Busk (2, p. 19, Pl. IV), Robertson (21, p. 256, Pl. 24), Pacific N.A.

Distribution. Nanoose Bay; Buccaneer Bay; off Snake Island; entrance to Departure Bay; Departure Bay. 15-35 fms.

Entalophora capitata Robertson.

Reference. Robertson (21, p. 257, Pl. 24), Pacific N.A.

Distribution. Sponge bed outside Departure Bay; Departure Bay; Friday Harbour. Low tide—20 fms.

Entalophora vancouverensis sp. nov. (Pl. I, Fig. 7).

The zoarium forms a flattened very irregular disc 3-4 mm. in diameter, from the middle of which a short circular stem rises to a height of 3-4 mm., when it branches generally into two or four. If it divides into four the portion between the bases enlarges somewhat to form a sort of platform from which the branches are given off at the corners, the whole forming a sort of "head." If it branches into two, then, after a course of about 3-4 mm., each of these forms a quadriradiate "head" in a similar manner. The four branches are not always equally developed and rarely equally spaced, but the appearance is fairly constant and so the species can be distinguished quite easily by this characteristic manner of growth. Occasionally the branches of two adjacent colonies touch one another and fuse. The zoœcia are in the form of tubes with their basal portions fused and the distal extremities free. They open on all sides of the branches and in the sheltered parts of the colony the free portion is of considerable length. The surface is minutely punctate and faintly striate. The oœcium is a small inflation of the colony in the area between the bases of the branches. The oœciopore has not been definitely ascertained; it may be an aperture about the same size as a zoœcium, but with practically no oœcial tube.

This form does not appear to have been described and is, in appearance, intermediate between *Entalophora clavata* and *supercytis;* it is proposed to name it *E. vancouverensis.*

Distribution. Cardale Point; Round Island. Low tide.

Genus DIASTOPORA (pars) Lamouroux, 1821.

Diastopora patina Lamarck.

Reference. Hincks (p 458, Pl. LXVI), England; Hincks (11*b*, p. 35), Pacific N.A.

Distribution Bull Passage. 15-25 fms.

Diastopora obelia Johnston.

Reference. Hincks (7, p. 462, Pl. LXI), England.

Distribution. Bull Passage. 15-25 fms.

Genus HETEROPORA Blainville, 1834.

Heteropora pelliculata Waters.

Reference. *Heteropora sp*? Whiteaves (24, p. 279); *Entalophora capitata* Robertson (16, p. 328, Pl. XXI); *H. pelliculata* Robertson (21, p. 258, Pl. 25), Pacific N.A.

Distribution. Brotchie Ledge, Victoria; Masset; Cape Ebenshaw; off Banks Island. 15 fms.

Robertson has noted that there is some variation in this species and a slender and a stout form are to be found. In the material here examined the same difference was found. The stouter form was from Masset, Queen Charlotte Islands (vide Robertson, Pl. 25, Fig. 52), and the more slender form from Brotchie Ledge, Victoria (vide Robertson, Pl. 25, Fig. 51).

Heteropora magna sp. nov. (Pl. I, Fig. 8).

The base of the zoarium is formed by a flat incrustation upon a stone, and this apparently grows throughout life. From this crust arise a number of stout circular stems 3-4 mm. in diameter; these branch dichotomously as they pass upwards and are of constant thickness, swelling somewhat at the tip. The colony thus tends to assume a spherical form save where interrupted by the substratum. The branches anastomose here and there, but not so frequently as in *H. pelliculata*, and the colony as a whole has a much more stout and compact appearance than in the latter species and may measure 100 x 70 mm. The zoœcial apertures are circular and for the most part level with the surface, but in the deeper lying branches they may project upwards as short tubes about 1 mm. long. The entire surface of the colony is covered with pores, which fill in all the spaces between the zoœcial apertures. In *H. pelliculata* there are a number of pores, interstitial canals, distributed around the zoœcial opening, but they are quite separate from one another and in some cases they are entirely covered by a thin calcareous lamella. In the present species, however, the pores of the interstitial canals occupy all the surface of the colony and are separated only by their common walls. Thus the surface has a much more porous appearance and in a number of specimens we have never once seen them hidden beneath a calcareous crust. Indeed the whole colony has a characteristic surface, the nearest approach to which in *H. pelliculata* is to be found only at the growing tips of the branches.

Nothing resembling an oœcium or oœciopore was found.

Distribution. Gabriola Pass; Brotchie Ledge, Victoria. 8-18 fms.

The specimen in the Provincial Museum at Victoria belonging to this species is roughly circular and measures 80 mm. in diameter; it is slightly less compact than the forms taken from Gabriola Pass.

While the present form resembles *H. pelliculata* in certain respects it nevertheless differs in the character of the surface, due to the relation between zoœcia and interstitial canals and in the form of growth. It does not appear to have been described previously and the name *H. magna* is suggested to call attention to its large size and massive build.

Family Lichenoporidae Smitt, 1866.

Genus LICHENOPORA Defrance, 1823.

Lichenopora hispida Fleming.

Reference. Hincks (7, p. 473, Pl. LXVIII), England; Hincks (11*b*, p. 36), Pacific N.A.

Distribution. Gabriola Pass; Bull Passage. 15-25 fms.

In some respects this is like *L. verrucaria*, but it is concave and has a wide upstanding margin.

Lichenopora radiata Audouin.

Reference. Hincks (7, p. 476, Pl. LXVIII), England; Robertson (21, p. 262, Pl. 24), Pacific N.A.

Distribution. Gabriola Pass. 15 fms.

Lichenopora verrucaria Fabricius.

Reference. Hincks (7, p. 478, Pl. LXIV), Harmer (5, p. 71), England; Osburn (15, p. 219, Pl. XVIII), Atlantic; Hincks (11*b*, p. 36) and Robertson (21, p. 263, Pl. 25), Pacific N.A.

Distribution. Northumberland Channel; Round Island; West of Hammond Bay. Low tide—20 fms.

Lichenopora regularis d'Orbigny.

Reference. Hincks (7, p 479, Pl. LXVIII), England.

Distribution Bull Passage. 15-25 fms.

Lichenopora fimbriata Busk.

Reference. Busk (2, p. 26).

Distribution. Round Island. Low tide.

Lichenopora fava sp. nov. (Pl. I, Fig. 9).

The zoarium is discoid and completely adnate, and has so far been found on pieces of old shells. It is usually circular and raised slightly in the middle, but may be a little less regular and very flat. The zoœcia are polygonal, but it is difficult to make out their disposition since they do not project from the surface of the colony and in most specimens are indistinguishable from the interzoœcial pores. The appearance of the colony is quite striking and, owing to the pores and zoœcia being approximately equal, the whole surface appears like a honeycomb. At first it was thought that this appearance was due to the colony being old and being ground down by wave action. However, closer examination showed that this was not the case for in some colonies inside the umbo of an old shell, or surrounded by Serpulid tubes and alive, there is no sign of the zoœcium projecting above the surface either in the older part of the colony or at the growing edge. The oœcium is an inflation of the central region, but the oœciopore has not been definitely recognized, unless it is an orifice like the others but of slightly larger size. At all events it is not a striking aperture.

Distribution. Northumberland Channel. 15-18 fms.

As noted above, the striking characteristic of this species is the non-projecting zoœcia, so that it resembles a honeycomb. If it is undescribed, as seems probable, the name *L fava* is therefore suggested.

Genus SUPERCYTIS

This genus has not been recorded previously from the Pacific Coast of North America.

Supercytis digitata d'Orbigny.

Reference. Busk (2, p. 29, Pl. V).

Distribution. Sponge beds outside Departure Bay; entrance to Departure Bay. 15-20 fms.

This seems to be younger than the form figured by Busk, some of the zoœcia open on the stalk, but it is so similar that it is here identified with *S. digitata.*

Sub-class ECTOPROCTA Nitsche, 1869.

Order *GYMNOLAEMATA* Allman, 1856.

Sub-order CHEILOSTOMATA Busk, 1852.

Family AETEIDAE Smitt, 1867.

Genus AETEA Lamouroux, 1812.

Aetea truncata Landsborough.

Reference. Hincks (7, p. 8, Pl. I), England; Robertson (19, p. 246, Pl. IV), Pacific N.A.

Distribution. Departure Bay; between Jesse and Newcastle Islands; Nanoose Bay; Northumberland Channel; North Bay; off Snake Island; West of Hammond Bay; Northwest Bay; off Banks Island; off Protection Island; Cape Ebenshaw; West Rockies; Friday Harbour. 5-35 fms.

Family EUCRATIIDAE Hincks, 1880.

Genus GEMELLARIA Savigny, 1811.

Gemellaria loricata Linnaeus.

Reference. Hincks (11*b*, p. 3); Robertson (19, p. 249, Pl. V), Pacific N.A.

Distribution. West of Rose Spit; inside Rose Spit; off Masset; Cape Ebenshaw; Rose Spit. 6-15 fms.

Genus BRETTIA Dyster, 1858.

This genus has not been recorded previously from the Pacific Coast of North America, but is represented in the present material by two species.

Brettia pellucida Dyster.

Reference. Hincks (7, p. 28, Pl. IV), England.

Distribution. Northumberland Channel; Departure Bay. 15-20 fms.

Brettia tubaeformis Hincks.

Reference. Hincks (7, p. 28, Pls. II and V), England.

Distribution. Cape Ebenshaw. 15 fms.

Family CELLULARIIDAE (pars) Johnston, 1849.

Genus CELLULARIA Pallas, 1766.

This genus has not been recorded previously from the Pacific Coast of North America.

Cellularia peachii Busk.

Reference. Hincks, 1880 (7, p. 3, Pl. V), England; Osburn (15, p. 223 Pl. XXI), Atlantic.

Distribution. West of Gabriola; Halibut Bank; Swiftsure Shoal. 15-25 fms.

Genus MENIPEA Lamouroux, 1812.

Menipea ternata Ellis & Solander, 1786

Reference. Hincks (7, p. 38, Pl. VI), England; Osburn (15, p 222, Pl. XXXI), Atlantic; Robertson (19, p. 251, Pl. V), Pacific N.A.

Distribution. False Narrows; Ucluelet; Cardale Point, Round Island; Northumberland Channel; west of Rose Spit; Swiftsure Shoal Low tide—25 fms.

Menipea gracilis Busk.

Reference. Hincks (11*b*, p. 3) and Robertson (19, p. 253, Pl. VI), Pacific N.A

Distribution Bull Passage; Swiftsure Shoal; Banks Island; Cape Ebenshaw. 15-25 fms.

Menipea occidentalis Trask.

Reference. *Menipea occidentalis* Trask (22, p. 113, Pl. 4), Pacific N.A.; *Menipea compacta* var. *triplex* Hincks (11*b*, pp 3 and 38), Pacific N.A.; *Menipea occidentalis* Robertson (19, p. 254, Pl. VI), Pacific N.A.

Distribution. Duke Point Lagoon; Cape Ebenshaw Low tide—15 fms.

Robertson (19, p. 255, Pl. VII) has recognized a sub-species of this under the name *M. occidentalis catalinensis* distinguished mainly by the number of spines and the number of zoœcia in an internode. The present material has some forms that approximate to the original species, but also a number of others that are intermediate between that and the sub-species. They have all been included under the one specific appellation here, since none of them quite reaches the extremes exemplified in Robertson's sub-species.

Menipea erecta Robertson.
Reference Robertson (19, p 256, Pl. VII), Pacific N.A.
Distribution. False Narrows; entrance to Departure Bay; Alert Bay. Low tide—15 fms

Menipea pribilofi Robertson.
Reference. Robertson (19, p. 257, Pl. VII), Pacific N.A.
Distribution. Ucluelet.

I have been able to examine some of the original type material and find the present form indistinguishable from it.

Genus SCRUPOCELLARIA Van Beneden.

Scrupocellaria californica Trask
Reference. *Scrupocellaria californica* Trask (22, p 114, Pl. 4), Pacific N A
Possibly *Scrupocellaria brevisetis* Hincks (11*b*, p. 5), Pacific N.A.
Distribution. False Narrows; Nanoose Bay; Swiftsure Shoal; Banks Island. Low tide—25 fms.

Scrupocellaria varians Hincks
Reference Hincks (11*b*, p. 4, Pl. XIX); Robertson (19, p. 260, Pl. VIII), Pacific N.A.
Distribution. False Narrows; between Jesse and Newcastle Islands; Round Island; Ballenac Islands; Northumberland Channel; North Bay; east of Protection Island; Nanaimo Harbour; entrance to San Juan Gulf; Ruxton Passage. Low tide—25 fms.

Scrupocellaria diegensis Robertson.

Reference. Robertson (19, p. 261, Pls. IX and XVI), Pacific N.A.
Distribution. Swiftsure Shoal. 25 fms.

Scrupocellaria inermis sp. nov. (Pl. I, Fig. 10).

Only one or two specimens of this were obtained and none of them shows an oœcium so that perhaps the colonies were all young and this may account for their size.

Zoarium, a small branched tuft about 10 mm. high. The branching is dichotomous, but one branch tends to keep on in the same line as the axis and the lateral ones pass off alternately to right and left. The number of zoœcia in an internode varies from 5 at the base to 9 at the apex. The joints are of a pale yellow. The zoœcia are biserial, alternate, broader above and narrowing below. The aperture is a regular oval occupying more than half the front surface; it is surrounded by a distinct margin and is without a scutum. No spines were to be found anywhere. The lateral avicularia are small, triangular, uniform in size and situated at the antero-ventral corner of the zoœcium. Frontal avicularia are always present on the terminal zoœcium in an internode and lie just below the aperture, practically in the middle line. They are not found on the basal zoœcia, but sometimes on the penultimate member and in one case, while absent in the eighth one, is present in the seventh. The vibracular chamber is situated at the antero-dorsal corner of the zoœcium. It is small, triangular, and the vibracular groove runs practically transversely to the axis of the branch. The vibraculum is short, fine, and generally curved and does not quite reach to the anterior end of the zoœcium in front. Rootlets are not unfrequently developed and arise from the base of the vibracular chamber. Oœcium; as noted above no material was available in which this structure was developed.

Of the forms described from the Pacific Coast of North America this most nearly resembles *S. varians*, but differs in size, being slightly smaller, in the absence of spines, of scutum and of median avicularia on the lower zoœcia in the internodes. It has shorter vibracula and none of the lateral avicularia are of the large form found here and there in *S. varians*. Compared with this species it is relatively unarmed and, as it does not appear to have been described, the name *Scrupocellaria inermis* is suggested.

Distribution. Trincomali Channel. 16 fms.

Genus CABEREA Lamouroux, 1816.

Caberea ellisii Fleming.

Reference. Hincks (7, p. 59, Pl. VIII), England; Osburn (15, p. 222, Pls. XXI and XXXI), Atlantic; Robertson (19, p. 263, Pls. VIII and IX), Pacific N.A.

Distribution. Gabriola Pass; Bull Passage; Nanoose Bay. 7-35 fms.

Caberea boryi Audouin.

Reference. Hincks (7, p. 61, Pl. VIII), England; (11*b*, p. 5), Pacific N.A.

Distribution. North of Gabriola; entrance to Departure Bay; Bull Passage; North Bay, Thetis Island; Swiftsure Shoal; Snake Island; Ruxton Passage; east of Protection Island. 10-30 fms.

Family BICELLARIIDAE Busk, 1852.

Genus BICELLARIA Blainville, 1830.

This genus has not been recorded previously from the Pacific Coast of North America.

Bicellaria brevispina sp. nov. (Pl. II, Fig. 11).

The zoarium is phytoid, transparent and composed of slender dichotomously branched stems. The zoœcia are alternate and arranged in two lateral closely apposed series. They are slightly turbinate and elongated, the upper end being broad and the lower much drawn out. The dorsal surface is smooth, the aperture is elongated and broader above than below. The spines vary in number and position, but are always quite short. In the majority of the zoœcia spines

are entirely absent; in others one may be developed at the antero-lateral corner; in others two may be found, one at each anterior corner or one at the antero-median corner and another about half way down the median border. In a few cases three spines are present, one at each front corner and one on the inner or antero-lateral border, or more rarely all three may be on the same side. These variations in the number and position of the spines may all occur in the same colony so that they are not varieties. Neither avicularia nor oœcia were found in any of the material, although both are probably developed.
Distribution. North of Gabriola Island. ? fms.

Genus BUGULA Oken, 1815.

Bugula avicularia Linnaeus.
Reference. Hincks (7, p. 75, Pl. X), England; Osburn (15, p. 226, Pl. XXI), Atlantic; Hincks (11*b*, p. 5), Pacific N.A.
Distribution. Jesse Island; Mudge Island. Low tide.

Bugula murrayana Johnston.

This widely distributed species is subject to considerable variation and three distinct types are included in the large amount of material examined. In addition to the typical variety there is a variety corresponding with that termed *fruticosa* by Packard and one like the specimens described by Robertson as "more delicate in appearance, forming smaller colonies." The species will be listed under three heads.

var. *typica*. Similar to the typical form with a tendency to exhibit more spines.
Reference. Hincks (7, p. 75, Pl. X), England; Osburn (15, p. 226, Pl. XXII), Atlantic; Hincks (11*b*, p. 6) and Robertson (19, p. 266, Pls. X and XVI), Pacific N.A.
Distribution. North of Gabriola; Northumberland Channel; Nanoose Bay; west of Rose Spit; west of Hammond Bay; Banks Island; Departure Bay; Ruxton Passage. 5-30 fms.

var. *fruticosa*. Packard.
Reference. Hincks (7, p. 93, Pl. XIV), England.
Distribution. Nanoose Bay; Northwest Bay; off Jesse Island; Banks Island; Cape Ebenshaw; Northumberland Channel. 10-25 fms.

var. *parva*. This variety is characterized by its smaller size, the narrower branches and the absence of marginal avicularia.
Reference. Robertson (19, p. 267, Pl. XVI), Pacific N.A.
Distribution. Trincomali Channel; between Jesse and Newcastle Islands; west of Gabriola Island; Burrard Inlet; Rose Spit. 15-25 fms.

Bugula californica Robertson.
Reference. Robertson (19, p. 267, Pls. X and XVI), Pacific N.A.
Distribution. Cardale Point; False Narrows; east of Protection Island. Low tide—25 fms.

Bugula pacifica Robertson.
Reference. Robertson (19, p. 268, Pls. X and XVI), Pacific N.A.

Distribution. Cardale Point; False Narrows; Gabriola Pass; Duke Point Lagoon; Round Island; Ballenac Islands; Cape Ebinshaw; Northumberland Channel; Black Rock. Low tide. 20 fms.

This agrees closely with the form described, save that the lateral spines are not quite so long.

Bugula pugeti Robertson.

Reference. Robertson (19, p. 271, Pl. XI), Pacific N.A.

Distribution. False Narrows; Jesse Island; Black Rocks; Brandon Island; Gabriola Pass; Cardale Point; Round Island; Ballenac Islands; entrance to Gabriola Pass. Low tide—15 fms.

Bugula curvirostrata Robertson.

Reference. Robertson (19, p. 272, Pl. XI), Pacific N.A.

Distribution. Trincomali Channel; between Jesse and Newcastle Islands; Buccaneer Bay; Nanoose Bay; Banks Island; Northumberland Channel. 8-20 fms.

Robertson says of this species that it "has not been taken north of Pacific Grove (California). It appears to be characteristic of southern waters and may perhaps occupy the place in the southern fauna taken in the north by *B. murrayana*." The two species overlap in the area now under consideration and, as will be seen, have been collected at the same places and actually taken in the same haul.

Bugula longirostrata Robertson.

Reference. Robertson (19, p. 274, Pl. XI), Pacific N.A.

Distribution. Cape Ebenshaw. 15 fms.

Bugula laxa Robertson.

Of this species Robertson says: "This species resembles both *Bugula* and *Flustra* so greatly that it is difficult to decide into which genus it should be placed. The shape of the zoœcia, the looseness of their connection with each other, and more especially the fact that each individual zoœcium arises from a bud formed independently from a parent zoœcium, and not from a common growing margin as in the *Flustras,* indicate a closer relationship to Bugula;" an opinion with which we concur.

In the material examined two distinct types could be distinguished, one referable to the form described by Robertson and a more slender variety.

var. *typica*. Resembling the type.

Distribution. False Narrows; off Brandon Island; Gabriola Pass; Ballenac Islands. Low tide—15 fms.

var. *attenuata*. This variety is distinguished by the fact that the arrangement of the zoœcia tends to be biserial, less frequently there are three in a row and only rarely four; the result is a much finer and drawn-out type of colony, although in other points it agrees with the species.

Distribution. Gabriola Pass (small amount); Ballenac Islands (plentiful). Low tide—15 fms.

Bugula cucullifera Osburn.
Reference. Osburn (15, p. 225, Pl. XXII), Atlantic.
Distribution. Nanoose Bay. 8-20 fms.

Genus BEANIA Johnston, 1847.

Beania columbiana sp. nov. (Pl. II, Fig. 12).

The zoarium is in the form of a flattened network attached loosely to a substratum. No long attaching stalk, such as we find in *B. mirabilis* or *B. longispinosa*, is present. The zoœcium is separate, boat-shaped and stands up at an angle of about 45° to the plane of the connecting tubes; the aperture is membranous and occupies the whole of the front and the orifice is terminal and somewhat between rectangular and semicircular. One of the most striking features is the enormous development of spines which pass in a double line around the margin of the aperture. On the curved anterior portion there are from 9-11 long, thin, pointed spines, standing out widely from the zoœcial wall, and a similar number of shorter spines which curve in slightly over the aperture. There are, as a rule, also six similar pairs of spines along each side of the aperture, while the broader posterior curved end bears no spines. It is to be noted that the spines are always in pairs, a longer one flaring outwards and a shorter one curving inwards; they actually arise from the same spot and frequently the pair have a short common stem. In addition to these spines on the ventral surface they are also developed on the dorsal surface in the region where the connecting stalks are given off. There are three stout spines lying in the interspaces between the anterior and lateral connecting stalks and each spine breaks up into two, or more usually three or four and in rare instances five long pointed ends.

From the basal portion of the dorsal surface arise six connecting stems almost at equal angles to one another. The two lateral ones pass out roughly at right angles to the line of the zoœcium, so that the two others pass obliquely forwards and two obliquely backwards. They are quite long and join with those of the neighbouring zoœcia so that the basis of the colony is this network of wide triangular meshes formed by the connecting stems. The zoœcia themselves are separated by a distinct space from one another and arranged in sloping lines.

Several pieces of this species were obtained, the two largest measuring 10 x 8 mm., but no rootlets or oœcia were found.

This is one of the most beautiful species examined and does not appear to have been described before; it is here proposed to call it *B. columbiana*.
Distribution. Banks Island; Cape Ebenshaw. 15 fms.

Genus STIRPARIA Goldstein, 1879 or 1880.

Stirparia ciliata Robertson.
Reference. Robertson (19, p. 279, Pls. XII and XIII), Pacific N.A.
Distribution. Bull Passage. 15-25 fms.

Stirparia occidentalis Robertson.
Reference. Robertson (19, p. 280, Pl. XIII), Pacific N.A.
Distribution. West Rocks. 8-25 fms.

Stirparia californica Robertson.

Reference. Robertson (19, p. 281, Pls. XIII and XIV), Pacific N.A.

Distribution. Burrard Inlet; Nanoose Bay; off Protection Gap; Departure Bay; entrance to Departure Bay. 8-20 fms.

Genus CORYNOPORELLA Hincks, 1888.

Corynoporella spinosa Robertson.

Reference. Robertson (19, p. 284, Pl. XIV), Pacific N.A.

Distribution. Swiftsure Shoal. 25 fms.

Family Cellariidae Hincks, 1880.

Genus CELLARIA Lamouroux, 1812.

Cellaria borealis Busk.

Reference. Robertson (19, p. 287, Pls. XIV and XVI), Pacific N.A.

Distribution. Banks Island.

Cellaria mandibulata Hincks.

Reference. Hincks (11*b*; p. 6) and Robertson (19, p. 288, Pls. XV and XVI), Pacific N.A.

Distribution. False Narrows; Buccaneer Bay; Swiftsure Shoal; Banks Island; Cape Ebenshaw. Low tide. 25 fms.

Cellaria diffusa Robertson.

Reference. Robertson (19, p. 289, Pls. XV and XVI), Pacific N.A.

Distribution. North of Gabriola Island; west of Gabriola Island; Trincomali Channel; Halibut Bank; Maude Island; between Jesse and Newcastle Islands; between Round and Mudge Islands; entrance to Departure Bay; Nanoose Bay; west of Hammond Bay; Northwest Bay; Swiftsure Shoal; off Protection Island; east of Snake Island; off Jesse Island; Banks Island; Northumberland Channel; entrance to Nanoose Bay; Ruxton Passage; West Rocks; Departure Bay. A widely distributed species. 5-40 fms.

Family Flustridae Smitt, 1867.

Genus FLUSTRA Linnaeus, 1758.

Flustra lichenoides Robertson.

Reference. Robertson (19, p. 291, Pls. XV and XVI), Pacific N.A.

This is a common species throughout the area and most of the material agrees with Robertson's description, but in addition to the range of variation which is there noted another form was found which was distinct enough to be rated as a variety.

var. *typica*. This agrees with Robertson.

var. *spinosa*. This differs from the typical form not only in the possession of a larger number of more developed spines, but also in being of a much more slender and delicate habit of growth so that it can easily be picked out with the naked eye.

Distribution. The two forms are fairly well mixed and separate records of the two varieties have not been kept. Between Jesse and Newcastle Islands; False Narrows; Cardale Point; Lock Bay; between Round and Mudge Islands; Gabriola Pass; Ballenac Islands; Duke Point Lagoon; Nanoose Bay; off Protection Gap; Trincomali Channel; Northwest Bay; Black Rock. Low tide. 20 fms.

Flustra membranaceo-truncata Smitt.
Reference. Robertson (19, p. 290, Pl. XV), Pacific N.A.
Distribution. Banks Island.

We have been able to examine some of Robertson's material and find the present form indistinguishable from it.

Flustra simplex sp. nov. (Pl. II, Fig. 13).

The zoarium is unilaminar and in the form of a small dichotomously branched colony. It is attached by stout tubular rootlets which arise from near the middle of the back of the lowermost zoœcia. The general form resembles that of a *Bugula* colony, its branches being comparatively narrow. The zoœcia are alternate in arrangement, elongated, rounded above and truncate and narrower below (linguiform). They are practically in a single row at the base, but increase until later they are from 9-10 in a transverse row at the broadest part. The aperture is oval and occupies the major part of the ventral side; the stoma projects slightly and is semicircular in shape. Spines and avicularia are absent and no oœcia were found.

In certain respects the shape of the zoœcia recalls those of *Flustra carbasea* (Ellis & Solander) as described by Hincks; particularly in the absence of spines, avicularia and oœcia. They are, however, of smaller and slightly different shape, the branching is more regular and the individual branches far more slender; indeed, as noted above, it is much like a *Bugula* in appearance.

It has not been found described and the name *Flustra simplex* is here suggested.
Distribution. North of Gabriola Island. ? fms.

Family Membraniporidae Busk, 1854.

Genus MEMBRANIPORA Blainville.

Membranipora circumclathrata Hincks.
Reference. Robertson (20, p. 259, Pl. 14), Pacific N.A.
Distribution. Cardale Point; Round Island; Bull Passage; Northumberland Channel; Nanoose Bay; Swiftsure Shoal; Friday Harbour. Low tide—20 fms.

Very similar to description, but occasionally two avicularia are present at the base of the aperture.

Membranipora horrida Hincks.
Reference. Hincks (11*b*, p. 7) and Robertson (20, p. 260, Pl. 14), Pacific N.A.
Distribution. False Narrows; Gabriola Pass; Round Island; Northumberland Channel; China Hat; Nanoose Bay; off Protection Island; off Snake Island; Friday Harbour. Low tide—20 fms.

This form is similar to the type, but there is a tendency to the production of more spines and variation in the avicularia.

Membranipora lacroixii Audouin.
Reference. Hincks (7, p. 129, Pl. XVII), England; Osburn (15, p. 227, Pl. XXII), Atlantic; Robertson (20, p. 261, Pl. 14), Pacific N.A.

The description given in Hincks allows for a wide range of variation, so much so that in the present material three forms stand out rather sharply and seem worthy of noting separately.

var. *triangulata*. In this variety there is a well marked triangular depression, surrounded by a raised margin, on each side immediately above the aperture giving the colony a characteristic appearance.

var. *paucispina*. Here the triangular depression is lacking and the zoœcium bears a few spines, one or two on each side above.

var. *multispina*. This variety is characterized by the absence of triangular depressions and the presence of a much larger number of spines, thus giving a distinctive appearance.
Distribution. Separate records of the distribution of the three varieties were not kept. Gabriola Pass; Cardale Point; Northumberland Channel; Ballenac Islands; Friday Harbour. Low tide—10 fms.

Membranipora occultata Robertson.
Reference. Robertson (20, p. 262, Pl. 14), Pacific N.A.
Distribution. False Narrows; Round Island; Duke Point Lagoon. Low tide.

This is similar to the description, but there is often one stiff spine and two flexible spines.

Membranipora patula Hincks.
Reference. Hincks (11*b*, p. 7) and Robertson (20, p. 263, Pl. 15), Pacific N.A.
Distribution. North of Gabriola Island; entrance to Departure Bay; Gabriola Pass; Namu Harbour; Fitzhugh Sound; Round Island; Nanoose Bay; west of Hammond Bay; China Hat; Northumberland Channel; off Snake Island; Banks Island; east of Protection Island; Nawhitte Bar; Friday Harbour. Low tide—30 fms.

Hincks (11*b*, p. 8) states that this "species forms brown or reddish-brown patches." Most of the material we have examined alive was of a deep purple colour, making a striking incrustation upon the substratum.

Membranipora pallida Hincks.
Reference. *Membranipora acifera* Macgillivray form *multispinata* Hincks (11*b*, p. 8, Pl. XIX); *Membranipora pallida* Hincks (11*b*, p. 39), Pacific N.A.
Distribution. In dredged material; locality not given.

Membranipora protecta Hincks.
Reference. Hincks (11*b*, p. 10, Pl. XIX), Pacific N.A.
Distribution. Round Island; Ballenac Islands; Bull Passage. Low tide—25 fms.

Membranipora spinifera Johnston.
Reference. Hincks (7, p. 149, Pl. XIX), England; Robertson (20, p. 265, Pl. 15), Pacific N.A.
Distribution. Gabriola Pass; Northumberland Channel; Ballenac Islands. Low tide—12 fms.

In some cases, in addition to the pair of pedunculate avicularia borne about half way along the margin of the zoœcium, another pair (or rarely two additional pairs) are borne right at the front and outside the row of spines.

Membranipora membranacea Linnaeus.
Reference. Hincks (7, p. 140, Pl. XVIII), England; Hincks (11*b*, p. 11) and Robertson (20, p. 267, Pl. 16), Pacific N.A.
Distribution. Ucluelet.

Membranipora serrata Hincks.
Reference. Hincks (11*b*, p. 12), Robertson (20, p. 268, Pl. 16), Pacific N.A.
Distribution. Departure Bay; Gabriola Pass; Ballenac Islands; etc. On kelp.

Membranipora villosa Hincks.
Reference. Robertson (20, p. 268, Pl. 16), Pacific N.A.
Distribution. Departure Bay; Gabriola Pass; Ballenac Islands; Round Island; etc. On kelp.

The distribution of the above two species is by no means complete; the places given are those from which bottled material is in the Station collection. They are found on Eel-grass, *Zostera marina;* Kelp, *Nereocystis leutkeana;* various algae, *e.g.*, *Laminaria bullata*, *Costaria costata*, *Cystophyllym geminatum*, etc. Actually the second species, *M. villosa*, was seen at practically every place where Eel grass or kelp was growing from Lasquiti Island in the north to Friday Harbour, San Juan Islands, U.S.A., in the south, and the first species at very nearly as many places.

Membranipora alcicornis sp. nov. (Pl. II, Fig. 14).

The zoaria form small, delicate, white, spiny incrustations on the surface of pebbles and shells. The zoœcia are small oval and alternate. The aperture is oval and large, occupying quite a third of the surface, and it is surrounded by a definite rim. The remainder of the surface is covered by a calcareous lamina marked by circular granulations. Thus it falls in the division of the *Membranipora* possessing a lamina, *i.e.*, those separated off by Busk as *Amphiblestrum*. At the anterior corners of the aperture are a pair of upstanding, simply branched spines; just below the corners are a second incurving pair, and these divide into two and into two again, and sometimes the foremost branch again bifurcates near the tip. About half way down on each side is another, somewhat more palmate, antler-like spine with 3 or rarely 4 "tines;" this curves in over the aperture. In certain respects this form recalls *M. cornigera* Busk or *Amphiblestrum cervicorne* Busk, but differs in a number of points from both species. No avicularia appear to be present. The oœcium is prominent, roughened, sub-spherical, and granular; its aperture is almost semicircular and directed posteriorly, and there is the faint indication of a rim around it. It lies at the anterior end of the zoœcium and nearly covers the lamina of the zoœcia in front.

A number of colonies were found but they presented very little variation, and that mainly in the relative size of the spines. It does not appear to have been described and the name *M. alcicornis* is suggested to call attention to the spines, which suggest Elk's horns, and which are mainly responsible for the beautiful appearance of the species.

Distribution. Between Jesse and Newcastle Islands; off Protection Island; Northumberland Channel; Gabriola Pass. 8-20 fms.

Membranipora cassidata sp. nov. (Pl. II, Fig. 15).

The zoarium forms a unilaminar incrustation over sponges, shells, hydroid stems, etc., and is of a very even texture. The zoœcium is large; the anterior three quarters is occupied by a large oval *aperture* surrounded by a definite rim and the posterior narrower region is covered by a granular lamella. The zoœcia are very regular in distribution and alternate in arrangement. A short, stout, hollow spine passes up vertically from near the anterior end of each side of the aperture; a smaller spine is sometimes developed a short distance in front of this, but is never visible when the oœcium is developed. Almost touching, but just in front and outside the main spine is a small avicularium borne on a short stalk; the mandible lies almost vertically and is directed anteriorly and slightly inwards. At the posterior end of each zoœcium in the middle line is a larger avicularium borne on a stouter stalk; its mandible is almost vertical and directed forwards and slightly upwards.

An oœcium is developed at the anterior end of practically all the older cells of a colony; indeed, it is usually only the marginal cells that are without. The oœcium is a hemispherical, helmet-shaped structure that entirely covers the posterior area of the zoœcium in front. It is smooth and possesses around its lower margin a sort of inset rim, forming a distinct and moderately deep ridge. The ridge around the oœcium is not straight as in *M. unicornis* Hincks, but of a bow shape.

The development of the oœcium entirely alters the morphological relations of the posterior avicularium. In the first place it actually increases very markedly in size, so that it becomes noticeably large. In the second, instead of the mandible being almost vertical and pointing forwards and slightly upwards, it comes to lie almost horizontally and points upwards and slightly backwards. In addition to this also instead of its main axis coinciding with that of the cell it becomes set at almost 45° to this line, so that the pointed end of the avicularium and its stalk is well to the right or left of the middle line. There appears to be no uniformity in the direction which is taken by the avicularium, so that they may point the same or opposite ways on two adjacent oœcia.

This is a fairly common species and a very characteristic one. It does not appear to have been described and the name *M. cassidata* is suggested to call attention to the helmeted appearance of the zoœcia.

Distribution. West of Gabriola; Buccaneer Bay; Sponge beds outside Departure Bay; entrance to Departure Bay; off Brandon Island; Gabriola

Pass; off Snake Island; Bull Passage; off Protection Gap; west of Hammond Bay. 15-35 fms.

Membranipora aquilirostris sp. nov. (Pl. II, Fig. 16).

The zoarium forms an approximately circular patch closely adherent to stones, shells, or kelp, and often overgrowing *Schizoporella hyalina;* the outer margin of the colony is usually of a deep yellow colour. It presents a close fine texture. The zoœcium is of moderate size, with the main part of the ventral wall occupied by a large oval aperture surrounded by a marked, smooth, raised margin and the narrower posterior region covered with a lamella. The operculum is semicircular. A pair of short incurving pointed spines are present about one-third of the way down each side. Sometimes, more particularly in the older parts of the colony, there may be a pair of spines on each side. A large avicularium is produced on the posterior flat region of the zoœcium, completely covering it. It is set at an angle of about 45° to the long diameter of the aperture, with the point of the mandible directed forwards. The mandible is almost horizontal, but is slightly more elevated at the anterior end. The beak is sharply recurved at the tip, this recalling the beak of an eagle.

The zoœcia are tightly packed and there is some variation in size. No oœcia were found on any of the colonies, although some of them were of considerable size.

A description of the species has not been found and it is proposed to call it *M. aquilirostris* to call attention to the shape of the avicularium.

Distribution. False Narrows; Gabriola Pass; off Protection Gap. Low tide—25 fms.

Membranipora alba sp. nov. (Pl. II, Fig. 17).

The zoarium forms a white incrustation upon the surface of stones and shells. The zoœcium is of fair size and the whole of the ventral surface is occupied by the large oval aperture. This is surrounded by a raised granular margin, the inner edge of which is minutely serrate, recalling the same structure in *M. lacroixii.* The operculum is somewhat rectangular with rounded corners. The avicularium of this form is very large, surrounded by a raised margin, and falls in the series like the ordinary zoœcia. From its structure and position it plainly indicates that it is to be regarded as a modified zoœcium. The mandible is very well developed, broad at the posterior end and passing off to a vibraculoid tip. It recalls that of *M. pallida,* but is, if anything, more developed. Indeed the present form resembles that species in several ways, but it entirely lacks spines, the apertures are more oval, the margins more granular and serrate and oœcia are developed.

The oœcium is a prominent structure in the form of a much flattened shallow hemisphere with a narrow semi-membranous rim around the front of it. It may be that intermediate forms will link this with *M. pallida* but, at present, the differences seem to merit it being listed as a separate species.

Distribution. Off Protection Gap. 20-25 fms.

Membranipora inconspicua sp. nov. (Pl. II, Fig. 18).

The zoarium forms a thin, inconspicuous, yellowish coloured crust upon the fronds of the kelp *Nereocystis luetkiana*. The small zoœcia are oval, tending towards polygonal. The edges are covered by a thin, almost transparent, white lamella, which passes upwards to a fairly regular oval aperture. The aperture thus has a sort of curved border round it, wider at the posterior end than elsewhere. Commonly two small avicularia are borne on this border, one on each side about one-third of the way from the front end: their rounded mandibles face upwards and slightly inwards and forwards. Sometimes, when an oœcium is present, a third slightly larger avicularium is produced at the end of this, its mandible facing upwards and directed forwards.

The margin of the aperture is beset with spines; the six at the anterior end being much longer and more upright than the others, so that they form a distinct group; around the remaining portion of the margin are 10 small pointed spines directed inwards over the aperture. When the oœcium is developed the anterior pair of spines generally disappears.

The oœcium is quite small, but prominent. It is smooth, sub-globular, with a semicircular mouth directed backwards, around which is a thinner rim. As noted, this sometimes bears an avicularium at its anterior end.

The species appears to be undescribed and the name *M. inconspicua* is here proposed. The general shape of the aperture, the arrangement and number of spines and the anterior avicularium strongly recall *M. craticula* Alder. However, the apertures have a far wider margin, upon which are the marginal avicularia; the oœcium is relatively smaller and has no transverse bar, and the spines do not overlap to such an extent.

Distribution. Northwest Bay; off Snake Island. 10-20 fms.

Membranipora varians sp. nov. (Pl. III, Fig. 19).

The zoarium forms small, fragile, semi-translucent, whitish crust over hydroid stems, etc. The zoœcium is not large and the anterior two-thirds is occupied by the oval aperture, around which passes a thin low rim; the posterior end is occupied by a semi-transparent, white membrane. Three avicularia are typically produced; the largest is borne at the front end of the zoœcium upon a short truncated conical stalk which grows forward over the hinder slightly pointed and directed almost vertically facing forwards. The two lateral avicularia are considerably smaller, their mandibles face forwards and they point in an oblique direction upwards and outwards. The distribution of the spines is subject to considerable variation. They may be absent altogether; one may be produced, either replacing one lateral avicularium or just behind and internal to it; two spines may be produced in the same manner, one on each side of the aperture; in addition to these, two or three spines may be developed around the anterior margin of the aperture. Thus it is possible for from 0-5 spines to be present, but actually four was the most observed. The spines themselves are cylindrical and hollow and may be short or very long; as a rule, those by the lateral avicularia are the longest.

No oœcia were found.

The species appears to be new and the name suggested is *M. varians* to call attention to the variation in the number and disposition of the spines and avicularia.

Distribution. Off Protection Gap; off Snake Island. 15-30 fms.

Family MICROPORIDAE Smitt, 1873.

Genus MICROPORA Gray, 1848.

Micropora coriacea Esper.

Reference. Hincks (7, p. 174, Pl. XXII), England; Robertson (20, p. 275, Pl. 17), Pacific N.A.

Distribution. Gabriola Pass. 15 fms.

Family CRIBRILINIDAE Hincks, 1880.

Genus CRIBRILINA Gray, 1848.

Cribrilina annulata Fabricius.

Reference. Hincks (7, p. 193, Pl. XXV), England; Osburn (15, p. 232, Pl. XXIV), Atlantic.

Distribution. Round Island; Ballenac Islands. Low tide.

One piece from the Ballenac Islands is three spined, but the rest is the four-spined variety noticed by Hincks (7, p. 194).

Cribrilina furcata Hincks.

Reference. Hincks (11*b*, p. 12, Pl. XX), Pacific N.A.

Distribution. False Narrows; entrance to Departure Bay; Northumberland Channel; Nanoose Bay; North Bay; off Protection Gap; Thetis Island; Departure Bay. Low tide—25 fms.

Cribrilina hippocrepis Hincks.

Reference. Hincks (11*b*, p. 13, Pl. XX), Robertson (20, p. 280, Pl. 18), Pacific N.A.

Distribution. Gabriola Pass. 15 fms.

Cribrilina radiata Moll. Found only in the form of var. *radiata* Hincks.

Reference. Hincks (7, p. 185, Pl. XXV, Fig. 5), England.

Distribution. Gabriola Pass; Northumberland Channel. 15-18 fms.

Genus MEMBRANIPORELLA (pars) Smitt, 1873.

This genus has not previously been recorded from the Pacific Coast of North America; it is represented in the present collection by one characteristic species.

Membraniporella corbicula sp. nov. (Pl. III, Fig. 20).

The zoarium forms very conspicuous rough, almost circular, light brown patches upon the leaves of *Zostera marina*. They are usually plentiful and vary in size from quite small up to 6-7 mm. in diameter. The zoœcia are of moderate size, oval in shape and fairly closely packed. The anterior end bears generally three spines, the median one pointed and the lateral ones longer and hollow. In some cases the median spine is replaced by two similar sized pointed spines. From the sides of the young zoœcium six or seven pairs of broad ribs grow in over the aperture, very soon they unite in the middle line and also touch one another at various points, so that they form a basket work over the front of the aperture. As is frequently the case in this genus the anterior pair of ribs is stronger and more prominent, forming a sort of lip.

The oœcium is a small almost hemispherical thin-walled chamber with two minute circular pores in the front. The anterior spines are lost when it develops and another pair of broad ribs appear which grow across and form an anterior pair of projecting lips almost hiding the oœcium.
No avicularia are present.

The name *M. corbicula* is suggested for this form, which does not appear to have been described, to indicate that the ribs form a basket-work.
Distribution. On Zostera near Station. Low tide.

Family Microporellidae, 1880.

Genus MICROPORELLA Hincks, 1877.

Microporella ciliata Pallas.

This has been well described by Hincks as a "protean species," offering, as it does, a wide range of variation. It is also very widely distributed both in space and time. In the material now being considered not only is there much variation in the amount of calcification, surface of the zoœcia, relative size of avicularia, number of avicularia, etc., but over and above this five quite distinct types can be made out which are deserving of listing separately.

var. *typica* Hincks. This is the form described as the general form by Hincks.

var. *stellata* Verrill. This variety was described by Verrill as *Porellina stellata*, but united with the present species by Osburn (15, p. 234) as *M. ciliata* var. *stellata*, who did not consider it worthy of specific rank. With this conclusion we are in agreement. It is marked in particular and is so named because the margin of the large circular pore is beset with a number of slender spicules which pass inwards towards the centre thus giving it a stellate appearance.

var. *umbonata* Hincks. This variety is marked by the presence of a very well developed central umbo beneath the central pore, which it hides to a greater or lesser extent. In addition there is a pair of well-developed umbonate processes passing forwards, one on each side of the aperture.

var. *vibraculifera* Hincks. Hincks mentions an Australian form in which the avicularia have long mandibles, but these are not nearly so long as in this variety, described by him from the Queen Charlotte Islands. The enormously long vibraculoid avicularia give this variety a very characteristic appearance.

var. *areolata*. This variety is not similar to any previously described. It is distinguished by having the avicularia much lower down on the side of the zoœcia than in the other types and also by a series of well-marked areolations around the edge of the cell.

Reference. Hincks (7, p. 206, Pl. XXVIII), England; Osburn (15, p. 234, Pl. XXIV), Atlantic; Hincks (11*b*, pp. 14 and 15, Pl. XVII), Pacific N.A.

Distribution. The various varieties of this widely distributed species are intermingled and separate records have not been kept. False Narrows; Gabriola Pass; Cardale Point; entrance to Departure Bay; Northumberland Channel; Ballenac Islands; Nanoose Bay; China Hat; off Snake Island; Cape Ebenshaw; off Protection Gap; Friday Harbour. Low tide—35 fms.

The var. *californica* Hincks of this species is raised to specific rank by Robertson, whose action I have followed in this point.

Microporella californica Busk.

Reference. Hincks (11*b*, p. 16, Pl. XVII), Robertson (20, p. 281, Pl. 18), Pacific N.A.

Distribution. False Narrows; Gabriola Pass; Northumberland Channel. Low tide—18 fms.

This species is the *M. ciliata* var. *californica* of Hincks and it undoubtedly is closely allied to that species.

Microporella malusii Audouin.

Of this species two different forms were found which merit separate treatment.

var. *typica* Hincks. This may be taken as typical as it is included within the limits of Hincks definition, although it is more closely described by Robertson. It is characterized by an irregularly punctate front wall, four or five spines at the front end.

var. *glabra*. The front wall of this variety is smoother, more shiny and the pores are smaller and confined to a row under the orifice and around the edge. Also, apparently only two marginal spines are present. The zoœcia are smaller and the whole colony smoother in appearance.

Reference. Hincks (7, p. 211, Pls. XXVIII and XXIX), England; Hincks (11*b*, p. 16) and Robertson (20, p. 282, Pl. 18), Pacific N.A.

Distribution. Between Jesse and Newcastle Islands; Gabriola Pass; Bull Passage; Nanoose Bay; Northumberland Channel; North Bay, Thetis Island; off Protection Gap; Swiftsure Shoal; Banks Island; Friday Harbour. 8-25 fms.

Microporella setiformis sp. nov. (Pl. III, Fig. 21).

The zoarium forms a fairly conspicuous white crust upon pebbles and old shells. The zoœcium is polygonal, somewhat ventricose, and its ventral wall is minutely punctate; when fresh it is covered with a shiny, hyaline epitheca, which gives the colony a porcelanous appearance. The aperture is higher than semicircular and surrounded by a very definite rim, the posterior margin is straight. Immediately below it in the middle line is a tiny circular pore which, as far as could be seen, was not provided with spines or plate, but it is surrounded by a narrow rim. On one or other or both sides of the zoœcium about the level of the pore lie the avicularia. They are quite small and oval, the base of the mandible is almost semicircular, but it is continued on as a setiform process set at an angle of about 45° to the line of the zoœcium.

No oœcium was found.

This is undoubtedly a *Microporella*, but does not seem referable to a described species. The name *M. setiformis* is suggested because of the setiform mandible.

Distribution. Between Round and Mudge Islands; Northumberland Channel. 15-25 fms.

Family PORINIDAE (pars) d'Orbigny, 1851.

Genus LAGENIPORA Hincks, 1877.

Lagenipora socialis Hincks.

Reference. Hincks (7, p. 235, Pl. XXXIV), England.

Distribution. Northumberland Channel; west of Hammond Bay; off Protection Gap; Ruxton Passage. 10-20 fms.

Lagenipora spinulosa Hincks.

Reference. Hincks (11*b*, pp. 31 and 40, Pls. III and IX) and Robertson (20, p. 283, Pl. 18), Pacific N.A.

Distribution. Between Jesse and Newcastle Islands; Buccaneer Bay; Gabriola Pass; Bull Passage; off Protection Island; west of Hammond Bay; China Hat; Northwest Bay; Swiftsure Shoal; off Snake Island; Banks Island; east of entrance to Departure Bay; West Rocks; Departure Bay. 8-40 fms.

Lagenipora erecta sp. nov. (Pl. III, Fig. 22).

In 1883 Hincks described from the Queen Charlotte Islands a form as *L. spinulosa* and stated that the zoarium formed small lobate patches. In the following year he again referred to a species by that name and says: "When I first described this species I had only met with small incrusting colonies, and was under the impression that they represented the mature and perfect form. I now find, however, that this is by no means the case. When fully grown the zoarium of *Lagenipora spinulosa* is erect and ramose, consisting of a cylindrical stem, which divides and sub-divides dichotomously, the branches terminating above in short bifid segments."

In the present collection of material both the original form described by Hincks as *L. spinulosa* and also the erect form that he later identifies as the same species are represented. There seems to be little doubt of this in either case; in the former the specimens agree with the description and the detailed drawing, and in the latter there is also agreement with the description and the natural size drawing.

While there is no doubt that there is a close resemblance between these two forms, at the same time we cannot agree with Hincks in regarding them as identical and think it better to separate this erect form as a separate species for a number of reasons which will appear below. In general, however, there is no difficulty in distinguishing between small pieces broken from the two forms.

The zoarium is erect, consisting of a cylindrical stem that branches dichotomously and maintains a fairly constant diameter throughout. The stem arises from a small base in which the zoœcia are similar to those of the stem and more regular in arrangement than in *L. spinulosa.* As Hincks has pointed out the colony bears a close resemblance, "so far as habit and general appearance are concerned, to an *Entalophora.*" The zoœcium is lageniform, the lower swollen portion forming part of the stem and the upper tubular neck standing well out. The body portion is marked by a series of shallow depressions, which give it a reticulate appearance. The meshes are larger and more regular than in *L. spinulosa* and pass over more gradually into the clear hyaline neck region, which is faintly marked by circular lines. The body portions are very regularly arranged in oblique rows, six of them occupying the circumference of the stem, with the result that the tubular necks stand out in the position of the six corners of a hexagon and fall into a spiral arrangement. The neck is tubular and of practically the same diameter throughout and, while there is a tendency for it to be wider at the free extremity, it does not flare out and produce spiny points in the manner characteristic of *L. spinulosa* and well shown in Hincks illustration. The top of the neck is less irregular than in the last-named species; it may have a pair of small avicularia of Scrupocellarian type, borne on very low processes; often only one appears to be present and sometimes none are present. The primary aperture is oval.

The oœcium is on the whole larger than in *L. spinulosa* and it has a larger, semicircular, flattened area in front, whose wall is marked by circular granulations. This area is separated by a ridge from the sub-spherical hinder portion upon which are faint lines running back from the ridge. The oœcium is borne at the end of the tubular neck, between it and the stem of the colony.

As noted, this appears to be the same as a form described by Hincks, but it seems advisable to raise it to a species with the name *L. erecta.*

Distribution. Between Jesse and Newcastle Islands; off Protection Gap; entrance to Departure Bay; off Snake Island; Northumberland Channel; Gabriola Pass. 10-20 fms.

Family MYRIOZOIDAE (pars) Smitt, 1867.

Genus SCHIZOPORELLA Hincks, 1880.

Schizoporella areolata Busk.

Reference. Robertson (20, p. 285, Pl. 18), Pacific N.A.

Distribution. Off Protection Gap. 15-20 fms.

Schizoporella auriculata Hassall.

This species is found in two varieties that have been recognized previously.

var. *typica.*

Reference. Hincks (7, p. 260, Pl. XXIX), England; Osburn (15, p. 237, Pl. XXV), Atlantic; Robertson (20, p. 286, Pl. 19), Pacific N.A.

Distribution. Between Jesse and Newcastle Islands; Departure Bay; off Protection Gap; Buccaneer Bay; entrance to Departure Bay. 12-25 fms.

Neither Robertson nor Hincks mentions the lateral areolae which are shown in Osburn and clear in the specimens.

var. *alba* Busk.

Reference. Busk (Challenger Rep. (1), Vol. X, p. 164, Pl. XIX).

Distribution. North of Gabriola Island; Northumberland Channel; Round Island; north of Jesse Island; West Rocks. 8-30 fms.

Schizoporella sinuosa Busk.

Reference. Hincks (7, p. 266, Pl. XLII), England; Osburn (15, p. 238, Pl. XXV), Atlantic.

Distribution. Between Jesse and Newcastle Islands; off Protection Gap; Friday Harbour. 15-25 fms.

Most of the specimens of this species were of a deep brownish purple colour.

Schizoporella cecilii Audouin.

Reference. Hincks (7, p. 269, Pl. XLIII), England; Hincks (11*b*, p. 17) and Robertson (20, p. 288, Pl. 19), Pacific N.A.

Distribution. Northumberland Channel. 15-18 fms.

Agrees most nearly with description given by Robertson, *i.e.*, without an umbo.

Schizoporella biaperta Michelin.

Reference. Hincks (7, p. 255, Pl. XL), England; Osburn (15, p. 237, Pl. XXV), Atlantic; Hincks (11*b*, p. 17) and Robertson (20, p. 287, Pl. 19), Pacific N.A.

Distribution. Northumberland Channel; Bull Passage. 15-25 fms.

Schizoporella hyalina Linnaeus.

This species is one of the widest spread and most abundant of the whole group. It also is well represented by fossil specimens. It presents a wide range of variation and in the material here considered five distinct varieties are recognizable and listed separately.

var. *typica* Hincks. This form is the typical one described by Hincks and figured by him (7, Pl. XVIII, Figs. 8 and 9). It is very hyaline, with marked areolae, a sinuous margin and the oœcia are borne upon small partially aborted cells.

var. *incrassata* Hincks. This is the form mentioned by Hincks (7, p. 272) as var. *incrassata* and is distinguishable *inter alia* by the loss of the hyaline appearance owing to the walls becoming thickened and opaque, so altering the entire texture of the colony.

var *tuberculata* Hincks. This form is referred to by Hincks (7, p. 272) as var. *tuberculata* and is stated to have a number of tubercles on the front of the cell and often a strongly developed umbo below the orifice. In this material the umbo is quite well developed, but although the surface is rough and somewhat opaque it is hardly as tuberculate as the form described by Hincks.

var. *intacta*. In this variety the hyaline character is fairly well shown, but there is no sign of the marginal areolae and the orifice is almost circular, with no sign of the sinus.

var. *parva*. This variety has the zoœcia noticeably smaller than the others and they tend to be more regularly arranged and not so jumbled as in other forms. It is calcified and deeply lined. The oœcium is well marked and quite pointed. A small umbo is frequently present and the orifice is slightly irregular.

Reference. Hincks (7, p. 271, Pls. XVIII and XLV), England; Osburn (15, p. 235, Pl. XXIV, as *Hippothoa hyalina*), Atlantic; Hincks (11*b*, p. 17) and Robertson (20, p. 289, Pl. 19), Pacific N.A.

Distribution. The various varieties are fairly well mixed and the form is apparently common everywhere throughout the region. It was seen at other places, but specimens from the following places were definitely identified: False Narrows; north shore of Newcastle Island; between Jesse and Newcastle Islands; west end of Jesse Island; Gabriola Pass; Black Rock; Brandon Island; off north-west shore of Brandon Island; entrance to Departure Bay; Duke Point Lagoon; Northumberland Channel; Cardale Point; Round Island; Ballenac Islands; Nanoose Bay; Ucluelet; entrance to San Juan Gulf; Friday Harbour; west of Rose Spit; west of Hammond Bay; Mayne Island; Northwest Bay; off Protection Gap; Swiftsure Shoal; Burrard Inlet; Banks Island; Departure Bay; east of Protection Island; Ruxton Passage; West Rocks. Low tide—40 fms.

Schizoporella linearis Hassall. Found only as var. *inarmata* Hincks.

Reference. Hincks (7, p. 247, Pl. XXXVIII), England; Hincks (11*b*, p. 41) and Robertson (20, p. 291, Pl. 20), Pacific N.A.

Distribution. Bull Passage; off Protection Gap. 15-25 fms.

Schizoporella crassirostris Hincks.

Reference. Hincks (11*b*, p. 18, Pl. XVIII), Pacific N.A.

Distribution. Gabriola Pass; entrance to Departure Bay; off Protection Gap; west of Gabriola Island; Friday Harbour. 8-30 fms.

Schizoporella longirostrata Hincks.

Reference. Hincks (11*b*, p. 18, Pl. XVII) and Robertson (20, p. 291, Pl. 20), Pacific N.A.

Distribution. Northumberland Channel; Bull Passage. 15-25 fms.

When fresh, this species is covered with a shiny brown epitheca, but when this is removed the surface appears white and granular and so the colony is quite different in appearance.

Schizoporella insculpta Hincks.

Reference. Hincks (11*b*, p. 19, Pl. XVII) and Robertson (20, p. 290, Pl. 20), Pacific N.A.

Distribution. Between Jesse and Newcastle Islands; west of Gabriola Island; Buccaneer Bay; False Narrows; Gabriola Pass; Lock Bay; west of Hammond Bay; Banks Island Low tide—30 fms.

This occurs as an incrusting layer and also as a bilaminar expansion.

Schizoporella tumulosa Hincks.

Reference. Hincks (11*b*, p. 19, Pl. XVIII) and Robertson (20, p. 293, Pl. 20), Pacific N.A.

Distribution. West of Gabriola; between Jesse and Newcastle Islands; between Round and Mudge Islands; Northumberland Channel; Gabriola Pass; entrance to Departure Bay; off Protection Gap; Bull Passage; Friday Harbour. 8-30 fms.

Schizoporella granulata sp. nov. (Pl. III, Fig. 23).

The zoarium forms a close, slightly granular encrustation over stones and shells. The zoœcia are roughly rectangular or sometimes hexagonal and fairly regularly arranged. In general appearance there is some resemblance to *S. areolata*, but the perforations in the front wall are much smaller as is the orifice. The orifice is relatively small, terminal, sub-circular and has a distinct sinus below. The whole surface is shiny and covered with minute pores, between the pores it is raised up into irregular knobs, giving a very granular appearance. In many cells there is a low umbonate projection below the sinus. There is a thin, opaque, white line between the zoœcia. No avicularia were found.

The oœcium is large, hemispherical and partly, or sometimes wholly, immersed. Its surface is minutely punctate and granulate like that of the zoœcium.

A similar form has not been found in the descriptions and so the name *S. granulata* is here suggested to call attention to the granular nature of the surface of both zoœcia and oœcium.

Distribution. Northumberland Channel. 15 fms.

Schizoporella fistulata sp. nov. (Pl. III, Fig. 24).

The zoarium forms a dull intense white crust over stones, etc. The zoœcium is rectangular or hexagonal in shape. The zoœcia are regularly arranged in lines and separated from one another by a raised lamella, along which are a series of small, circular areolations. The orifice is small, almost circular, and possesses a narrow but well-marked sinus. Below the sinus is a spout-like projection which bears at its tip a tiny avicularium with a rounded mandible. Apart from the circumferential areolations the surface of the zoœcium is smooth and plain. In some respects it is like *S. oligopus*, but has a totally different avicularium and none of the "tube feet" for attachment found in that species.

The oœcium is a prominent hemispherical structure whose surface is punctured by a series of irregularly arranged oval perforations. When it is developed a side flange passes back from it along each side of the orifice, which thus becomes sunken.

This form, apparently not described before, is here termed *S. fistulata*, from the spout-like appearance of the base of the avicularium.

Distribution. Departure Bay. 15 fms.

Schizoporella ordinata sp. nov. (Pl. III, Fig. 25).

The zoarium forms a large white encrustation over stones, shells, and particularly over the valves of a large barnacle. The zoœcium is oblong and fairly regular in shape, save at one or two places in the colony where the alignment is altered. The orifice is large, terminal and possesses a distinct, broad shallow sinus on its lower margin. The zoœcia for the most part are in quite regular lines and separated from one another by an opaque white lamella appearing as a line. The glistening surface is very thick and regularly punctured by a series of fairly large circular pores. There is also a tendency for it to form a small umbonate process beneath the sinus and the space between the two forms a smooth, crescentic area sloping to the aperture. No avicularia were found.

The oœcium is large hemispherical, prominent and occupies the main part of the zoœcium ahead. The front is marked by a somewhat smooth, depressed area perforated by an irregular series of large pores. The remaining portion is much thicker and bears a series of heavy ridges running backwards.

The form does not appear to have been described and the name *S. ordinata* is suggested as the zoœcia are for the most part arranged regularly in rows.
Distribution. Gabriola Pass 8-18 fms.

Genus HIPPOTHOA Lamouroux, 1812.

Hippothoa divaricata Lamouroux. Nearest to var. *conferta* Hincks.
Reference. Hincks (7, p. 288, Pl. XLIV), England; Osburn (15, p. 235, Pl. XXIV), Atlantic; Robertson (20, p. 296, Pl. 21), Pacific N.A.
Distribution. Northumberland Channel. 15-18 fms.

In some ways this resembles var *conferta* Hincks. There are no stalks to the zoœcia, but the latter are not so closely packed. As Robertson has noted, the oœcia are borne on lateral zoœcia inferior in size to the remainder.

Genus MYRIOZOUM Donati, 1751.

Three members of this genus have been recorded from the Pacific coast by Robertson, of which *M. crustaceum* is not represented in the present collection. Of the other two certain notes expanding Robertson's description are added.

Myriozoum coarctatum Sars.
Reference. Hincks (11*b*, p. 21) and Robertson (20, p. 295, Pl. 21), Pacific N.A.
Distribution. Namu; Bull Passage. 15-25 fms.

N.B.—The present form agrees fairly well with Robertson's description and figure, but that author states that the avicularia are wanting. These structures are often missing in older parts of the colony, but there are practically always some to be found near the orifices a short distance from the growing ends of the branches. The avicularia are minute and easily overlooked, but there may be one on either side or a pair, one on each side. In any case their position is constant; they are situated just lateral to the bend of the upper end of the orifice. The front wall of the zoœcia is reticulated, but can hardly be described as covered with large pores.

Myriozoum sub-gracile d'Orbigny.

Reference. Robertson (20, p. 296, Pl. 21), Pacific N.A.

Distribution. North of Gabriola Island; near Maude Island; Namu; west of Hammond Bay; off Protection Gap; Swiftsure Shoal; off Snake Island; Alert Bay. 12-30 fms.

N.B.—The material examined does not agree very closely with Robertson's description and still less with the figure, but there is little doubt that it is referable to the same species. This author states that the front wall is "granular, not punctate except at the base of the colony where the zoœcia are hidden under a calcified porous layer." In all the specimens we have examined, the stem is reticulated as in *M. coarctatum*, but the pores of the reticulum, while perhaps a little small, are deeper than in that species.

There is a well-marked rim around the orifice, not shown in Robertson's figure, and the avicularium is nearer to the orifice. Almost every orifice has an avicularium larger than figured, above its centre; the mandible is slightly pointed and directed downwards and a little obliquely.

Myriozoum tenue sp. nov. (Pl. III, Fig. 26).

The zoarium is ramose, branches dichotomously, and resembles that of the preceding two species, save that it is much more slender than either of them and is usually of a more intense white colour. The zoœcia are alternate, immersed, and the front wall is reticulate as in the other two species. The orifice is almost circular above, but with a straight lower margin and a well-marked sinus. It has not such a distinct rim as in *M. coarctatum* or *M. sub-gracile*. The basal portion of an old colony becomes granular and all trace of orifices and avicularia disappear.

Small avicularia are plentiful; almost every orifice in the younger parts of the colony has one on either side or one on each side and their position is constant. They lie just above the orifice and are surrounded by a rim which makes them easy to distinguish. The species cannot be confused with *M. coarctatum*, however, since it is far more slender, the orifice is almost circular instead of being considerably higher than wide, and the one or two avicularia lie just above the orifice and not lateral to it.

Oœcia are not infrequently developed. They appear as low crescentic inflations above the orifice, which thus becomes partly immersed; their surface is smoother and not so markedly reticulate. They usually occur in bands about two zoœcia deep around the stem and so form an annular enlargement that is just visible to the naked eye. Oœcia have not been found in either *M. coarctatum* or *M. sub-gracile*.

The name *M. tenue* is put forward because this is the most slender of the three species found on the coast.

Distribution. Sponge bed outside Departure Bay; Buccaneer Bay; Swiftsure Shoal. 15-25 fms.

In dealing with *M. sub-gracile* Robertson (20, p. 296) says: "These specimens possess one avicularium above the zoœcium, although a specimen examined from Baffin's Bay has two small avicularia above each zoœcium." It may be that this specimen is an example of *M. tenue* as here described.

Family Escharidae (pars) Smitt, 1867.

Genus LEPRALIA (pars) Johnston, 1847.

Lepralia nitescens Hincks.
Reference. Hincks (11*b*, p. 22, Pl. XVIII), Pacific N.A.
Distribution. Northumberland Channel. 15-18 fms.

Lepralia regularis sp. nov. (Pl. III, Fig. 27).

The zoarium forms a yellowish-grey, one-layered crust and has so far only been found upon the valves of a Brachiopod, *Terebratella transversa*, and appears as an even layer perforated by a series of regularly arranged pores. The zoœcia are longer than wide, slightly hexagonal in shape and arranged alternately in very regular rows. They are very deep from back to front, but their surfaces are all level, so that the top of the colony is quite even. The orifice is semicircular above but widens noticeably below and has a straight posterior margin; it is typical of the genus. The calcareous zoœcial wall is traversed by three or four rows of roughly circular pores, three or four in a row and separated by slightly raised bars. At each end of the transverse bars is a noticeably large pore with a raised white rim; the appearance of these four rimmed pores, four on each side of the zoœcium, is very remarkable.

No oœcia or avicularia were found in any of the colonies.

The form does not appear to have been described and the name *L. regularis* is suggested because of the regular arrangement of the zoœcia and also of the four pairs of rimmed pores along the side of each.

Distribution. This species was found on the valves of *Terebratella transversa* dredged near Friday Harbour, but no further details are available.

Genus PORELLA Gray, 1848.

Porella concinna Busk.
Reference. Hincks (7, p. 323, Pl. XLVI), England; Osburn (15, p. 247, Pl. XXVII), Atlantic; Robertson (20, p. 300, Pl. 22), Pacific N.A.
Distribution. Gabriola Pass; Northumberland Channel; off Protection Gap; Bull Channel; Burrard Inlet; east of Snake Island. 8-30 fms.

Porella marsupium MacGillivray.

This species appears under two varieties.

var. *typica*. Similar to the species as described, *i.e.*, the pouch-like swelling from which the name marsupium is derived is imperforate.
Distribution. Off Protection Gap. 15-25 fms.

var. *porifera* Hincks. This form is similar to that described by Hincks. There is a certain amount of variation in the number of pores and the radiating lines on the oœcium are not always shown. More common than the preceding variety.
Reference. Hincks (11*b*, p. 24, Pl. IV), Pacific N.A.

Distribution. Gabriola Pass; Round Island; Ballenac Islands; off Protection Gap; Nanoose; west of Hammond Bay; Friday Harbour. Low tide—25 fms.

Porella major Hincks.
Reference. Hincks (11*b*, p. 25, Pl. IV), Pacific N.A.
Distribution. Near Maude Island; Gabriola Pass. 8-25 fms.

Porella acutirostris Smitt.
Reference. Osburn (15, p. 248, Pl. XXVIII), Atlantic.
Distribution. Round Island; Northumberland Channel. Low tide—18 fms.

Porella columbiana sp. nov. (Pl. III, Fig. 28).

The zoarium forms a thin, smooth, somewhat shiny crust on shells. It may reach 30 mm. in diameter and has a smooth margin. The zoœcium is small, elongate, oval and slightly ventricose. In the young zoœcia, the surface is almost hyaline, with faint areolations around the edge; in older members the surface becomes opaque and calcareous and the areolations are more distinct. The primary orifice is semicircular. The lower lip is tumulous and has in the middle a short, spout-like stalk, bearing a small avicularium with a rounded mandible directed upwards.

The oœcium is hemispherical, smooth and projecting; the lower border entire. From its hinder edges two low flanges run back to the swollen lower lip and thus a somewhat rectangular secondary orifice is formed, but it is not well marked.

In some respects it recalls *P. major*, but the zoœcia are larger, the areolations much more marked, the oœcium projects more and the walls of the secondary aperture are not so well developed. So far as observed also it is always adnate and never rises into frills or foliaceous expansions.

The species does not appear to have been recorded and the name *P. columbiana* is here suggested.

Distribution. Northumberland Channel; Friday Harbour. 15-18 fms.

Porella bispina sp. nov. (Pl. III, Fig. 29).

The zoarium forms a small, thin, white patch upon stones and shells. The growth is unequal and so the circumference is irregular. The zoœcium is short and fairly broad and its surface granular and glistening near the growing edge; in the older parts of the colony the surface is much denser owing to the calcification that takes place and renders the individual zoœcia much less distinct. The primary orifice is slightly longer than a semicircle, its posterior wall is straight and it bears two long oral spines at its anterior end. On one side or other of the orifice rises a rounded prominence, bearing upon its inner surface an avicularium with a rounded mandible. A thick collar-like flange arises on the opposite side of the orifice. As growth proceeds and the ventral wall increases in thickness the primary orifice sinks more and more below the general level of the surface and before long a definite pyriform secondary orifice is established.

The oœcium is small, higher than hemispherical, and partly immersed. On its front surface is a characteristic triangular, flattened, thin-walled area.

With the increase of calcification, the avicularium and the oœcium become submersed and the whole surface of the colony presents a fairly level, granular surface, perforated by the pyriform secondary apertures.

The species appears to be undescribed and on account of the two oral spines in the young zoœcium the name *P. bispina* is suggested.

Distribution. Northumberland Channel; Gabriola Pass. 8-18 fms.

Porella cribriformis sp. nov. (Pl. IV, Fig. 30).

The zoarium forms a yellowish-white encrustation on the spines of sponges, etc. The zoœcium is polygonal, its ventral wall thick, hyaline and perforated by regularly spaced circular pores. The primary orifice is almost circular, but the posterior wall is straight, with a pair of small lateral denticles. The peristome is well developed, giving rise to a secondary orifice, which includes a typical avicularium with a rounded mandible in the middle line. In a few cases this avicularium is absent.

The oœcium is hemispherical and partly immersed. Its wall is more opaque than that of the zoœcium and it is perforated by a number of irregular pores.

This form is here listed as *Porella* although the presence of the two denticles on the lower margin is not at all typical and suggests a sinus as in *Schizoporella*. However, the peristome and its enclosed avicularium with a rounded mandible ally it more closely with *Porella*. The name *P. cribriformis* is suggested since the ventral wall of the zoœcium is perforated in a regular sieve-like manner.

Distribution. Sponge beds outside Departure Bay; off Snake Island. 15-35 fms.

Genus SMITTIA Hincks, 1879.

Smittia landsborovii Johnston.

Two quite distinct forms are here referred to this species. The one has been termed *S. landsborovii* var. *porifera* by Hincks, *Escharella porifera* by Smitt and *Smittia porifera* by Osburn. Its position is still in doubt, for while specimens from the St. Lawrence were definitely referred to the var. *porifera* by Hincks (12, p. 225), Osburn does not comment on this, but deals with the Atlantic forms as *S. porifera*, and, lastly, Robertson has described as *S. landsborovii* a form from the Pacific Coast of North America, which appears to be the same as that dealt with by Osburn. The present specimens are here placed under Hincks's name although a more extended examination of his species may show the desirability of removing the var. *porifera* as an independent species.

The other form agrees fairly well with one described and figured by Hincks.

var. *porifera* Hincks.

Reference. Hincks (7, p. 341, Pl. XXXVI, Fig. 1), England; (12, p. 225, Pl. XIV), Atlantic; Osburn as *S. porifera* (15, p. 245, Pl. XXVI), Atlantic; Robertson (20, p. 305, Pl. 23), Pacific N.A.

Distribution. Sponge beds outside Departure Bay; Northumberland Channel; entrance to Departure Bay; off Protection Gap. 15-25 fms.

var. *areolata*. This is similar to two of the forms figured by Hincks and is marked by a line of areolæ around the margin of the zoœcium. The oœcium is partly immersed and covered with large irregular pores.

Reference. Hincks (7, p. 341, Pl. XLVIII, Figs. 7 and 8), England.

Distribution. Sponge beds outside Departure Bay; entrance to Departure Bay; Bull Passage; Northwest Bay; off Protection Gap; Jesse Island. 10-25 fms.

Smittia trispinosa Johnston.

Reference. Hincks (7, p. 353, Pl. XLIX), England; Robertson (20, p. 302, Pl. 22), Pacific N.A.

Distribution. Gabriola Pass; Ballenac Islands; Northwest Bay; Friday Harbour. 8-15 fms.

The material from Friday Harbour had very few avicularia.

Smittia collifera Robertson.

Reference. Robertson (20, p. 304, Pl. 23), Pacific N.A.

Distribution. False Narrows. Low tide.

This agrees fairly closely with Robertson's description but no spines were found.

Smittia cellata sp. nov. (Pl. IV, Fig. 31).

The zoarium forms a coarse irregular white crust upon shells (*Pecten rubida*). The zoœcia are oblong and slightly rectangular; they are separated from one another by a raised lamina and bear a series of deep areolations or cells around their edge. The central region is opaque and granular. In general appearance they recall *S. reticulata* but, the avicularium, somewhat like that of *S. affinis,* is large and lies to one side of the middle line, the pores in the oœcium are larger and more irregular and there is no indication of the 3 or 4 spines in the young cell. The primary orifice is round and the secondary orifice more semicircular. The peristome is fairly well developed and bears a longish avicularium to one side of the middle line. The tooth is slender, moderately long and bifid at the extremity.

The oœcium is globose, hemispherical and projecting, and its surface perforated by a series of large irregular pores.

The form does not appear to have been described and the name *S. cellata* is suggested to call attention to the cell-like areolations around the margin of the zoœcium.

Distribution. Northumberland Channel. 15-18 fms.

Smittia torquata sp. nov. (Pl. IV, Fig. 32).

The zoarium forms a somewhat glistening crust over pieces of old shells. The zoœcium is elongate, oval and slightly ventricose. The wall is granular and hyaline and round the edge there is a series of more or less distinct areolations. Below the aperture is a crescentic, somewhat clearer, slightly raised area. The primary aperture is large and sub-orbicular and bears in the middle of its posterior margin a well-marked bifid tooth. On one side of the aperture is a flange-like peristome bearing an avicularium upon its median edge. A similar flange, without an avicularium, is present on the other side, thus forming a more or less continuous peristome. The zoœcia are fairly regularly arranged in alternate rows and there is a tendency in some parts of the colony for calcification to set in and then the wall becomes opaque and the marginal areolations more marked. Both spines and oœcia appear to be absent.

It appears to be undescribed and the name *S. torquata* is proposed.
Distribution. Gabriola Pass. 8-18 fms.

Genus PHYLACTELLA Hincks, 1872.

Phylactella pacifica sp. nov. (Pl. IV, Fig. 33).

The zoarium forms a dense white encrustation upon stones, etc., which to the naked eye appears marked off into a series of rhomboidal areas each bearing a round pore. The zoœcia are roughly rhomboidal in shape, marked off by a distinct lamina and surrounded by a series of fairly regular areolations. The wall is thick, opaque, finely granular and not developed between the partitions of the areolæ, which are in consequence very deep. The whole is covered by a thin glistening epitheca. The primary aperture is almost semicircular but a little raised; it does not appear to bear a denticle. The peristome is very high and approximately circular, so that the lower border of the primary aperture projects in as a kind of narrow edge. The secondary aperture is circular and its margin intact.
No avicularia are present.

The oœcium is large, hemispherical and projecting. Its surface is finely granular like that of the zoœcium and it is not marked off by perforations or ridges. The posterior edge is often raised up into a kind of flange, thus making a front lip to the secondary aperture.

The form appears to be undescribed and the name *P. pacifica* is suggested.
Distribution. Friday Harbour. ? fms.

Genus RHAMPHOSTOMELLA Lorenz, 1886.

This genus does not appear to have been recorded from this area by previous writers, but it is represented in the present collection by three distinct species.

Rhamphostomella costata Lorenz.
Reference. Osburn (15, p. 244, Pls. XXVI and XXXI), Atlantic.
Distribution. Northwest Bay. 10-15 fms.

Rhamphostomella curvirostrata sp. nov. (Pl. IV, Fig. 34).

The zoarium forms a white, granular crust over the surface of sponges, serpulid tubes, etc. The zoœcia are elongated, ovoid, somewhat ventricose and separated from one another by a slightly raised lamina; in the young stages they are shiny and smooth, but later they become coated with a white, granular, calcareous layer and a series of well-marked areolations are formed around the margin. The primary orifice is large, rounded in front and more or less straight behind; it bears a broad somewhat rectangular tooth on its posterior border. The tooth is slightly rounded on its inner border and has two delicate sharply pointed spines, one at each corner. A high peristome is developed, deeply channelled on the posterior side, and the secondary aperture is rotundo-rectangular. The rostrum is very large; starting at one of the lower corners it passes obliquely forwards on a curve to join the anterior corner of the opposite side, and finally its distal extremity fuses with the peristome and thus the secondary aperture is divided into two unequal pieces. Practically the whole of the rostrum is occupied by a large curved avicularium, the mandible of which faces obliquely backwards and upwards and its point is directed obliquely forward. The rostrum entirely hides the tooth and almost obscures the channel in the peristome.

The oœcium is a partly immersed, but nevertheless a prominent hemispherical structure. Its surface is punctured irregularly by a number of small pores, each on a slight rounded prominence. The pores are generally round, but occasionally longer and slit-like.

The form is a typical *Rhamphostomella* but does not appear to have been described. The name *R. curvirostrata* is suggested because of the characteristic and striking curved rostrum.

Distribution. Bull Passage; Northumberland Channel. 15-25 fms.

Rhamphostomella porosa sp. nov. (Pl. IV, Fig. 35).

The zoarium forms a white, often very irregular crust over sponge spicules, hydroids, etc., and often rises up into small curved bilamellar expansions. The zoœcia are roughly rectangular, tightly packed together and project at an angle to the base. The primary orifice is quite large and rounded; on its posterior side it bears a small median rectangular tooth and two tiny triangular denticles. A high peristome deeply channelled in front is developed, which produces a somewhat keyhole-shaped secondary orifice. At one side of the lower part of this arises an upstanding rostrum, which bears a large avicularium and curves upwards and inwards towards the middle line. The ventral wall is perforated laterally by a series of large irregular pores.

The oœcium is large and hemispherical and its smooth surface is perforated irregularly by a number of pores. In the older parts of the colony an oœcium is produced on practically every zoœcium. Owing to the slanting position of the tightly packed zoœcia, the development of the large peristome, the large avicularium bearing rostrum and the large oœcium, the ventral wall of the zoœcium is almost completely hidden. All that can be seen then is the secondary orifice, rostrum and oœcium, so that the colony presents a very characteristic appearance.

It appears to be close to *R. bilaminata* Hincks, but is readily distinguishable by the far larger size of the rostrum and peristome among other points. No similar form has been found described and it is proposed to name it *R. porosa* on account of the pores in the zoœcial wall and in the oœcium.

Distribution. Cape Ebenshaw. 15 fms.

Genus MUCRONELLA Hincks, 1880.

Mucronella peachii Johnston. Found only in the form var. *labiosa* Busk.

Reference. Hincks (7, p. 360, Pl. LI), England; Osburn (15, p. 243, Pl. XXVI), Atlantic.

Distribution. Northumberland Channel; Bull Passage; Nanoose Bay. 15-25 fms.

This is more like the form *labiosa* figured by Hincks (7, Pl. LI, Fig. 1) and usually has four spines, although there is sometimes one. The denticle is somewhat broad.

Mucronella ventricosa Hassall.
Reference. Hincks (7, p. 363, Pl. L), England; Osburn (15, p. 243, Pl. XXVI), Atlantic; Hincks (20, p. 26), Pacific N.A.
Distribution. Entrance to Departure Bay; off Protection Gap. 15-25 fms.

Similar to description save that the mucro is not distinctly bifid.

Mucronella microstoma Norman.
Reference. Hincks (7, p. 370, Pl. XXXVIII), England.
Distribution. Northumberland Channel. 15-18 fms.

This agrees fairly well with the description, but the individual cells appear to be somewhat more closely packed with a tendency to a raised ridge between the cells and indications of areolations on each side of this.

Mucronella simplicissima Busk.
Reference. Busk. (Challenger. Vol. X (1), p. 160, Pl. XXII).

This form agrees quite closely with Busk's description in general characters, save that he states his to be porcellanous and smooth, while the present material is shiny, but has irregularly scattered perforations; hence it is described as var. *perforata* in preference to making a new species.

var. *perforata*. As noted above this is marked by perforations of the surface.
Distribution. North of Gabriola Island; near Maude Island; Buccaneer Bay; Northumberland Channel; Northwest Bay; Burrard Inlet. 10-30 fms.

Mucronella pavonella Alder.
Reference. Hincks (7, p. 376, Pl. 39), England; Osburn (15, p. 243, Pl. XXVI), Atlantic; Hincks (11*b*, p. 26) and Robertson (20, p. 308, Pl. 23), Pacific N.A.
Distribution. Near Maude Island; south of Brandon Island; Nanoose Bay; Gabriola Pass; Northwest Bay; off Protection Gap; entrance to San Juan Gulf. 15-25 fms.

Mucronella praelonga Hincks.
Reference. Hincks (11*b*, p. 27, Pl. IV), Pacific N.A.
Distribution. Nawhitti Bar. ? fms.

The form here is similar to the description, save that all the specimens are bilamellar and the anterior spine is not so well developed as in Hincks's material; it is little more than a prominence.

Genus RETEPORA Imperato, 1572.

Two forms were found in the material collected; one agreeing closely with *R. pacifica* and possessing a single large dorsal avicularium at the base of each fenestra, spines on the young zoœcia and a mucro or tooth on the margin of the oœcium. It was also of an apricot colour. The other form agrees with this fairly well in general appearance, but is lighter in colour and slightly coarser in texture. However, it differs from this in that it lacks the large dorsal avicularium and has instead a number of smaller scattered dorsal avicularia, which need not come at the base of the fenestrae; no spines were found on the young zoœcia and the margin of the oœcium, as far as could be seen, was intact. It agrees fairly well with the description and figures of *R. tesselata* given by Busk, and while it differs in certain respects it is here provisionally listed under that name.

Retepora tesselata Hincks.
Reference. Busk (1, pp. 112, 113, Pl. XXVII), Cape of Good Hope.
Distribution. Trincomali Channel; Nanoose Bay; entrance to Departure Bay; Goose Island. 15-25 fms.

Retepora pacifica Robertson.
Reference. Robertson (20, p. 310, Pl. 24), Pacific N.A.
Distribution. Banks Island; Clan-innick. 13 fms.

Genus RHYNCHOPORA Hincks, 1880.

This genus has not been recorded previously from the Pacific Coast of North America and it is here represented by one species.

Rhynchopora bispinosa Hincks.
Reference. Hincks (7, p. 385, Pl. XL), England.
Distribution. Northumberland Channel. 15-18 fms.

This form agrees well with the description given. Hincks, however, points out (7, p. 385) that "This form is a difficulty in the way of the systematist. . . . It must be regarded as one of those transition forms . . . ." Finally he suggests it might be regarded as a Myriozoidan with strong affinities with the present family. The material here described certainly suggests affinities with *Schizoporella*, but the present paper is not the place in which to enter into detailed discussions of these taxonomic points and for the purposes of this list it is left as it stands.

Family CELLEPORIDÆ Hincks, 1880.

Genus CELLEPORA (pars) Fabricius.

Cellepora incrassata Lamarck.
Reference. Hincks (11*b*, p. 29) and Robertson (20, p. 312, Pl. 24), Pacific N.A.
Distribution. North of Gabriola Island; North Bay, Thetis Island; near Maude Island; between Jesse and Newcastle Islands; south of Brandon Island; Bull Channel; Buccaneer Bay; sponge beds outside Departure Bay; False Narrows; Nanoose Bay; Lock Bay; entrance to Departure Bay; Gabriola Pass; Northumberland Channel. Low tide—30 fms.

This common form is much like the next species and we do not find the criterion for distinguishing this given in Robertson to hold in all cases. This author states that on the oœcium of *C. incrassata* there is a triangular depressed area, while in *C. costazii* this area bears perforations. In the material here treated both conditions are found within the limits of the present species.

Cellepora costazii Audouin.

This species exhibits three distinct varieties which merit separate note.

Reference. Hincks (7, p. 411, Pl. LV), England; Robertson (20, p. 313, Pl. 24), Pacific N.A.

var. *typica.* Agreeing with the description given by Hincks and possessing large spatulate avicularia scattered irregularly over the surface.

var. *inarmata.* This is like the preceding form in most respects, but as pointed out by Hincks the large spatulate avicularia which render the former so easy to distinguish are entirely absent and hence this form is harder to distinguish from *C. incrassata.*

Distribution. The records of these two varieties have not been kept distinct. Trincomali Channel; between Jesse and Newcastle Islands; Buccaneer Bay; Nanoose Bay; North Bay, Thetis Island; west of Hammond Bay; Banks Island; Namu; Northwest Bay; north of Brandon Island; Swiftsure Shoal; Cape Ebenshaw; entrance to San Juan Gulf; West Rocks; Northumberland Channel; Bull Passage. 10-25 fms.

var. *erecta.* This form is like the typical in possessing tiny and large spatulate avicularia, but differs in habit of growth. It is much more erect, forming short stems, and also the oœcia are sunk to the level of the general surface, instead of standing up markedly as in the other varieties.

Distribution. Hammond Bay; west of Neck Point; Banks Island; Ruxton Passage. 10-25 fms.

Cellepora armiger sp. nov. (Pl. IV, Fig. 36).

The zoarium forms a small coarse nodule encrusting the stem of a hydroid. The body of the zoœcium is lageniform and its wall marked with a reticulation similar to that of *C. costazii* or *C. incrassata.* The primary orifice is oval, without a sinus and surrounded by a marked peristome, forming a short tube. This bears a stalked avicularium on each side, the mandibles of which face inwards and in many cases they are practically vertical, facing one another. The apex of the mandible is bluntly pointed. The anterior wall of the peristome is often produced and notched; between this and the stalk of the avicularium is often a short spine. On the ventral wall of the peristome are two triangular processes which, in certain zoœcia, almost meet in the middle line, forming a characteristic shield-like structure with a cleft in its upper border. The zoœcia are irregularly arranged and several groups project up a short distance. The oœcium is a well-marked hemispherical structure borne on the dorsal wall of the peristome above which it projects slightly. The dorsal wall of the oœcium is smooth, but on its ventral wall is a flattened crescentic area perforated by a number of small circular pores.

The form is an interesting one, for it appears to be almost intermediate between *Cellepora* and *Lagenipora.* It appears to be undescribed and the name *C. armiger* is suggested on account of the shield-like structure borne on some of the zoœcia.

Distribution. Northumberland Channel. 15-20 fms.

Sub-order CTENOSTOMATA Busk, 1852.

Family ALCYONIDIIDAE Hincks, 1880.

Genus ALCYONIDIUM Lamouroux, 1821.

The characters separating several of the species in this genus are somewhat indefinite, but provisionally the material has been identified as follows.

Alcyonidium gelatinosum Linnaeus.

Two entirely different forms apparently belonging to this species have been found, that is, they appear to correspond with two forms included within its limits by Hincks. In a group like the present, where the characters separating the species are often indefinite, it may subsequently be deemed advisable to separate these two varieties which are so distinct in form. At present they are kept in the same species.

var. *typica*. Corresponding with that described by Hincks as typical form.
Reference. Hincks (7, p. 491, Pl. LXIX), England; Osburn (15, p. 252, Pl. XXVIII), Atlantic; Hincks (11*b*, p. 36) and Robertson (17), Pacific N.A.
Distribution. Jesse Island; Black Rocks; Brandon Island. Low tide.

The colour varies from a white to a dark mud-colour and the tentacles number 16-17.

var. *lobata*. This specimen, collected in 1906, is not very well preserved, but, as far as can be seen, it represents the lobate form of *A. gelatinosum* figured by Hincks (7, Pl. LXIX, Fig. 1). The general form and arrangement of the zoœcia is fairly similar to that of the more typical forms of the species. No details of the structure of zoœcium or polyp could be made out and it is placed with this species provisionally, although in form it is totally unlike other specimens.
Reference. Hincks (7, p. 491, Pl. LXIX), England.
Distribution. Namu.

Alcyonidium mamillatum Alder.
Reference. Hincks (7, p. 495, Pl. LXIX), England.
Distribution. North of Gabriola; Houston Channel; Departure Bay; north of Brandon Island; entrance to Departure Bay; Duke Point Lagoon; north-west corner of Galiano Island; Northwest Bay; Nanoose Bay; Banks Island; Northumberland Channel. Low tide—25 fms.

This is very like the description, but the colony is larger than indicated by Hincks and the polyp tube is longer.

Alcyonidium parasiticum Fleming.
Reference. Hincks (7, p. 502, Pl. LXIX), England; Osburn (15, p. 251, Pl. XXVII), Atlantic.
Distribution. Between Jesse and Newcastle Islands. 15-20 fms.

Similar to description, 15 tentacles counted in several cases.

Alcyonidium mytili Dalyell.
Reference. Hincks (7, p. 498, Pl. LXX), England; Osburn (15, p. 251, Pl. XXVIII), Atlantic; Robertson (17), Pacific N.A.
Distribution.

Alcyonidium spinifera sp. nov. (Pl. IV, Fig. 37).

The zoarium forms a greyish-white, gelatinous mass, overgrowing the calcareous alga *Corallina rubra* (?). From the main stem arises a series of lateral bilamellar outgrowths which give it a resemblance to a minute *opuntia* with its cladodes. This analogy is heightened by the presence of numerous fairly long sharp spines just visible to the naked eye. Each spine arises from a specially modified part of the colony which looks as if it might represent a metamorphosed zoœcium. The spine is hollow, composed of a thin chitinous material, often bifid at the extremity and sometimes bearing another one or two branch spinelets on the stem.

The zoœcium is an elongated hexagon, or occasionally pentagonal or rhomboidal. The outer surface is slightly rounded and the orifice, situated at the end commonly, but not invariably, projects as a short cylindrical papilla. The partitions show fairly clearly on the surface. As already noted, the spines appear to arise from small highly modified zoœcia without a polyp and they are separated by septa from the others.

Distribution. Ucluelet. Low tide.

Genus ASCHORIZA Fewkes, 1889.

Aschoriza occidentalis Fewkes.

Reference. Fewkes (3) and Robertson (18, p. 99, Pl. XIV), Pacific N.A.

Distribution. Entrance to Departure Bay. 25 fms.

Family Vesiculariidae Hincks, 1880.

Genus BOWERBANKIA Farne' 1837.

Bowerbankia gracilis Leidy.

This occurs in two forms of which one, the var. *caudata*, given as a separate species by Hincks, is placed by Osburn as a variety of *B. gracilis*. We have followed the latter author in this matter.

Reference. Hincks (7, p. 521, Pl. LXXV), England; Osburn (15, p. 253, Pl. XXVIII), Atlantic.

var. *typica*. This is like the typical form with small zoœcia.

var. *caudata*. In this as noted by Osburn there is a small tail-like process at the base of the zoœcium, which is on the whole larger than in the other form.

Distribution. Separate records of the two species have not been kept; indeed they intermingle and, as Osburn has pointed out, intergrade to a certain extent. Northumberland Channel; north-east corner of Galiano Island; Nanoose Bay; North Bay, Thetis Island; Hope Island. Low tide—25 fms.

Family Cylindroeciidae Hincks, 1880.

Genus CYLINDROECIUM Hincks, 1880.

Cylindroecium repens sp. nov. (Pl. IV, Fig. 38).

The zoarium is in the form of isolated flask-shaped zoœcia, arising from a stolon creeping over the fronds of algae and shells. The stolon branches and anastomoses only rarely and the branches are not necessarily related to the dilatations. The stolon is of a yellowish colour, and through its transparent walls the opaque whitish coenosarc is clearly visible. The zoœcia arise as lateral dilatations from the stolon, which passes on, and not as enlargements of the stolon itself as in *C. dilataium*. They are separated by considerable intervals, but there is a tendency for them to be arranged in groups of two, one on each side, or sometimes in threes. A branch of the coenosarc of the stolon passes into each lateral swelling. Each enlargement gives off a series of radiating, spine-like rooting processes, similar in appearance to those of *C. dilatatum* Hincks (7, Pl. LXXIX). The zoœcium is a direct continuation of the dilatation, which is obviously only its basal portion and the free part is erect and gradually diminishes in diameter so that it forms a long tapering neck-like portion. Sometimes the narrow end piece is bent at an angle to the remainder. The preservation was not sufficiently good to allow of an examination of the structure of the polyp.

The name *C. repens* is suggested on account of its creeping habit and the decumbent condition of the zoœcia.

Distribution. Northumberland Channel; between Jesse and Newcastle Island. 15-20 fms.

Family TRITICELLIDAE G. O. Sars, 1873.

Genus TRITICELLA Dalyell, 1848.

This genus has not been recorded previously from the Pacific Coast of North America and is here represented by two forms which, while not in entire agreement with previous descriptions, appear to be closely allied to such forms and so are here provisionally included in the genus.

Triticella pedicellata Alder.
Reference. Hincks (7, p. 247, Pl. LXXX), England.
Distribution. Nanoose Bay. 15-20 fms.

The membranous area is not distinct and there appears to be no joint between zoœcium and stalk.

Triticella tegeticula sp. nov. (Pl. IV, Fig. 39).

The stolon forms a very dense matting or network over the substratum and the zoœcia are packed close together. The zoœcium is ovoid and stout and borne on a fairly long stalk, from which it is sharply marked off and which appears to be flexible. Although there is a certain amount of wrinkling there does not appear to be a definite joint between the zoœcium and the stalk and a membranous area is not at all defined. Thus it will be seen that it is not quite a typical *Triticella;* in spite of this, however, it has a close general resemblance to that characteristic genus, and it does not appear advisable to separate the present form from it without more detailed anatomical examination.

The specimen was found on a *Pinnixa* sp., and its stolon forms one continuous tissue over the surface, with branches coming out from it here and there. From this basal reticulum hundreds of zoœcia arise, so that the whole colony bears a superficial resemblance to an encrusting hydroid form like *Hydractinia*, save that the zoœcia project further than the hydroids.

The polyp has a simple complete circle of tentacles 12-16 in number.

A description of this form has not been found and the name *T. tegeticula* is suggested from the mat-like structure of the stolon.

Distribution. False Narrows.

NOTE ON DISTRIBUTION

It was pointed out in the introduction that the present list contains 173 species, 22 additional varieties of some of them and that 39 of the species appear to be new. Thus it is a more extensive list than either Hincks's, which contains 96 species or Robertson's papers, which contain 115 species. Compared with the lists from other areas it indicates a rich fauna in these waters, thus: Whiteaves gives 115 species from Eastern Canada, Osburn has 81 species to report from the Wood's Hole region, Herdman lists 136 from the Irish Sea and the Plymouth list contains 103. In several of these cases it is to be borne in mind that the list is the result of a number of years' work and various previous accounts had been given. The present list cannot be considered as exhaustive, for all the shore regions have not been thoroughly explored and most of the dredging was at less than 30 fms.

The abundance of marine life in this region has been the subject of comment by other workers; thus Fraser (4, p. 100) records that ". . . in a single haul with a two-foot hand dredge, made in this locality (Northumberland Channel) on May 17th, 1912, 36 species of hydroids were obtained. Although this is a record, it is scarcely an isolated case as it is quite a common occurrence to get 20 species in a couple of hours' dredging."

This spot in Northumberland Channel is a very favourable one, for the tide sweeping through False Narrows and Dodd's Narrows, the latter forming a formidable "tide-rip," forms whirlpools and, entering this broader deeper region, becomes much quieter. Even allowing for this, however, its fauna is extraordinary. Four or five hauls with a small dredge 2′ 6″ wide and 8″ high were made at this place, but of these only two were really productive owing to the dredge becoming clogged with kelp in the others. Of these two also, one was much richer than the other. Large numbers of living scallops were obtained, but, in addition, hundreds of old valves or pieces of the valves of the two scallops that were named *Pecten rubida* and *Pecten hastata* a few years ago, but doubtless by this time have different names, as is usual with West Coast shells. A large number of pebbles also furnished a valuable hunting ground.

Thousands of colonies, large and small, were identified upon this débris and the following list gives the species obtained in just the two hauls mentioned above, and probably most of them came in the one.

Entoprocta.

Myosoma spinosa
Gonypodaria parva

Cyclostomata.

Crisia geniculata
Crisia sp?
Tubuliopora fasciculifera
Tubulipora sp?
Stomatopora granulata
Stomatopora diastoporides
Stomatopora incrassata
Stomatopora major
Stomatopora depressa
Lichenopora verrucaria
Lichenopora fava

Cheilostomata.

Aetia truncata
Bugula murrayana
Bugula curvirostrata
Membranipora circumclathrata
Membranipora horrida
Membranipora lacroixii
Membranipora patula
Membranipora spinifera
Membranipora protecta
Membranipora serrata
Membranipora villosa
Membranipora alcicornis
Cribrillina furcata
Cribrilina radiata var. radiata
Lagenipora socialis
Lagenipora erecta
Microporella ciliata var. vibraculifera
Microporella ciliata var. umbonata
Microporella californica
Microporella malusii var. typica
Microporella setiformis
Schizoporella auriculata var. alba
Schizoporella cecelii
Schizoporella biaperta
Schizoporella hyalina var. typica
Schizoporella hyalina var. incrassata
Schizoporella longirostrata
Schizoporella tumulosa
Schizoporella granulata
Porella concinna
Porella acutirostris
Porella columbiana
Porella bispina
Smittia landsborovii var. porifera
Smittia cellata
Rhamphostomella curvirostrata
Mucronella peachii var. labiata
Mucronella microstoma
Mucronella simplicissima var. perforata
Rhynchopora bispinosa
Cellepora incrassata
Cellepora costazii

One or two of the fragments could only be referred to their genus, but were apparently not the same species as already identified. The list contains 53 distinct species, two of them represented by two varieties, an extraordinarily large number. The list given above does not complete the record of the species that have been taken from this comparatively small area in Northumberland channel, not more than a mile long and 400-600 yards wide. At other times the following species were also obtained, an addition of 9 species and 1 variety, and beyond doubt systematic dredging would yield further forms.

Entoprocta.

Gonypodaria nodosa

Cyclostomata.

Idmonea atlantica

CHEILOSTOMATA.

Brettia pellucida

Meripea ternata
Scrupocellaria varians

Bugula murrayana
var. fruticosa
Bugula pacifica
Cellaria diffusa

Hippothoa divaricata

Lepralia nitescens

This undoubtedly represents the richest collecting ground encountered, but on the 10th of August, 1921, three hauls with the same dredge off Protection Gap yielded 37 species, one of them represented by two varieties.

In August, 1921, a short visit was paid to the Marine Biological Station, Friday Harbour, San Juan Islands, U.S.A. During one afternoon a few specimens were collected on or near the wharf of the station and some on odd bits of broken shells and pebbles in the débris brought in from dredging. No further data are available beyond the fact that they were dredged in not very deep water in the vicinity of Friday Harbour. It is thought worth while, however, to give a list of them here, since, while this region falls within the Vancouver Island area in a broad sense, they were obtained from an area near another laboratory and not readily accessible from Nanaimo.

CYCLOSTOMATA.

Tubulipora fasciculifera
Entalophora capitata

CHEILOSTOMATA.

Aetia truncata

Membranipora circumclathrata
Membranipora horrida

Membranipora lacroixii
Membranipora patula

Membranipora villosa

Membranipora serrata

Microporella ciliata
var. vibraculifera
Microporella ciliata
var. umbonata
Microporella malusii
var. typica
Schizoporella sinuosa
Schizoporella hyalina

Schizoporella crassirostris
Schizoporella tumulosa

Lepralia regularis sp. nov.

Porella marsupium

Porella columbiana sp. nov.
Smittia trispinosa
Phylactella pacifica sp. nov.

We think that the above examples and the list in itself are ample evidence of the very rich fauna in the waters around Vancouver Island. That this is true also of other animals is shown by the work of Dr. Fraser on the Hydroids (4) and of Dr. Huntsman on the Holostomatous Ascidians (13), practically the only other groups that have been studied at all closely. It is hoped that further collecting may make it possible to furnish a more detailed survey of the Polyzoa of this interesting region.

REFERENCES

1. BUSK, G. Report on the Polyzoa collected by H.M.S. *Challenger* during the years 1873-76. Part I. The Cheilostomata. *Challenger Reports.* Vol. 10, 1884.

2. ——— Report on the Polyzoa collected by H.M.S. *Challenger* during the years 1873-76. Part II. The Cyclostomata, Ctenostomata and Pedicellina. *Challenger Reports.* Vol. 17, 1886.

3. FEWKES, J. W. New Invertebrata from the Coast of California. *Bull. Essex Inst.* Vol. XXI, 1889.

4. FRASER, C. M. Some Hydroids of the Vancouver Island Region. *Trans. Roy. Soc. Canada.* Vol. VIII, 1914.

5. HARMER, S. F. On the development of *Lichenopora verrucaria* Fabr. *Quart. Jour. Micro. Sci.* n.s. Vol. 39, 1896.

6. ——— Polyzoa. *Cambridge Natural History.* Vol. II, London, 1901.

7. HINCKS, T. A History of the British Marine Polyzoa. 2 Vols. *London,* 1880.

8. ——— Polyzoa of the Queen Charlotte Islands; Preliminary Notice of New Species. *Ann. Mag. Nat. Hist.* Vol. 10, 1882.

9. ——— Report on the Polyzoa of the Queen Charlotte Islands, Pt. I. *Ann. Mag. Nat. Hist.* Vol. 10, 1882.

10. ——— Report on the Polyzoa of the Queen Charlotte Islands, Pt. II. *Ann. Mag. Nat. Hist.* Vol. 11, 1883.

11. ——— Report on the Polyzoa of the Queen Charlotte Islands, Pt. III. *Ann. Mag. Nat. Hist.* Vol. 13, 1884.

11*b* ——— The preceding three reports were issued as Report on the Polyzoa of the Queen Charlotte Islands. *Geol. and Nat. Hist. Survey Canada,* 1884.

12. ——— The Polyzoa of the St. Lawrence: a Study of Arctic Forms. *Ann. Mag. Nat. Hist.* March, 1888.

13. HUNTSMAN, A. T. Holostomatous Ascidians from the Coast of Western Canada. *Contrib. to Canadian Biology,* 1912.

14. LOMAS. Report on the Polyzoa of the L.M.B.C. District. *Proc. Liverpool Lit. & Phil. Soc.* No. XL, 1886.

15. OSBURN, R. C. The Bryozoa of the Woods Hole Region. *Bull. Bur. Fisheries Washington.* Vol. XXX, 1910.

16. ROBERTSON, A. Papers from the Harriman Expedition VI The Bryozoa. *Proc. Washington Acad. Sci.* Vol. II, Oct., 1900.
Republished as The Bryozoa of the Expedition. *Harriman Alaska Exp.* Vol. XI, 1904.

17. ——— Studies in Pacific Coast Entoprocta. *Proc. Califor. Acad. Sci.* Vol. II, 1900

18. ——— Some Observations on *Ascorhiza occidentalis* Fewkes, and Related Alcyonidia. *Proc. Calif. Acad. Sci.* Vol. III, 1902.

19. ——— Non-incrusting Chilostomatous Bryozoa of the West Coast of North America. *Univ. California Pub. Zool.* Vol. 2, 1905.

20. Robertson, A. The incrusting Chilostomatous Bryozoa of the West Coast of North America. *Univ. California Pub. Zool.* Vol. 4, 1908.

21. ——— The Cyclostomatous Bryozoa of the West Coast of North America. *Univ. California Pub. Zool.* Vol. 6, 1910.

22. Trask, J. New Species of Zoophytes from the Bay of San Francisco. *Proc. California Acad. Sci.* Vol. I, 1857.

23. ——— On some new Microscopic Organisms. *Proc. California Acad. Sci.* Vol. I, 1857.

24. Whiteaves, J. F. On a recent species of Heteropora from the Strait of Juan de Fuca. *Amer. Jour. Sci. Arts.* (3), Vol. 24, 1882.

EXPLANATION OF PLATES

The outlines were all made with the aid of a Camera lucida and at the various magnifications indicated.

Plate 1.

Figs. 1, *a* and *b*. *Gonypodaria parva* sp. nov. ×36. Two individuals from different specimens.

1*c*. *Gonypodaria nodosa* ×36. A young specimen to show the difference in size and shape.

MD, Muscular dilatation. Ph. 1, 2, Phalanges 1 and 2. S, Stolon. Z, Zooid.

Fig. 2. *Tubulipora striata* sp nov. ×25. Portion of colony.
G, Growing edge. OP, Oœcial pore. OT, Oœcial tube. ZT, Zoœcial tube.

Fig. 3. On plate 2.

Fig. 4. *Tubulipora intermedia* sp. nov. ×11. Colony from the ventral surface.
B, Basal attaching portion. O, Oœcium. OP, Oœcial pore. OT, Oœcial tube. S, Stalk of colony. ZT, Zoœcial tube.

Fig. 5. *Stomatopora depressa* sp. nov. ×25. Colony viewed from above.
F, Founder zoœcium. D, Zoœcium with ventral wall broken away. O, Oœcium. OS, Oœciostome. ZT, Zoœcial tube.

Fig. 6. *Idmonea palmata* sp. nov. ×10. Portion of the end of one of the branches of the colony.
G, Growing end of colony. OP, Oœcial pore. OS, Oœciostome. OT, Oœcial tube. ZT, Zoœcial tube.

Fig. 7. *Entalophora vancouverensis* sp. nov. ×14. Portion of the end of a colony.
G, Growing end of colony. ZT, Zoœcial tube.

Fig. 8. *Heteropora magna* sp. nov. ×25. Portion of the surface of a branch to show the arrangement of zoœcia and interstitial canals.
I, Interstitial canals. Z, Zoœcium.

Fig. 9. *Lichenopora fava* sp. nov. ×25. Portion of the surface of a colony to show honey-comb appearance of zoœcia and interstitial pores.
G, Growing edge of colony.

Fig. 10. *Scrupocellaria inermis* sp. nov. ×40. Portion of a colony to show branching.

A, Aperture. Av, Lateral avicularium. J, Joint. MAv, Median avicularium. V, Vibraculum. VC, Vibracular chamber.

PLATE 2.

Fig. 3. *Tubulipora labiata* sp. nov. ×25.

a. Portion of colony with short tubes and an oœcium seen from above.

b. Portion of colony with long tubes seen partly from the side.

O, Oœcium. OP, Oœcial pore. OS, Oœciostome. OT, Oœcial tube. ZT, Zooœcial tube.

Fig. 11. *Bicellaria brevispina* sp. nov. ×31. Portion of colony to show branching.

A, Aperture. O, Operculum. S, Spine.

Fig. 12. *Beania columbiana* sp. nov. ×37. Three neighbouring zooœcia to show the relation of the zooœcia to the connecting tubes. The spines on the dorsal side have been omitted for the sake of simplifying the drawing.

A, Aperture. CT, Connecting tube. O, Operculum. S, Spine.

Fig. 13. *Flustra simplex* sp. nov. ×25. Growing end of a moderately wide branch.

R, Rudimentary zooœcia. S, Stoma.

Fig. 14. *Membranipora alcicornis* sp. nov. ×37.

A, Aperture. AS, Anterior Spine. O, Oœcium.

Fig. 15. *Membranipora cassidata* sp. nov. ×30.

A, Aperture. Av, Anterior avicularium. L, Lateral avicularium. M, Mandible. Ma, Margin. O, Oœcium. S, Spine.

Fig. 16. *Membranipora aquilirostris* sp. nov. ×25.

A, Aperture. Av, Anterior avicularium. M, Mandible. Ma, Margin. S, Spine. St, Stolon.

Fig. 17. *Membranipora alba* sp. nov. ×25.

A, Aperture. Av, Avicularium. M, Mandible. Ma, Margin. O, Oœcium. S, Stoma.

Fig. 18. *Membranipora inconspicua* sp. nov. ×40.

A, Aperture. Av, Avicularium. AS, Anterior Spine. L, Lateral avicularium. M, Margin. O, Oœcium.

PLATE 3.

Fig. 19. *Membranipora varians* sp. nov. ×36.

A, Aperture. Av, Anterior avicularium. AS, Anterior Spines. L, Lateral avicularium. M, Margin. S, Lateral spines.

Fig. 20. *Membraniporella corbicula* sp. nov. ×30.

The anterior zooœcia are young and the basketwork of calcareous bars has not been completely formed.

Fig. 21. *Microporella setiformis* sp. nov. ×25.
A, Aperture. Av, Avicularium. P, Pore.

Fig. 22. *Lagenipora erecta* sp. nov. ×37.
Av, Avicularium. B, Body of Zoœcium. O, Oœcium. S, Secondary Aperture. T, Tubular portion of zoœcium.

Fig. 23. *Schizoporella granulata* sp. nov. ×30.
A, Aperture. O, Oœcium. S, Sinus.

Fig. 24. *Schizoporella fistulata* sp. nov. ×25.
A, Aperture. Av, Avicularium. O, Oœcium. T, Tubular process.

Fig. 25. *Schizoporella ordinata* sp. nov. ×30.
A, Aperture. O, Oœcium. S, Sinus.

Fig. 26. *Myriozoum tenue* sp. nov. ×36.
(*a*) Portion of the surface of the stem with ordinary zoœcia.
(*b*) Portion of the stem in the region with oœcia.
A, Aperture. Av, Avicularium. O, Oœcium. S, Sinus.

Fig. 27. *Lepralia regularis* sp. nov. ×25.
A, Aperture. P, Pores. S, Curious stalked pores characteristi fo the species.

Fig. 28. *Porella columbiana* sp. nov. ×30.
A, Aperture. Av, Avicularium. O, Oœcium. P, Peristome.

Fig. 29. *Porella bispina* sp. nov. ×30.
The three uppermost zoœcia are at the growing edge, the three lower ones no longer project but are below the general layer of the colony. A, Primary aperture. Av, Avicularium. O, Oœcium. P, Peristome. SA, Secondary aperture. S, Spine.

PLATE 4.

Fig. 30. *Porella cribriformis* sp. nov. ×30.
A, Aperture. Av, Avicularium. O, Oœcium.

Fig. 31. *Smittia cellata* sp. nov. ×25.
A, Aperture. Av, Avicularium. D, Denticle. O, Oœcium.

Fig. 32. *Smittia torquata* sp. nov. ×25.
A, Aperture. Av, Avicularium. D, Denticle.

Fig. 33. *Phylactella pacifica* sp. nov. ×25.
A, Aperture. O, Oœcium.

Fig. 34. *Rhamphostomella curvirostrata* sp. nov. ×25.
A, Aperture. Av, Avicularium. M, Mandible. O, Oœcium. R, Rostrum.

Fig. 35. *Rhamphostomella porosa* sp. nov. ×30.
A, Aperture. Av, Avicularium. O, Oœcium. R, Rostrum.

Fig. 36. *Cellepora armiger* sp. nov. ×30.
A, Aperture. Av, Avicularium. O, Oœcium. S, Shield-like structure.

Fig. 37. *Alcyonidium spinifera* sp. nov. ×25.

a. A small piece of the surface.

b. Two isolated spines.

A, Aperture. S, Spine.

Fig. 38. *Cylindroecium repens* sp. nov. ×25.

A, Aperture. B, Branch of stolon. BS, Basal spine-like process. C, Coenosarc. Cc, Coenosarc connection from stolon to polyp. S, stolon.

Fig. 39. *Triticella tegeticula* sp. nov. ×13. A small piece teased off from a much larger colony.

A, Aperture. B, Basal mat-like stolon. P, Polyp. S, Stalk.

262

PLATE I

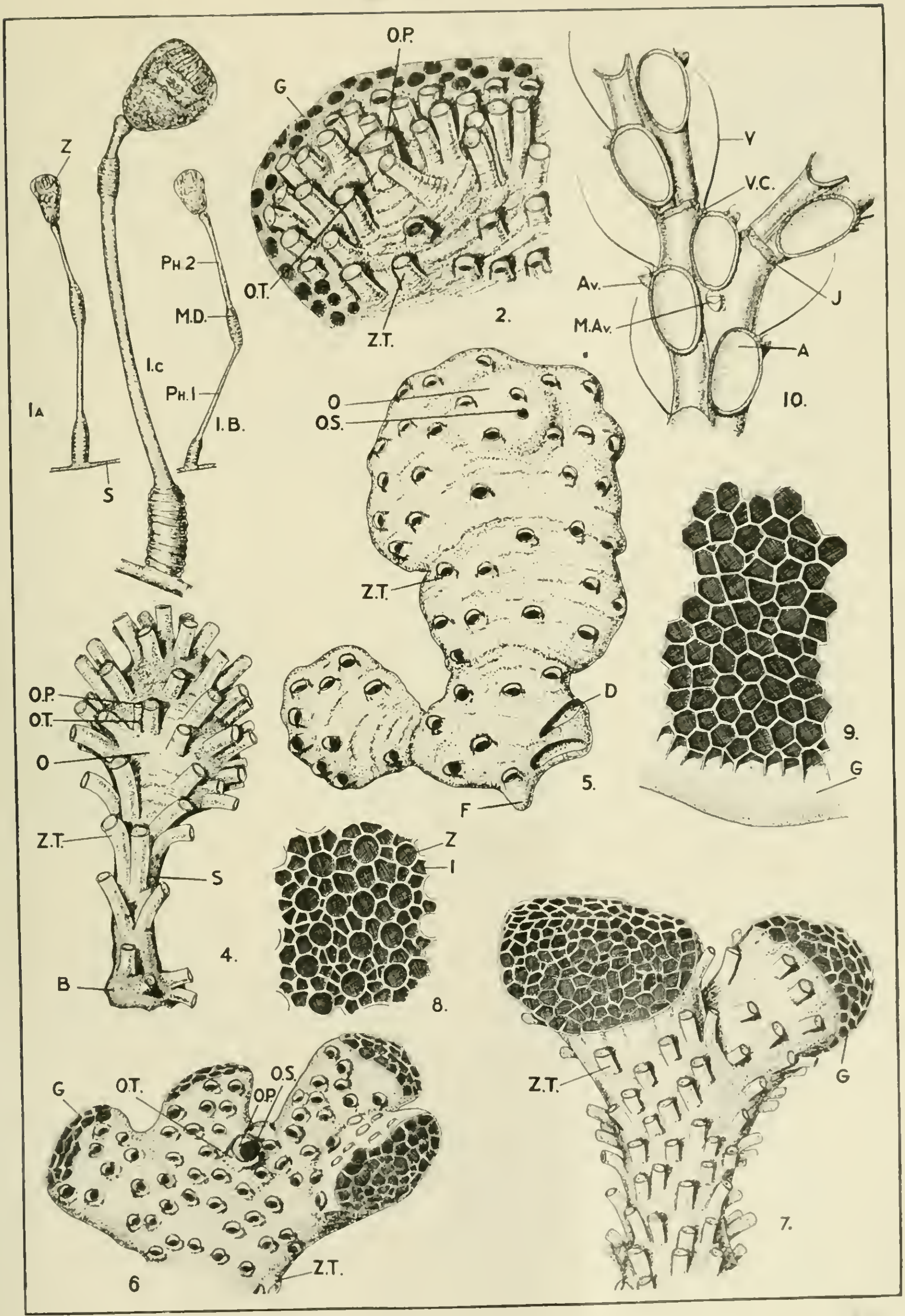
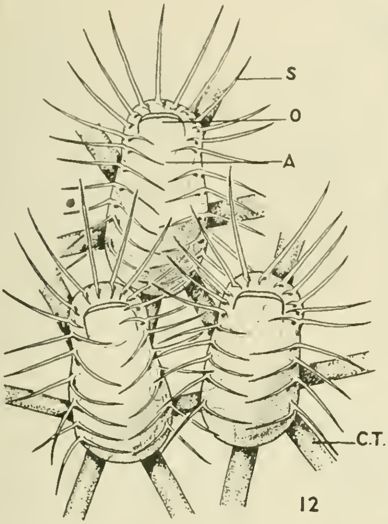
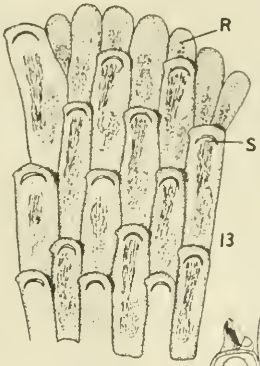

Z
S
1A
I.C
PH.2
M.D.
PH.1
I.B.
O.P.
G
O.T.
Z.T.
2.
V
V.C.
AV.
M.AV.
J
A
10.
O
O.S.
Z.T.
D
F
5.
9.
G
O.P.
O.T.
O
Z.T.
S
B
4.
Z
I
8.
G
O.T.
O.S.
O.P.
Z.T.
6
Z.T.
G
7.

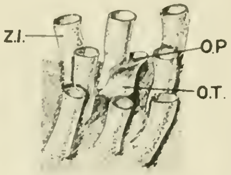
PLATE II



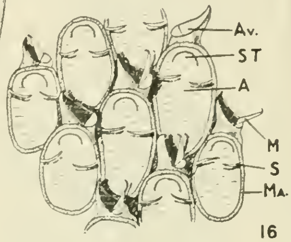
12



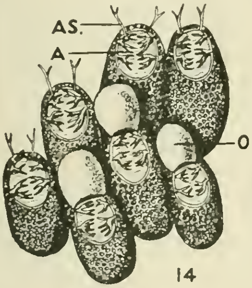
13



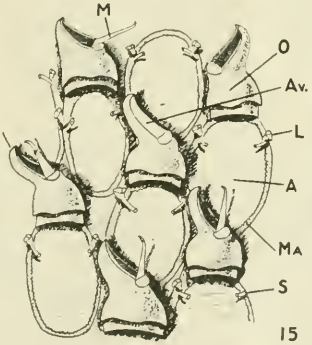
3 B.



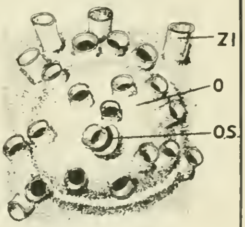
16



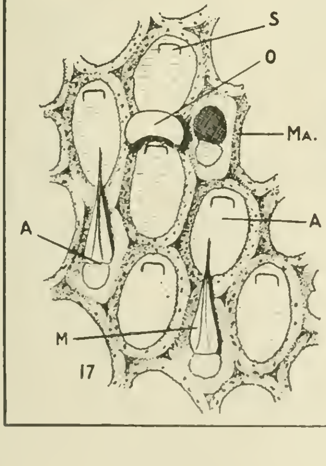
14



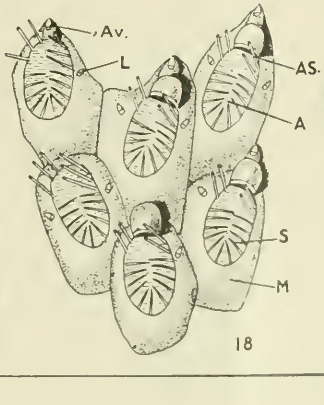
15



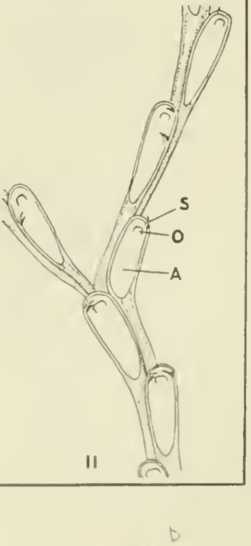
3 A.



17

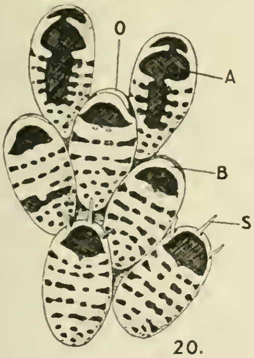


18

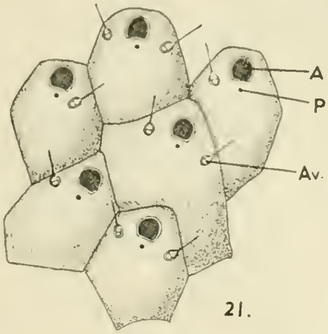


11

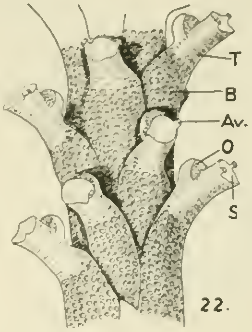
PLATE III



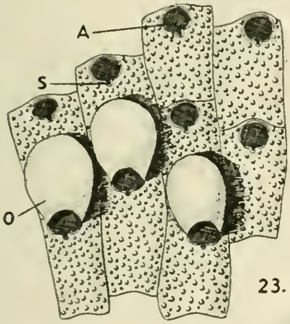
20.



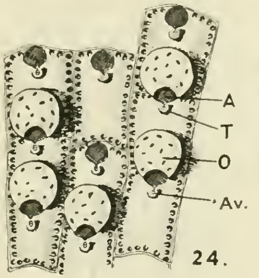
21.



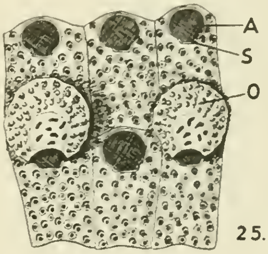
22.



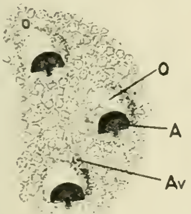
23.



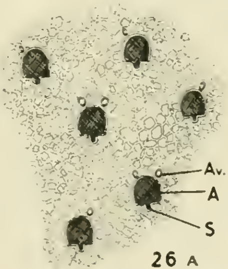
24.



25.

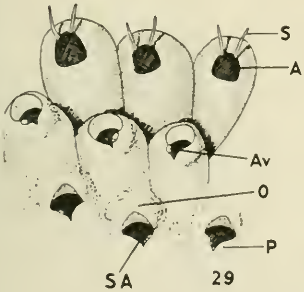


26 B

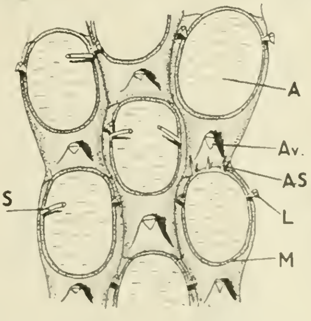


26 A

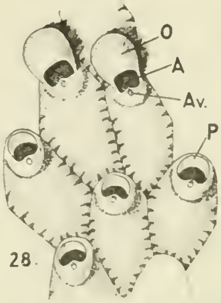
27.



29

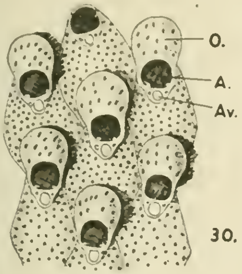


19.

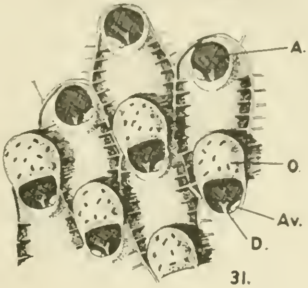


28.

PLATE IV

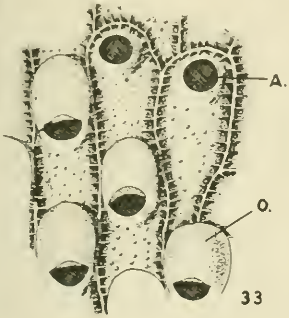


30.

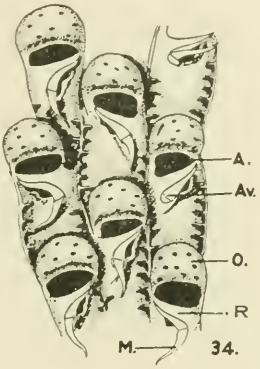


31.

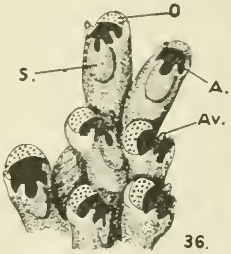
32.



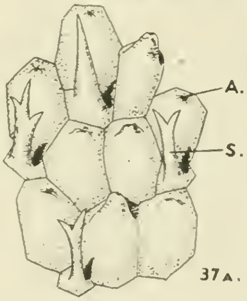
33



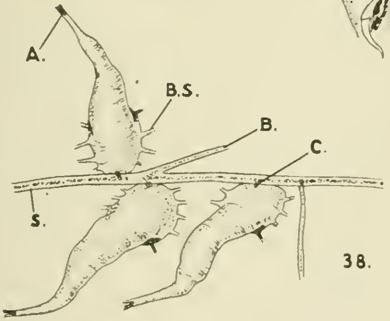
34.



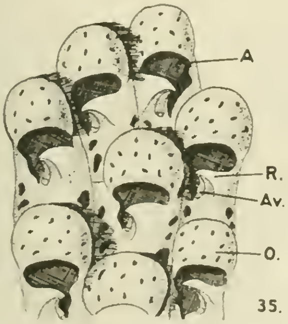
36.



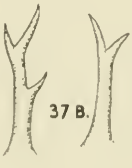
37 A.



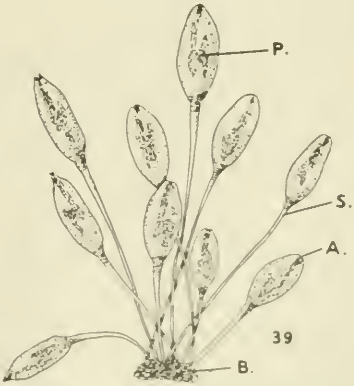
38.



35.



37 B.



39

No. 11

POLYCHAETOUS ANNELIDS FROM THE NANAIMO DISTRICT.

PART I. SYLLIDÆ TO SIGALIONIDÆ.

BY

EDITH BERKELEY.

205

Polychaetous Annelids from the Nanaimo District.

Part I. Syllidæ to Sigalionidæ.

By EDITH BERKELEY.

The polychaetous annelids comprised in the following list have all been collected within a radius of twenty miles of Nanaimo, Vancouver Island. I have collected all the species listed personally, though a few of them were already represented in the collection of the Marine Biological Station, Departure Bay, which was kindly placed at my disposal for study by Dr. C. Maclean Fraser, the Director of the station. I am also indebted to Dr. Fraser for the dredged material I have examined, for access to the resources of the station in the matter of literature, and for assistance in other directions.

The list cannot claim to be a complete record of the polychaetes occurring within the area, since sufficient dredged material, particularly from depths exceeding 25 fathoms, has not been examined, but it probably comprises most of the species occurring at this and lesser depths, and of the shore forms.

It is proposed to publish the list in instalments as work on the groups is completed. The present instalment comprises the Syllidae, Hesionidae, Aphroditidae, Amphinomidae, Palmyridae, Polynoidae, and Sigalionidae, and records 43 species.

Most of the species listed have been described from Pacific waters by Johnson, Moore, Treadwell, or others.

The following species have been previously recorded from both Alaska and California, but not from the intermediary region: *Syllis alternata*, *Syllis armillaris*, *Euphrosyne arctia*, *Euphrosyne hortensis*, *Peisidice aspera*.

The following from Alaska only: *Autolytus prismaticus*, *Hololepida magna*, *Gattayana ciliata*, *Pholoë minuta*.

The following from California only: *Heteropale bellis*, *Evarne triannulata*, *Sthenalais verruculosa*.

The species *Syllis borealis*, *Pionosyllis lamelligera*, *Pionosyllis prolifera*, *Amblyosyllis lineata*, *Castalia fusca*, *Halosydna gelatinosa*, have not previously been recorded on the Pacific coast of North America.

Odontosyllis parva, *Autolytus magnus*, *Malmgrenia nigralba*, and *Lepidasthenia longicirrata* are placed on record as new species, and *Odontosyllis phosphorea* var. *nanaimoensis* and *Amblyosyllis lineata* var. *alba* as new varieties.

Family SYLLIDÆ.

Syllis borealis Malmgren.

Syllis borealis Malmgren (1867), Annul. Polych., p. 42.

Pionosyllis (*Syllis*) *hyalina* McIntosh, British Annelids. Vol. 2, Pt. 1, p. 166.

This form resembles *Syllis hyalina* Grube very closely, differing only in having a uniform brown mottling over the anterior third of the dorsum instead of brown bandings, and in the absence of bifid setæ. McIntosh places the species in the genus Pionosyllis on account of the bifid setæ and considers it synonymous with Malmgren's *Syllis borealis*. He points out, however, that Malmgren figures setæ with simple tips.

The specimens in this collection are all characterized by setæ with simple tips and, though I have not had access to Malmgren's description, I have therefore placed the form, provisionally, in his species.

Collected at Newcastle Island.

Two specimens of an epitokous form, apparently of this species, were taken at night in August at the Station float.

Syllis alternata Moore.

Syllis alternata Moore (1908), p. 323; Treadwell (1914), p. 176.

Collected off Clarke Rock.

Syllis armillaris (Müller) Oersted.

Syllis armillaris McIntosh, British Annelids. Vol. 2, Pt. 1, p. 188; Moore (1908), p. 323; Treadwell (1914), p. 176.

The markings of the specimens correspond more closely to the description given by Moore than to that of McIntosh.

Collected at False Narrows and at Mudge Island.

A sexual form (female) collected at Cardale Point is probably that of this species. It corresponds with *Ioida macrophthalma* as described by McIntosh, except that the swimming bristles start on the third segment and the eyes are red. The eggs give the animal a strikingly golden appearance.

Syllis elongata Johnson.

Pionosyllis elongata Johnson (1901), p. 403.
Syllis elongata Moore (1909), p. 236.
Syllis (Pionosyllis) elongata Treadwell (1914), p. 176.

Collected at Mudge Island.

An epitokous form taken repeatedly at the Station float at night during the summer months possibly appertains to this species. The setæ and cirri agree. The body is broad anteriorly and tapers uniformly to a sharp point. It has 30 setigerous segments and the swimming bristles start on the second post-cephalic segment.

Johnson states that stolonization does not occur in this species, though the terminal segments become much enlarged at sexual maturity, but Moore thinks it probable that this enlarged region separates.

Pionosyllis gigantea Moore.

Pionosyllis gigantea Moore (1908), p. 325; Treadwell (1914), p. 176.

Dredged off N.East Newcastle Island in 20-25 fathoms.

Pionosyllis lamelligera De St. Joseph.

Pionosyllis lamelligera McIntosh, British Annelids. Vol. 2, Pt. 2, p. 236.

The specimens agree with McIntosh's description, except that (as preserved) they are devoid of colour.

Collected at False Narrows.

Pionosyllis prolifera Krohn.

Pionosyllis prolifera McIntosh, British Annelids. Vol. 2, Pt. 1, p. 161.

A single specimen, with an immature bud, seems to agree in the main with McIntosh's description. Anteriorly it has the dorsal cirri alternately long and short, as described by Marenzeller (McIntosh, p. 163) and the longer ones have as many as 40 articulations. The median tentacle is about the same length as the longer dorsal cirri and the lateral tentacles are about half as long. The bud starts at somite 32 and is twice as broad as the nurse-stock. The parapodia have each two acicula ending in small knobs, and the last 9 or 10 parapodia of the bud have each, in addition to the ordinary setæ, a simple straight spine. The anterior portion of the nurse-stock has a narrow simple brown band on each somite.

Collected at Horsewell Point.

Trypanosyllis gemmipara Johnson

Trypanosyllis gemmipara Johnson (1901), p. 405; Treadwell (1914), p. 177; Moore (1908), p. 328.

Collected at False Narrows.

Odontosyllis phosphorea Moore, var. *nanaimoensis*, var. nov.

Odontosyllis phosphorea Moore (1909), p. 327.

The swarming of this species has been discussed by Potts (Proc. of the Cambridge Philosophical Society, Vol. 17, Pt. 2, p. 193) and by Fraser (Trans. of the Royal Society of Canada, Vol. 9, Sect. 4, p. 43). In both cases it has been identified with *Odontosyllis phosphorea* Moore. Whilst resembling this species in many respects it has been found, by comparison with both Moore's description and a specimen obtained from San Diego Bay, to differ from it in the following particulars:

The prostomium is only slightly, or not at all, pigmented and the eyes are carried on it dorsally rather than laterally. The nuchal fold is entirely unpigmented. The intersegmental lines of black pigment are much thickened at the centre on every third or fourth segment, giving the appearance of a line of heavy spots along the middle of the dorsum; whereas in *O. phosphorea* Moore the lines, though heavier at every fourth segment, are broken in the centre and this spotted effect is absent. The neuropodium, with the attached ventral cirrus, projects more abruptly from the body than in *O. phosphorea* and the cirrus has no distinct distal piece. The notocirrus arises from a short but distinct cirrophore, is shorter than figured by Moore, and is lanceolate. The swimming bristles start on somite 21 instead of on somite 24 The secondary process of the bifid hooks of the blades of the neurosetae are closely adjacent to the main hook, not some distance below it as in *O. phosphorea*.

These differences seem sufficiently marked to necessitate the establishment of, at least, a new variety.

The average length of the sexually mature form is about 25 mm., but individuals are found running up to 35 mm.

Taken swarming in Departure Bay from July to November; dredged off Clarke Rock and at Porlier Pass.

Odontosyllis parva sp. nov. Pl. 1, Figs. 1-2.

A single incomplete specimen consisting of head and 36 anterior segments. Length about 15 mm. Less than 1 mm. wide.

Prostomium (Pl. 1, Fig. 1) twice as broad as long, rounded laterally and nearly straight anteriorly, bearing the three tentacles on the anterior edge. Median tentacle is about two and a half times the length of the prostomium and the lateral tentacles about one and a half times the length. Eyes four, large, brown, and with lenses; posterior pair dorsal, anterior pair latero-ventral. Palps small, folded downwards, not visible from dorsum.

Two pairs of peristomial cirri; the dorsal pair are as long as the lateral tentacles, the ventral pair are shorter. The nuchal fold arises from the dorsum of somite 2, is a semicircular flap and covers half the large posterior eyes. The dorsal cirri of somite 2 are as long as the median tentacle. The subsequent ones are much shorter and lanceolate.

The parapodia are not prominent; that of somite 24 (Pl. 1, Fig. 2) has the following characters: Beneath the notocirrus is a small prominence, the notopodium, covering the end of a curved aciculum. The neuropodium projects beyond the notopodium, but is short and blunt, terminating in two rounded lobes. The neuropodium has a single straight aciculum and about 12 compound setæ, all sub-acicular. The setæ have fairly stout shafts which are curved in the ventral part of the fascicle and straight in the dorsal part. The ends of the shafts are oblique, dilated, and slightly roughened. The terminal pieces are practically equilateral triangular in form, the length of the side being equal to the diameter of the shaft, and have boldly bifid tips. The ventral cirrus is a heavy rounded knob, larger than the neuropodium. A small tuft of rudimentary swimming bristles arises just dorsal of the notopodium.

The body (as preserved) is yellowish and has no distinctive markings.

Collected at False Narrows on Bryozoa.

Amblyosyllis lineata Grube, var. *alba*, var. nov.

Amblyosyllis lineata McIntosh, British Annelids. Vol. 2, Pt. 1, p. 225.

This form is entirely devoid of colour in the living condition, except a slightly yellowish head with red eyes. The palps are conical and are bent abruptly downwards and outwards and certain individuals have on each side of the prostomium a conical process partially covering the anterior eye. In all other respects it agrees closely with McIntosh's description of *Amblyosyllis lineata* Grube, and is therefore considered a variety of that species. It occurs fairly commonly in the cavity of siliceous sponges in the region and attains a length of as much as 35 mm.

Found in sponges dredged off Maude Island and off N.East Newcastle Island in 20-25 fathoms.

Sphaerosyllis sp.

Several specimens of this interesting genus occur in the collection, both males and females, all collected at the same spot and probably of one species. They are too imperfectly preserved to describe fully. The occurrence is placed on record here for reference in the hope of obtaining more material later. The following are characters of the male:

Length, 2 mm. 35 segments. Swimming bristles start on somite 11. Last four or five segments have no swimming bristles. Anal segment has two heavy cirri.

Eyes four, dark brown, anterior pair larger, wider apart and with lenses Median and lateral tentacles broadly ellipsoid. Palps project straight forward, are fused, except at the tip, and are larger and more prominent than those figured by McIntosh (British Annelids. Vol 2, Pt. 1, p. 156) for *Sphaerosyllis hystrix*. Proboscis has one large tooth, papillae insignificant or absent.

Parapodium has small globular dorsal cirrus and four or five compound setæ with extremely slender tapering terminal pieces (suggesting superficially the simple setæ of *Genetyllis*). In the posterior region a rather heavy simple seta also occurs in each parapodium.

The female seems to resemble the male in all particulars except that there are no swimming bristles, and green ova, two to each segment, carried ventrally, begin on somite 8 and extend for about 15 somites.

Collected amongst Bryozoa on rock at low tide mark at Horsewell Point.

Autolytus prismaticus Fabricius (?).

Nereis prismatica Fabricius (1780), Fauna Groenl, p. 302.
Proceraea gracilis Verril (1874), Amer. J. Sci., p. 132.
Autolytus prismaticus Chamberlin (1920), Rep. Can. Arctic Exp. Vol. 9, Pt. B, p. 12.

The nurse-stock of this *Autolytus* corresponds with Verrill's description of *Proceraea gracilis* in such particulars as are given by him. Chamberlin considers *Proceraea gracilis* synonymous with *Autolytus prismaticus*.

The sexual forms have been reared in captivity. Budding commences after somite 13 and only one bud, consisting of about 33 somites and pygidium, is produced at a time. All the buds produced from any one nurse-stock are of one sex. As first separated the sexual forms have the six anterior setigerous segments free from swimming bristles, then follow nineteen with swimming bristles. The caudal region tapers more sharply in the male than the female and is free from swimming bristles in both cases. The heads are typically those of *Polybostrichus* and *Sacconereis* respectively and have red eyes. Four to six setæ of the usual *Autolytus* type, and one simple seta with straight shaft dilated sub-terminally and having a finely pointed bent tip, occur on each parapodium. The females have not developed brood-sacks but are distended with ova. The males are a golden colour, the sperms making the first six (2-7) segments dense white.

The literature at my disposal has been insufficient to enable me to confirm the synonymy or to check the diagnosis by means of the sexual forms

Nurse-stock collected in January amongst *Obelia* growing on buoy moored off Biological Station. Free sexual forms in May, August and November at the Station Float, and females with brood-sacks in tow taken below Dodd's Narrows in September.

Autolytus magnus sp. nov , *Sacconereis* phase (Pl. 1, Figs. 3-4).

A single specimen. Length, 40 mm. Width over parapodia at middle of median region 6 mm. Body divided into three regions. The anterior region, consisting of 15 somites, has no swimming bristles. The median region, on which all the swimming bristles are borne, begins at somite 16 and extends to somite 50; this region carries a large brood-sack filled with larvae. The posterior region tapers uniformly to a fine point.

Prostomium twice as broad as long. Eyes two pairs; the anterior pair, which are the wider apart, are very large, have prominent lenses, and look laterally and ventrally; the posterior pair, also with lenses, are about a quarter the size of the anterior and are completely dorsal. The median tentacle arises between the posterior eyes and is much longer than the lateral tentacles. The lateral tentacles arise together from the anterior margin of the prostomium and their bases entirely fill the space between the anterior eyes; they are five or six times as long as the prostomium. Palps not visible from the dorsum. They project very little from the ventral surface of the prostomium which they completely cover. They are bounded anteriorly by the bases of the lateral tentacles and laterally by the anterior eyes. They are completely coalesced in front, but the groove between them becomes distinct near the mouth.

Tentacular cirri two pairs; the dorsal ones closely resemble the lateral tentacles, the ventral ones are about one-third the length of the dorsal. The cirrus of the first setigerous somite is nearly twice as long as the lateral tentacle; subsequent cirri (after that of somite 4) tend to be alternately short and long throughout the anterior region, gradually becoming more uniform in length posteriorly.

Parapodia (Pl. 1, Figs 3-4) terminate in two heavy lips, both of which are postsetal. The cirrophores are strongly developed and carry coarse unjointed cirri. Four or five acicula are present in each parapodium. The setæ, which arise in a dense tuft, are slender and have straight shafts enlarged distally and roughened near the articulation. The appendages are relatively small and bidentate; the teeth are heavy and of about equal size.

The preserved specimen is colourless.

Taken swarming at the Station Float in February.

Autolytus sp.?, *Polybostrichus* phase.

Length, 5 mm. Head, of usual *Polybostrichus* type, followed by 14 narrow segments, form the anterior region of the body. The median region is broader than the anterior one, consists of 23 segments, and carries the swimming bristles. The caudal region consists of ten or eleven segments.

The cirri are longer and more slender on the anterior region of the body than on the median and posterior regions.

Each parapodium carries about six compound setæ, the shafts of which are curved, have dilated ends, and bear rather heavy, short terminal pieces with boldly bifid tips. After somite 30 each parapodium has, in addition, a single simple seta with a bent tip diminished to a fine point.

A single specimen taken in surface tow in Departure Bay in August.

Family HESIONIDÆ.

Castalia fusca Johnston.

Castalia fusca McIntosh, British Annelids. Vol. 2, Pt. 1, p. 127.

The specimens average about half an inch in length. McIntosh gives the length one to three inches. Otherwise the agreement with the description is good.

Collected on Station Flat.

Podarke pugettensis Johnson.

Podarke pugettensis Johnson (1901), p. 397.

Collected at False Narrows; Departure Bay Beach; Mudge Island; Nanoose Bay Beach. Dr. Willey found this species in the ambulacral grooves of *Luidia* sp.? and *Pteraster* sp.? collected at Porlier Pass.

Family APHRODITIDÆ.

Aphrodita japonica Marenzeller.

Aphrodita japonica Marenzeller (1879), p. 111; Moore (1908), p. 338.

Dredged between Norway and Hall Islands in 15-20 fathoms; Houston Passage in 15 fathoms; Pylades Channel in 30 fathoms.

Aphrodita negligens Moore.

Aphrodita negligens Moore (1905), p 526; Treadwell (1914), p. 178.

The eyes of the specimens in this collection are larger and the palps somewhat longer than Moore describes.

Dredged at Porlier Pass in 10-15 fathoms; Trincomalee Channel in 16 fathoms; between Round and Mudge Islands in 25 fathoms.

Aphrodita parva Moore.

Aphrodita parva Moore (1905), p. 529; Treadwell (1914), p. 178.

Dredged between Departure Bay and Clarke Rock in 25 fathoms; Trincomalee Channel in 16 fathoms.

Family AMPHINOMIDÆ.

Euphrosyne arctia Johnson.

Euphrosyne arctia Johnson (1897), p. 159.

Euphrosyne arctica Moore (1908), p. 340; Treadwell (1914), p. 178.

Dredged in Nanoose Bay in 15 fathoms.

Euphrosyne bicirrata Moore.

Euphrosyne bicirrata Moore (1905), p. 532.

Dredged S.E. Snake Island in 20-30 fathoms; off Grey Rocks; near Maude Island in 25 fathoms; Clarke Rocks; Halibut Bank; between Jesse and Newcastle Islands; between Round and Mudge Islands in 18 fathoms.

Euphrosyne hortensis Moore.

Euphrosyne hortensis Moore (1905), p. 534; Treadwell (1914), p. 178.

The spurred dorsal setæ tend to have longer spurs in the specimens in this collection than are figured by Moore.

Dredged S.E. Snake Island in 20-30 fathoms; off Grey Rocks; N.W. of Departure Bay; near Maude Island in 25 fathoms; off Clarke Rock.

Family PALMYRIDÆ.

Heteropale bellis Johnson.

Heteropale bellis Johnson (1897), p. 163.

Collected at Mudge Island in 15 fathoms; False Narrows (in shell of Giant Barnacle); Horsewell Point.

Family POLYNOIDÆ.

Halosydna pulchra Johnson.

Polynoe pulchra Johnson (1897), p. 177.

Halosydna pulchra Moore (1908), p. 329; Treadwell (1914), p. 179.

Collected off Jesse Island; off Gabriola Island; Houston Passage. Commensal with the following: *Stichopus californica*, *Asterias* sp.?, *Luidia* sp.?, *Solaster stimpsoni*, *Pteraster tessalatus*.

Halosydna insignis Baird.

Halosydna insignis Baird (1865), p. 188; Moore (1910), p. 329; Treadwell (1914), p. 180.

Polynoe brevisetosa Johnson (1897), p. 167.

Collected at Horsewell Point; False Narrows; Mudge Island; Newcastle Island; Nanoose Bay; Cardale Point. Found free under stones throughout the district. Also, with *Polynoe tuta*, both commensal with *Thelepus crispus*.

Halosydna lordi Baird.

Halosydna lordi Baird (1865), p. 190; Moore (1908), p. 330; Treadwell (1914), p. 181.

Polynoe lordi Johnson (1897), p. 175.

Collected at Mudge Island; False Narrows; off San Juan Island in 15-20 fathoms. Commensal with *Fissuridea aspera* and *Puncturella multifilosa*. One specimen found commensal with *Thelepus crispus* had 78 segments and 40 pairs of elytra, but agreed otherwise with Johnson's description.

Halosydna fragilis Baird.

Halosydna fragilis Baird (1865), p. 191.

Polynoe fragilis Johnson (1897), p. 179; Moore (1908), p. 332; Treadwell (1914), p. 181

Collected at Rock Bay; Mudge Island; Jesse Island, and at many other localities throughout the district. Commensal with *Evasterias troschelii*, *Luidia* sp.?, *Orthasterias leptolena*, *Orthasterias columbiana*.

Halosydna gelatinosa Sars.

Halosydna gelatinosa McIntosh, British Annelids. Vol. 1, Part 2, p. 384.

Collected off Newcastle Island in 25 fathoms; off Round Island in 25 fathoms.

This species is represented in the collection by two specimens, one of which is immature. The larger specimen agrees closely with McIntosh's description except in that the palps are rather longer than figured and the segmental papillæ are not prominent. It has 39 bristled segments and a caudal regeneration cone. McIntosh describes 43 bristled segments.

Lepidonotus caeloris Moore.

Lepidonotus caeloris Moore (1903), p. 412; Treadwell (1914), p. 182.

Collected off Maude Island in 25 fathoms; Cardale Point; off Newcastle Island in 25-30 fathoms.

Malmgrenia nigralba sp. nov. (Pl. 1, Figs. 5-7).

Body about 18 mm. in length. Tapers anteriorly and posteriorly. Greatest width about 4 mm. at somite 20. There are 39 bristled segments. The colour scheme of the body is strikingly black and white. The dorsal surface is pearly white anteriorly. Posteriorly there are touches of black pigment gradually increasing in density until the last few segments, which are exposed and entirely black. Styles of dorsal cirri are black with white tips. Elytra are white, each bearing a heavy black ring. The ventral surface anteriorly is white with touches of black at the base of the ventral cirri and on the segmental papillæ. Posteriorly there are also pigmented areas distributed over the surface of each segment.

Prostomium (Pl. 1, Fig. 5) broader at base than in front. The anterior border runs into the base of the lateral tentacles (as in *Halosydna*). Anterior eyes are wider apart than the posterior pair and are only just visible from the dorsum. Median tentacle has dark brown, well-developed ceratophore. Its style has a few small clavate papillæ and it tapers evenly to a point; the basal two-thirds is heavily pigmented and it is about the same length as the prostomium. The lateral tentacles have distinct basal joints and styles about one-third the length of the median tentacle; they are slightly pigmented throughout. The palpi are white, smooth, uniformly tapering and about twice the length of the prostomium. The tentacular cirri are very similar to the median tentacle. The caruncle is heavily pigmented.

Parapodia are short and blunt. The notopodium is very small and bears about a dozen short, slightly curved, finely serrated, tapering setæ. Both these and the neurosetæ agree very closely with those described by McIntosh for *Malmgrenia andreapolis* (British Annelids Vol. 1, Part 2, p. 383).

The dorsal cirri extend nearly to the end of the setæ. They are uniformly tapered and bear a few small clavate papillæ. The ventral cirri are slender, reach just beyond the base of the nearest setæ and bear clavate papillæ.

There are fifteen pairs of elytra. The first pair are small and circular, the next two or three pairs reniform and the remainder large and irregularly rounded. Each of the anterior elytra bears the well-defined group of anterior papillæ characteristic of the genus (Pl. 1, Fig. 6). Posteriorly these become increasingly less conspicuous and the rings of black pigment more broken. The posterior portion of the dorsal surface of all the elytra is embossed with a reticular pattern of white lines in very slight relief (Pl. 1, Fig. 7).

Collected on sand-bed at very low tide at Piper's Lagoon.

Hololepida magna Moore.

Hololepida magna Moore (1905), p. 541; Moore (1908), p. 329.

This remarkable species has been represented hitherto by a single specimen taken at Kasaan Bay, Prince of Wales' Island, Alaska, in 95-114 fathoms. Two complete specimens occur in this collection, both dredged in 15-20 fathoms between Round Island and Mudge Island.

Lepidasthenia logicirrata sp. nov. (Pl. 1, Figs. 8-13).

Body is flattened, tapers anteriorly; widest portion at somite 8. The type is in three portions and has a regenerated tail. Length 55 mm. Width at somite 8 over setæ 7 mm. There are 92 segments. General body colour (as preserved) pale brown with areas of darker brown pigmentation at the base of the parapodia, elytrophores and cirrophores, especially in the anterior portion of the body. The dorsum is conspicuously marked with groups of 12, or more, fine dark lines across the centre of each segment.

Prostomium (Pl. 1, Fig. 8) wider than long with lateral protuberances. Eyes two pairs. Anterior pair large, on lateral protuberances, looking forward; posterior pair half the size of the anterior pair, closer together and a little forward of the posterior margin of the prostomium. Well marked suture. Median tentacle has large ceratophore and style nearly five times the length of the prostomium. It is smooth, delicate and tapered gradually to a filamentous tip and has only a slight sub-terminal enlargement, immediately beyond which is a dark band. The styles of the lateral tentacles arise a little below the level of that of the median tentacle; they are about three times the length of the prostomium and taper uniformly to filamentous tips. The sub-terminal enlargement is barely perceptible and there is no pigmented band. The palps are almost as long as the median tentacle; they are about one-third of the width of the prostomium at the base; they taper smoothly and end abruptly in filamentous tips. The peristomial cirri arise from strong cirrophores, are the same length as the palps and exactly resemble the median tentacle.

Parapodia (Pl. 1, Fig. 9) are rather long. The notopodium is slender, pointed and achætous. The neuropodium has a very stout aciculum and bears two kinds of setæ. Dorsally are 5 or 6, long, slender and unhooked (Pl. 1, Fig. 13). Medially are 20 or 30 stout setæ with strong bifid ends (Pl. 1, Figs 11 and 12), and ventrally there are about 3 of the same type as the dorsal ones, but smaller and curved back more sharply (Pl. 1, Fig. 10). The dorsal cirri are smooth. In the anterior region of the body they are more than twice the length of the parapodium, including the setæ; posteriorly they are shorter, but still extend well beyond the setæ. The ventral cirrus of somite 2 resembles the peristomial cirri in form and size; on other parapodia it is simple, small and slender. On the ventral surface of each parapodium a row of conspicuous, globose papillæ extends from the base of the ventral cirrus to the body.

Elytra are broadly oval, thin, flexible, semi-transparent and blotched with pale brown. They are perfectly smooth on both surface and edge and fine venations radiate from the elytrophore. They are symmetrically borne on the anterior portion of the body on somites 2, 4, 5, 7, 9 . . . 19, 21, 23, 26, 29, 32, 34, 37, 40, 43. Posteriorly they are asymmetrically borne. On the right side (looking forward) on somites 46, 49, 52 . . . 85, 88, 91, and on the left side on somites 47, 50, 53 . . . 86, 89, 92.

Dredged in 15 fathoms from sponge-bed off Jesse Island.

Hermadion truncata Moore.

Hermadion truncata Moore (1902), p. 272.

The specimens differ from Moore's description only in that the ends of the notosetæ are not so definitely frayed out as figured.

Collected at False Narrows; off Round Island and off Newcastle Island.

Polynoe tuta Grube.

Polynoe tuta Grube (1855), p. 82; Moore (1908), p. 331.

Halosydna tuta Baird (1865), p. 188.

Harmothoe tuta Johnson (1901), p. 394.

Collected on Station Flat and at Mudge Island. Commensal, together with *Halosydna insignis*, with *Thelepus crispus*.

Lagisca multisetosa Moore.

Lagisca multisetosa Moore (1902), p. 267.

The specimens in the collection agree with Moore's description except in respect of the markings. They are more heavily pigmented and more definitely patterned than he describes.

Harmothoe imbricata Linnaeus.

Harmothoe imbricata Johnson (1897), p. 181; McIntosh (1900), Vol. 1, Part 2, p. 314; Moore (1908), p. 334; Treadwell (1914), p. 182.

Collected at Horsewell Point; False Narrows; Mudge Island; Cardale Point; Station Flat; Nanoose Bay. Common throughout the region. Occurs at Mudge Island with *Halosydna insignis*, both commensal with *Thelepus crispus*.

Evarne triannulata Moore.

Harmothoe triannulata Moore (1910), p. 346.

This species has been previously recorded only from Southern California (San Nicolas and Santa Rosa Islands) dredged from considerable depths; nevertheless the specimens agree closely with Moore's description and there seems little doubt of their identity.

Dredged off Mudge Island in 15-20 fathoms; off Newcastle Island in 15-20 fathoms; False Narrows.

Gattayana ciliata Moore.

Gattayana ciliata Moore (1902), p. 263.

Collected at Houston Passage; off Round Island in 15 fathoms; off Newcastle Island in 25 fathoms; off Piper's Lagoon in 15-20 fathoms.

Gattayana senta Moore.

Gattayana senta Moore (1902), p. 259.

Dredged in 20-25 fathoms off Newcastle Island.

Family SIGALIONIDÆ.

Peisidice aspera Johnson.

Peisidice aspera Johnson (1897), p. 184; Moore (1908), p. 338; Treadwell (1914), p. 183.

Collected at Nanoose Bay.

Pholoë minuta Fabricius.

Pholoë minuta Moore (1908), p. 338; McIntosh, Vol. 1, Part 2, p. 437.

Collected off Newcastle Island in 25 fathoms.

Sthenalais verruculosa Johnson.

Sthenalais verruculosa Johnson (1897), p. 187; Treadwell (1914), p. 184.

Collected off Newcastle Island in 25 fathoms.

REFERENCES.

CHAMBERLIN, R. V.

1920. Annelids. *Report of the Canadian Arctic Expedition*, 1913-1918, Vol. 9, Pt. B.

JOHNSON, H. P.

1897. A preliminary account of the Marine Annelids of the Pacific Coast, with descriptions of new species. *Proc. Calif. Acad. Sci.* (3), Vol. 1, 153-198.

1901. The Polychaeta of the Puget Sound Region. *Proc. Boston Soc. Nat. Hist.*, Vol. 29, 381-437.

MCINTOSH, W. C.

The British Annelids. Vol. 1, Pt. 2; Vol. 2, Pts. 1 and 2. Ray Society. London.

MOORE, J. P.

1902. Descriptions of some new Polynoidae, with a list of other Polychaeta from North Greenland Waters. *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 54, 258-278.

1903. Polychaeta from the Coastal Slope of Japan and from Kamtchatka and Behring Sea. *Ibid.*, Vol. 55, 401-490.

1905. New Species of Polychaeta from the North Pacific, chiefly Alaskan waters. *Ibid.*, Vol. 57, 525-554.

1908. Some Polychaetous Annelids of the North Pacific Coast of North America. *Ibid.*, Vol. 60, 321-364.

1909. Polychaetous Annelids from Monterey Bay and San Diego, California. *Ibid.*, Vol. 61, 235-295.

1909. The Polychaetous Annelids dredged by the U.S.S. *Albatross* off the Coast of Southern California in 1904. 1. Syllidæ, Sphaerodoridæ, Hesionidæ and Phyllodocidæ. *Ibid.*, Vol. 61, 321-351.

1910. *Idem.*, 2. Polynoidæ, Aphroditidæ and Sigalionidæ. *Ibid.*, Vol. 62, 328-402.

TREADWELL, A. L.

1914. Polychaetous Annelids of the Pacific Coast in the Collections of the Zoological Museum of the University of California. *University of California Publications in Zoology.* Vol. 13, No. 8, 175-234.

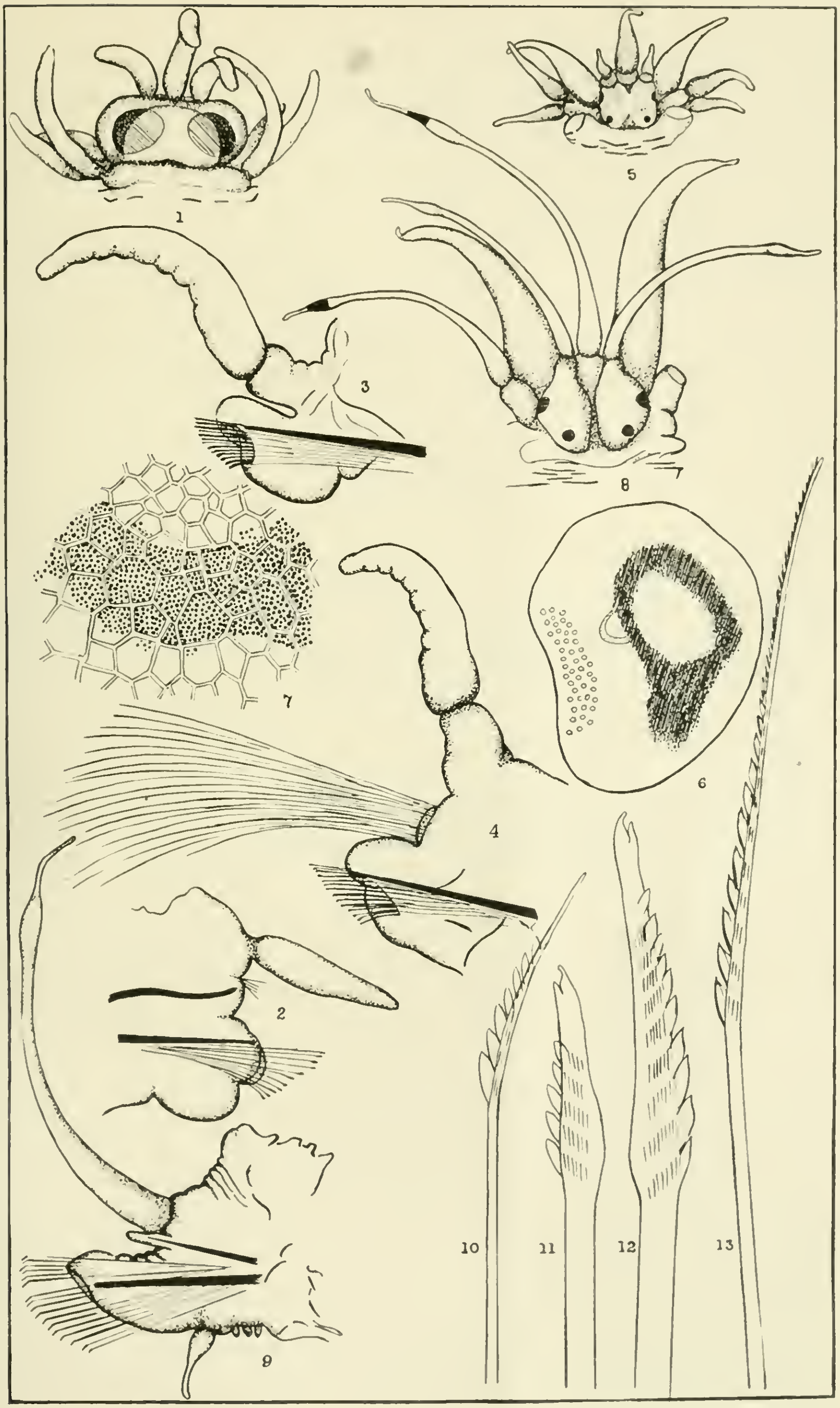
VERRILL, A. E.

1874. Results of recent Dredging Expeditions on the Coast of New England. *Amer. Jour. Sci.*, p. 132.

EXPLANATION OF PLATE.

PLATE 1

Fig. 1. Head of *Odontosyllis parva*. ×45.
Fig. 2. Twenty-fourth parapodium of *Odontosyllis parva*. ×75.
Fig. 3. Tenth parapodium of *Autolytus magnus*. ×18.
Fig. 4. Parapodium from median region of *Autolytus magnus*. ×18.
The prostomium is fore-shortened in the drawing; in reality it is longer and more pyriform.
Fig. 5. Head of *Malmgrenia nigralba*. ×15.
Fig. 6. Elytron of *Malmgrenia nigralba*. ×48.
Fig. 7. Portion of elytron of *Malmgrenia nigralba* showing detail of pigment ring. ×80.
Fig. 8. Head of *Lepidasthenia longicirrata*. ×10.
Fig. 9. Twelfth parapodium of *Lepidasthenia longicirrata*. ×15.
Fig. 10. Ventral neuroseta of *Lepidasthenia longicirrata*. ×190.
Fig. 11. Short median neuroseta of *Lepidasthenia longicirrata*. ×190.
Fig. 12. Long median neuroseta of *Lepidasthenia longicirrata*. ×190.
Fig. 13. Dorsal neuroseta of *Lepidasthenia longicirrata*. ×190.


1
5
3
8
7
6
4
2
10
11
12
13
9

No. 12.

THE HYDROMEDUSÆ OF THE WEST COAST OF NORTH AMERICA, WITH SPECIAL REFERENCE TO THOSE OF THE VANCOUVER ISLAND REGION.

BY

R. EARLE FOERSTER
(*University of British Columbia*).

CONTENTS

The Hydromedusæ of the West Coast of North America, with Special Reference to those of the Vancouver Island Region

By R. Earle Foerster.

INTRODUCTION.

References to the Medusæ of the B.C. Coast, as far as collecting and classification are concerned, are very meagre when compared to the whole mass of Medusan literature, especially so when one realizes the richness of the marine fauna in this region in numbers as well as variety.

The first mention of Medusæ from the B.C. Coast is found in L. Agassiz's Contributions to the Natural History of the United States, vol. 4, 1862, based on a collection made by his son, Alexander Agassiz, in the Strait of Georgia and the Straits of Fuca.

Three years later, 1865, A. Agassiz, in his North American Acalephs, vol. 2, published complete descriptions and figures of the species included in his collection, 14 species in all.

In 1900, a collection of medusæ was made by Cresswell Shearer in company with Prof. MacBride of Montreal, chiefly in the vicinity of Victoria Harbour and the adjoining waters of Puget Sound. The collection comprised 13 Hydromedusæ and 1 Siphonophore. Of the Hydromedusæ 5 species were new to Science. The results of the examination of the collection were published by Louis Murbach and Cresswell Shearer, first in the Annals and Magazine of Natural History, series 7, vol. IX, 1902, and then in the Proceedings of the Zoological Society of London, vol. II, pp. 164-191, 1903.

And, lastly, in 1916, a description of a new genus, *Halimedusa typus*, collected by Dr. J. Playfair McMurrich at Amphitrite Point, West Coast of Vancouver Island, was given by Dr. H. B. Bigelow.

The collection, on which this paper is based, is in the Museum of the Dominion Biological Station, Nanaimo, B.C., and was kindly loaned for examination by Dr. C. McLean Fraser, Director of the Station. It extends over a period of 9 years, from 1912-1921. All the forms are preserved in formalin. In addition, the author collected a number of species during the summer of 1921 and examined them alive. In such cases, colour notes and other changeable characters are included in the description.

In all, the collection numbers 34 species. This does not pretend to be the complete list of all medusæ in the Vancouver Island Region but is merely a list of those Hydromedusæ which have been collected so far in this region. The species are:

Anthomedusæ—

- *Sarsia flammea* Hartlaub.
- *Sarsia mirabilis* L. Agassiz.
- *Sarsia princeps* Haeckel.
- *Neoturris pileata* (Forskal).
- *Bougainvillia multitentaculata* sp. nov.
- *Bougainvillia nordgaardii* (Browne).

Stomotoca atra Agassiz.
Halitholus pauper Hartlaub.
Leuckartiara octona (Fleming).
Leuckartiara breviconis (Murbach and Shearer).
Leuckartiara nobilis Hartlaub.
Bougainvillia superciliaris (Gould).
Rathkea blumenbachii (Rathke).
Proboscidactyla flavicirrata Brandt.
Proboscidactyla polynema (Hartlaub).
Neoturris pelagica (Agassiz and Mayer).
Catablema vesicarium (Agassiz).

Leptomedusæ—

Melicertum campanula Oken.
Polyorchis penicillata Agassiz.
Obelia longissima Hincks.
Obelia species(?).
Tiaropsidium kelseyi Torrey.
Clytia edwardsii (Nutting).
Mitrocoma discoida Torrey.
Mitrocoma sinuosa sp. nov.
Halistaura cellularia (Agassiz).
Staurophora purpurea sp. nov.
Eutonina indicans (Romanes).
Aequorea aequorea (Forskal).
Phialidium languidum var. *gregarium* (Agassiz).

Trachomedusæ—

Gonionemus vertens Agassiz.
Eperetmus typus Bigelow.
Aglantha digitale (Müller).

Narcomedusæ—

Aegina rosea Eschscholtz.

Of these species 3, as noted, are new to Science: *Bougainvillia multitentaculata*, *Mitrocoma sinuosa*, *Staurophora purpurea*, and 8 species are new to the Coast: *Bougainvillia nordgaardii* (Browne), *Leuckartiara octona* (Fleming), *Halitholus pauper* Hartlaub, *Neoturris pileata* (Forskal), *Proboscidactyla polynema* (Hartlaub), *Sarsia flammea* Hartlaub, *Leuckartiara nobilis* Hartlaub, *Obelia* species(?).

Practically all of these species have been collected from the East Coast of Vancouver Island and the majority from within a radius of ten miles of the Biological Station, a fact which emphasizes the richness of the region in marine fauna, for what applies to Medusæ applies equally well to the majority of marine forms.

The description of these species does not pretend to be a complete one but rather a comparison with the original descriptions, which comparison, if not definitely mentioned, is inferred. Where possible, the descriptions given by Dr. A. G. Mayer (Medusæ of the World, vols. 1 and 2, 1910) have been used in the comparison. A complete synonymy and distribution list with reference to the West Coast are also given.

As the title indicates, this paper purposes to include all species of Hydromedusæ found on the West Coast of North America, between the Gulf of Panama and the Bering Sea. Of those species not found in the Vancouver Island Region, however, the complete synonymy and distribution with reference to the West Coast alone are given, the idea in mind being to bring all the Medusæ of the

West Coast together, to give the complete synonymy having reference to the West Coast as well as the distribution on the Coast and to eliminate, as far as possible, any repetition of description, etc. It is hoped that this will be of service to students of Medusæ, not as a monograph but as a handbook or book of reference regarding the West Coast *Hydromedusæ*.

The literature on the Medusæ of the West Coast, exclusive of Vancouver Island, is more extensive.

The first-recorded collection is that of Mertens in Bering Sea and the Northwest Pacific, published in 1834 by Brandt. Next, in order of time, is the report of L. Agassiz in 1862, based on the collection made by his son, A. Agassiz, and later published by the latter in 1865, with descriptions and figures. The collecting was done between the Gulf of Georgia and San Francisco. In 1889, W. J. Fewkes published a report on "New Invertebrata from the Coast of California," collected in 1887, which deals chiefly with Medusæ. In 1897, O. Maas gave his report on the Medusæ collected by the *Albatross* during an exploration off the West Coasts of Mexico, Central and South America, and off the Galapagos Islands, during 1891. In 1902, A. Agassiz and A. G. Mayer published the results of their examination of the Medusæ collected by the *Albatross* in the tropical Pacific from August, 1899, to March, 1900. Then there is a lapse of seven years until 1909, when two publications were issued, one a Memoir on the Medusæ collected by the *Albatross* from October, 1904, to March, 1905, in the tropical Pacific and examined by Dr. H. B. Bigelow, the other a Bulletin by H. B. Torrey on "The Leptomedusæ of the San Diego Region." In 1913, Dr. H. B. Bigelow published his report on "The Medusæ and Siphonophorae collected by the U.S. Fisheries Steamer *Albatross* in the Northwestern Pacific, 1906," and again, in 1920, reported on the Medusæ and Ctenophora collected by the Southern Party of the Canadian Arctic Expedition, 1913-1916, chiefly in the Arctic Ocean but with a few references to the West Coast of Alaska.

In all, then, 10 reports have been made on the Medusæ of the West Coast of North America, a number which signifies that only a beginning has been made in the systematic study of these forms in this region.

The drawings included in the plates are all taken from preserved specimens. Owing to the large size of many of the specimens, it was impossible to make camera lucida drawings of all, so that some are drawn with the camera lucida, while others are free hand. The latter are not intended to be perfectly exact representations but may, nevertheless, be of some service in exemplifying the characters in mind and in further classification.

The work embodied in this research was carried on during the months of June, July and August, 1921, at the Dominion Biological Station, Nanaimo, B.C., through the kindness of the Director, Dr. C. M. Fraser, and completed at the Zoological Laboratories of the University of British Columbia, Vancouver, B.C., during the tenure of a Bursary from the Honorary Advisory Council for Scientific and Industrial Research.

I wish to take this opportunity of expressing my indebtedness to Dr. C. McLean Fraser, Professor of Zoology, University of British Columbia, for his suggestion of this subject for research work and also for his advice and encouragement during the carrying on of the work.

SYSTEMATIC DISCUSSION.

In the preliminary classification of the specimens in the collection, the classification adopted by Mayer in his "Medusæ of the World," 1910, was used. Although it proved most efficient in identifying the various specimens, it was found, however, that the system of nomenclature it involved was not used by modern investigators. Therefore, in the final analysis, Mayer's system has been altered considerably to conform with the views of the more modern authors, such as Browne, Bigelow, Hartlaub and others.

It was at first thought advisable to refer to all departures from the classification of Mayer, but it has since been considered as beyond the scope of this paper. Such changes as do occur in nomenclature or classification will at once be evident to those examining this report, and since full explanations of these have been given by the above-mentioned investigators, nothing would be gained by their repetition here.

The chief difference between the systems lies in the complete abandonment of all sub-families. These have been either elevated to separate families or incorporated in the family without further division.

In some cases, confusion exists as to the correct nomenclature or generic distinctions. In such cases, brief discussions are given. It was considered more advisable to include these discussions under the heading "Systematic Discussion" rather than to separate them into their several family discussions. Therefore family and generic discussion is eliminated from the text.

Family Pandeidæ.

Regarding this family, there has been considerable discussion. Since *Tiara* has been found to be preoccupied for a mollusc, two names have been given to the family called by Haeckel, *Tiaridæ.*

Bigelow, 1913, has elevated the sub-family name *Pandeidæ* Haeckel, to that of the family name.

Hartlaub, 1913, on the other hand, states: "Bigelow, 1913, will den Familiennamen 'Tiaridae' durch 'Pandeidae' ersetzt haben, weil der Gattungsname 'Tiara' nicht mehr haltbar sei. Ich kann die dringende Notwendigkeit solcher Anderung nicht anerkennen und finde, dass sich aus mancherlei Gründen die Konservierung des durch Haeckels grosse Monographie eingebürgerten Namens mehr empfiehlt."

He would use the new term *Neoturridæ.* It would seem to be more correct and more justifiable and tend to cause less confusion to elevate the sub-family name, adopted by Haeckel, rather than to introduce a new term. Therefore Bigelow's nomenclature has here been adopted.

Again, Hartlaub includes under the family *Neoturridæ* such genera as *Amphinema* and *Stomotoca*, which Bigelow prefers, and rightly so, to separate into families. The latter, however, accepts Hartlaub's division of the old *Tiara* or *Turris* group into the genera *Halitholus*, *Leuckartiara*, *Catablema* and *Neoturris*.

as found in Hartlaub, 1913, pp. 242-245. A similar division has been made in this report.

Family Williadæ.

Mayer has united the tribes *Williadæ*, including the genera *Proboscidactyla* Brandt and *Willsia* Forbes, and *Bythotiaridæ*, including the genera *Bythotiara* Gunther, *Sibogita* Maas and *Niobe* Mayer, under the sub-family *Dendrostaurinæ*, but Bigelow and Hartlaub choose to keep them separate, the former as the family *Williadæ* and the latter as the family *Bythotiaridæ*.

Genus Eutonina.

There seems to be some confusion as to the generic name *Eutonina* Hartlaub.

Bigelow, 1913, in his generic discussion of *Eutonina* states: "Mayer uses the name *Eutimium* Haeckel for this group (he, however, does not include the number of tentacles as a generic character), but the type species of that genus, *E. elephas* Haeckel, was beyond question a *Eutima*. I formerly used the name *Eutimalphes;* but *Eutonina* seems to have the better claim, because its type species is well known, while that of *Eutimalphes*, *E. pretiosa* Haeckel, was founded for a fragmentary specimen which may have been a *Tima*. It has never been seen since first recorded."

Haeckel, 1879, restricts *Eutimium* to include those forms possessing 4 tentacles, so that whether *E. elephas* Haeckel be a *Eutima* or not, *Eutonina indicans* (Mayer's *Eutimium socialis*) can in no case belong to the genus *Eutimium* as it possesses numerous tentacles.

Regarding *Eutimalphes* Haeckel, there seems to be no foundation for Bigelow's statement that *E. pretiosa* Haeckel was based on a fragmentary specimen, as both Haeckel's description and figure denote a fully-developed and complete individual. Haeckel describes *Eutimalphes* as possessing numerous tentacles and several marginal cirri. Therefore, as *Eutonina indicans* possesses no marginal cirri, it cannot belong to the genus *Eutimalphes*.

Hartlaub has suggested the name *Eutonina* for these forms. Bigelow, however, departs from Hartlaub's generic description by enlarging the genus to include forms "seldom with marginal cirri or warts." This implies the probable presence of marginal cirri and in such a case is synonymous with *Eutimalphes*.

Therefore the classification may be left as laid down by Haeckel with the addition of the new genus *Eutonina* as follows:

Eutonina Hartlaub.

Eucopidæ with 8 adradial otocysts and very numerous tentacles; without marginal cirri, etc. *Eutonina indicans* (Romanes).

Genera *Gonionemus* and *Gossea*.

Mention should be made of the difference of opinion existing as to the classification of such forms as *Gonionemus* and *Gossea*, etc. Mayer, 1910, and Goto, 1903, have used as distinguishing characters, the presence or absence of tentacular suckers. Browne, 1904, and Bigelow, 1909 and 1913, have used the structure of the otocyst. An excellent explanation is given by Bigelow, 1916. The latter's system has here been used.

In conclusion, it must be made clear that in no case does the author pretend to give a complete synonymy of the various species. These may be found in Mayer, 1910. As far as possible, the original binomial designation has been given with its reference and, as well, all references made by authors to the Medusæ of the Pacific Coast of North America.

GEOGRAPHIC DISTRIBUTION.

In examining the distribution of the Hydromedusæ of the West Coast of America, two tables have been prepared. One deals with the general distribution of each species, and gives the number of species for the various areas; the other gives the comparative distribution according to regions.

As mentioned in the Introduction, the specimens referred to especially in this paper have been collected chiefly in the Vancouver Island Region and almost wholly on the East Coast of the Island. Of the 34 species contained in the collection, 24 were found only on the East Coast of Vancouver Island, while, of the remaining 10 species, 8 were common to the Vancouver Island Region, and the Region of the B.C. Coast North of Vancouver Island, extending to the Gulf of Alaska. These species are: *Aequorea aequorea*, *Eutonina indicans*, *Leuckartiara breviconis*, *Melicertum campanula*, *Polyorchis penicillata*, *Sarsia flammea*, *Sarsia mirabilis*, *Stomotoca atra*. Only 2 species were collected which were restricted to the Northern Region, these being *Bougainvillia multitentaculata* (sp. nov.) and *Leuckartiara nobilis*. It is quite probable that other forms are common to the two above-mentioned regions which are abundant in the Vancouver Island Region, such as *Proboscidactyla flavicirrata*, *Phialidium languidum* var. *gregarium* and *Aglantha digitale*. Very little collecting has been carried out North of Vancouver Island along the B.C. Coast, which would explain the paucity of species reported from this area. Those collections which were made in this district, Banks Island and Loredo Channel (by Dr. C. M. Fraser while engaged in Sea Lion work, etc.), in which the opportunity of securing specimens afforded itself only in the evening or early morning while the boat was anchored overnight, clearly showed that the specimens were plentiful and varied and would bear investigation. Moreover, the specimens from the Northern region were much larger in size than those found further South, e.g., *Stomotoca atra*.

Turning to the South, of the 34 species in the collection, only 6 are common to the Vancouver Island Region and the region of the San Juan Archipelago. These are *Aequorea aequorea*, *Gonionemus vertens*, *Halistaura cellularia*, *Phialidium languidum* var. *gregarium*, *Polyorchis penicillata* and *Stomotoca atra*. *Aequorea aequorea*, *Polyorchis penicillata* and *Stomotoca atra* are thus found to be common to all three regions mentioned and, in fact, are found as far South as the San Francisco to Panama Region.

One specimen in the collection, *Polyorchis penicillata*, has been found also on the West Coast of Vancouver Island at Sea Otter Cove in the North, at Grant's Landing in the south. Two other species not in the collection but included in the text are found on the West Coast of Vancouver Island. *Halimedusa typus*, an Anthomedusan, has been found only at Amphitrite Point, while one Leptomedusan, *Obelia borealis,* has been reported from Ucluelet as well as from the B.C. Coast North of Vancouver Island and the San Juan Archipelago.

Of new species, i.e., new to Science, there are three, one Anthomedusa, *Bougainvillia multitentaculata,* and two Leptomedusæ, *Mitrocoma sinuosa* and *Staurophora purpurea.* Regarding the first-named of these, Bigelow has said of the genus: "Considering how wide an area is covered by these few records, and how many species and races of Bougainvillea are known from both sides of the North Atlantic, probably the present record of *B. britannica* is but a forerunner of others to come from the Pacific."—Bigelow, 1920. Thus another species of this large genus has been found, making the number of species reported from the North Pacific four. *Bougainvillia multitentaculata* was found in the region of B.C. North of Vancouver Island, whereas the other two were found in the Vancouver Island Region.

There are 8 species new to the Coast, 7 Anthomedusæ and 1 Leptomedusa. Of the Anthomedusæ, *Bougainvillia nordgaardii* has been found in the South Pacific and North Atlantic; *Halitholus pauper* and *Proboscidactyla polynema* have been reported from the North Atlantic only; *Leuckartiara nobilis* has been previously reported from the North Atlantic and the Mediterranean; *Leuckartiara octona* is common to the South Pacific, East Coast of North America, North Atlantic, South Atlantic and Mediterranean, and also to the Western Pacific; *Neoturris pileata* is common to the North Atlantic, Mediterranean and Western Pacific, while *Sarsia flammea* has been recorded from the North Atlantic and Arctic Oceans. The Leptomedusa, *Obelia* species(?), has not been determined.

There are 19 species new to the Vancouver Island Region. These include the three new species as well as the following: *Bougainvillia nordgaardii, Bougainvillia superciliaris, Catablema vesicarium, Eperetmus typus, Eutonina indicans, Halitholus pauper, Leuckartiara octona, Leuckartiara breviconis, Mitrocoma discoida, Neoturris pelagica, Neoturris pileata, Obelia* species(?), *Proboscidactyla polynema, Sarsia flammea, Sarsia princeps,* and *Tiaropsidium kelseyi.* Of these, several have been referred to in the previous paragraph. Regarding the remainder: *Catablema vesicarium* has been reported from Bering Sea and Alaska, as well as from the East Coast of North America and the North Atlantic. *Eperetmus typus* has been previously known from Alaska and the Arctic Ocean. *Eutonina indicans* has been found in Alaskan waters and in the North Atlantic. *Leuckartiara breviconis* has been reported from Bering Sea, North Atlantic and Arctic Oceans; *Mitrocoma discoida* is reported from San Diego; *Neoturris pelagica* from the San Francisco to Panama Region; *Sarsia princeps* from Bering Sea, East Coast of North America, North Atlantic and Arctic Oceans, and *Tiaropsidium kelseyi* from San Diego.

Of the Anthomedusæ, 51 species have been found along the whole Coast. Of these, 18 species are found in the Vancouver Island Region. Of these 18 species, 10 are common to the Region North of Vancouver Island and the Vancouver Island Region, while 8 are found in the Vancouver Island Region and not North of it. 5 species are common to the Vancouver Island Region and the Region South of it, while 13 species are found in the Vancouver Island Region and not South of it. Of those in the Vancouver Island Region, as mentioned above, 3 are found on the West Coast of the Island, two of them, *Polyorchis penicillata* and *Obelia borealis* common to the Region South of Vancouver Island, whereas the third, *Halimedusa typus*, is reported only from the West Coast.

From this comparison it can be seen that, among the Anthomedusæ, the greater number are common to the Vancouver Island Region and North of it rather than to the Vancouver Island Region and South of it, the proportion being 2:1.

Regarding the Leptomedusæ, there are 58 species reported from the whole Coast and 23 from the Vancouver Island Region. Here the reverse condition is found as compared with the Anthomedusæ, there being 12 species common to the Vancouver Island Region and North of it, 11 found in the Vancouver Island Region and not North of it, 16 species common to the Vancouver Island Region and South of it, and 7 found in the Vancouver Island not South of it, the proportion in this case being 14:13 in favour of those common to the Vancouver Island Region and South of it.

For the Trachomedusæ, of which there are 21 species reported from the entire Coast, 4 species are found in the Vancouver Island Region. There are 2 species common to the Vancouver Island Region and North of it, and 2 species found in the Vancouver Island Region and not North of it; there is one species common to the Vancouver Island Region and South of it and 3 species found in the Vancouver Island Region and not South of it. In this case the proportion is, as in the Anthomedusæ, greater for those species common to the Vancouver Island Region and North of it in contrast with those common to the Vancouver Island Region and South of it, the proportion being, as before, 2 : 1.

There is only one Narcomedusa, *Aegina rosea*, found in the Vancouver Island Region out of 11 found on the entire Coast. It is common to the Vancouver Island Region and North of it only.

Regarding the species from the whole Coast, it is seen that 101 species have been reported from South of the Vancouver Island Region, 54 from North of Vancouver Island and 46 from the Vancouver Island Region. This does not suggest that the species are any more numerous to the South than to the North, but merely goes to show that more work has been done on Medusæ to the South and that more is required on those to the North. This is further brought out by the fact that, of the 101 species South of the Vancouver Island Region, 50 are restricted to this division, whereas of the 54 from North of the Vancouver Island Region, only 5 are restricted to the Northern Division. Of the 46 species from the Vancouver Island Region, only 5 species are restricted to that Region.

It is interesting to note that of the species common to the West Coast and the South Pacific, 13 of these species are common to the Southern Division, which is not uncommon, whereas 10 species are common to the South Pacific and the Northern Division. In the Northern Division, however, most of the forms are found on the surface, while in the Southern waters they are secured in depth hauls.

There are 35 species common to the North Atlantic and the West Coast; 32 are common to the Western Pacific and the West Coast, and 31 are common to the East and West Coasts of America.

It is important to note that whereas some forms, such as *Aglantha digitale, Bougainvillia superciliaris, Catablema vesicarium, Leuckartiara octona, Melicertum campanula, Pandea rubra, Pantachogon haecklii* and *Rathkea blumenbachii*, are found common to the Arctic Ocean, North Atlantic, Northern Division and Southern Division of the West Coast, that is, the Southern Division North of San Francisco, or other temperate waters, other forms such as *Aegina rosea, Aequorea aequorea, Halicreas papillosum, Sarsia eximia*, etc., are reported from cool, temperate zone waters, such as Bering Sea, North Atlantic, Northern Division of the West Coast, as well as from tropical or warm temperate zone waters, the South Pacific, San Francisco to Panama Region, South Atlantic, Philippines, etc. Therefore, one cannot tell by the reported location of a species in the Vancouver Island Region, whether it is strictly a Northern or Southern species or a local form.

There are 20 species common to the West Coast and the Arctic Ocean—8 Anthomedusæ, 6 Leptomedusæ, 4 Trachomedusæ and 2 Narcomedusæ. Of the Anthomedusæ, 4 species belong to the genus *Sarsia*. 7 of the 8 species are found in the Vancouver Island Region and North of it, while the eighth, *Sarsia eximia*, is found both to the South and North of it but not in it. *Sarsia mirabilis* is common to both the Northern and Southern Divisions, as well as to the Vancouver Island Region. Regarding the Leptomedusæ, 4 of the 6 species are common to the Northern Division and the Arctic, while of the remaining 2, *Obelia dichotoma* and *Obelia geniculata*, the former is common to both the Northern and Southern Divisions, the latter only to the Southern Division.

Of the 4 Trachomedusæ, 3 species, *Aglantha digitale Eperetmus typus* and *Ptychogastria polaris*, are found in the Northern Division, the first two named being common also to the Vancouver Island Region. The fourth species, *Halicreas papillosum*, is found both in Bering Sea and in the Region extending from San Francisco to Panama. The 2 Narcomedusæ, *Aeginopsis laurentii* and *Aeginura grimaldii*, are found only in the Northern Division of the West Coast, but the latter has been reported from the South Pacific and the Philippines.

It might be well here to explain some of the regions named in the General Distribution Table. Alaska refers primarily to the Gulf of Alaska, but it also includes the West Coast of the peninsula. The B.C. Coast, North of Vancouver Island, is that region lying between Vancouver Island on the South and the Gulf of Alaska on the North. The Vancouver Island Region includes both the East and West Coasts. The South Atlantic and Mediterranean Sea regions are taken in conjunction. The Western Pacific embraces that region extending from Kamtchatka on the North to the Philippines on the South. Owing to the comparatively few species found in this region, and to the fact that many of them are found both in the North and South, it was not thought advisable to divide this area into Northern and Southern Divisions.

GEOGRAPHICAL DISTRIBUTION OF THE HYDROMEDUSÆ FOUND OFF THE WEST COAST OF NORTH AMERICA.

	Bering Sea.	Aleutian Islands.	Alaska.	B.C. Coast, North of Vancouver I.	Vancouver Island Region.	San Juan Archipelago.	Puget Sound Region.	Cape Flattery to San Francisco.	San Francisco to Panama.	South Pacific.	East Coast of North America.	North-East Atlantic.	South Atlantic Mediterranean.	Western Pacific.	Arctic Ocean.
Aegina citrea									×				×	×	
Aegina rosea	×	×			×					×			×	×	
Aegina species?		×												×	
Aeginopsis laurentii	×										×			×	×
Aeginura grimaldii	×									×		×	×	×	×
Aequorea aequorea			×	×	×	×	×	×	×	×	×	×	×	×	
Aequorea coerulescens		×				×			×	×					
Aequorea rugosa			×				×								
Aglantha digitale		×	×		×						×	×			×
Aglantha digitale var. intermedia									×	×					
Aglantha proboscifer?									×						
Aglaura hemistoma									×	×	×	×	×	×	
Amphinema australis									×						
Amphinema turrida									×		×				
Amphogona apsteini									×					×	
Botrynema ellinorae	×														
Bougainvillia bougainvillei	×				×			×							
Bougainvillia brittanica		×	×								×	×			
Bougainvillia fulva									×	×				×	
Bougainvillia glorietta									×						
Bougainvillia nordgaardii					×					×		×			
Bougainvillia multitentaculata					×										
Bougainvillia superciliaris		×			×						×	×			×
Calycopsis nematophora	×	×												×	
Campelicium medusifera									×						
Catablema multicirrata	×	×	×											×	
Catablema vesicarium	×		×		×						×	×			×
Chiarella centripetalis									×						
Clytia attenuata						×	×								
Clytia cylindrica						×									
Clytia edwardsii				×	×	×	×								
Clytia hendersoni									×						
Clytia inconspicua				×	×	×	×								
Clytia johnstoni				×	×		×	×			×	×			
Clytia kincaidi					×	×	×								
Clytia universitatis									×						
Colobonema typicum									×					×	
Crossota brunnea	×	×						×						×	
Crossota pedunculata								×							
Cunina globosa									×						
Cunina peregrina									×						
Cunoctantha octonaria									×		×			×	
Cunoctantha tenella.									×						
Ectopleura dumortieri									×		×	×	×		

Geographical Distribution of the Hydromedusæ—*Continued*

	Bering Sea.	Aleutian Islands.	Alaska.	B.C. Coast, North of Vancouver I.	Vancouver Island Region.	San Juan Archipelago.	Puget Sound Region.	Cape Flattery to San Francisco.	San Francisco to Panama.	South Pacific.	East Coast of North America.	North-East Atlantic.	South Atlantic, Mediterranean.	Western Pacific.	Arctic Ocean.
Eirene medusifera									×						
Eirene mollis									×						
Endocrypta huntsmani				×		×									
Eperetmus typus			×		×										×
Eucheilota bakeri									×						
Eutima levuka									×						
Eutimalphes brownei									×						
Eutonina brownei									×						
Eutonina indicans			×	×	×							×			
Eutonina scintillans									×						
Geryonia proboscidalis									×					×	
Gonionemus agassizii		×													
Gonionemus vertens					×	×	×								
Gossea brachyura									×						
Halicreas papillosum	×								×			×		×	×
Halimedusa typus					×										
Halistaura cellularia			×		×	×	×								
Halitholus pauper					×							×			
Heterotiara anonyma	×							×						×	
Hybocodon prolifer			×		×						×	×			
Leuckartiara breviconis	×			×	×							×			×
Leuckartiara nobilis				×								×	×		
Leuckartiara octona					×					×	×	×	×	×	
Liriope indica										×					
Liriope rosacea									×					×	
Liriope species(?)									×						
Liriope tetraphylla									×		×			×	
Lymnorea alexandri									×						
Melicertum campanula				×	×						×	×			×
Melicertum georgicum					×										
Microcampana conica									×						
Mitrocoma discoidea					×				×						
Mitrocoma sinuosa					×										
Neoturris fontata									×						
Neoturris pelagica					×				×						
Neoturris pileata					×							×	×	×	
Obelia borealis			×	×	×	×									
Obelia commisuralis								×			×				
Obelia corona									×						
Obelia dichotoma			×	×	×	×	×		×	×	×	×			×
Obelia dubia			×	×	×	×									
Obelia fragilis							×								
Obelia geniculata								×	×	×	×	×			×
Obelia gracilis						×	×								
Obelia griffini					×	×	×								
Obelia longissima		×		×	×	×	×	×							

GEOGRAPHICAL DISTRIBUTION OF THE HYDROMEDUSÆ—*Continued*

	Bering Sea.	Aleutian Islands.	Alaska.	B.C. Coast, North of Vancouver I.	Vancouver Island Region.	San Juan Archipelago.	Puget Sound Region.	Cape Flattery to San Francisco.	San Francisco to Panama.	South Pacific.	East Coast of North America.	North-East Atlantic.	South Atlantic, Mediterranean.	Western Pacific.	Arctic Ocean.
Obelia multidentata						×									
Obelia plicata			×		×	×	×					×			
Obelia purpurea									×						
Obelia surcularis							×								
Obelia species(?)			×												
Obelia species(?)					×										
Octocanna polynema									×				×		
Orchistoma species (?)									×						
Pandea rubra		×					×					×		×	
Pandea violacea									×						
Pantachogon haecklii							×								
Pennaria pacifica									×						
Pennaria species(?)									×						
Phialidium discoida									×						
Phialidium languidium				×					×	×					
Phialidium languidium var. gregarium				×	×	×									
Phialium duodecimalis									×						
Phialopsis diegensis									×						
Phialucium comata									×						
Polyorchis peniciliata				×	×	×	×	×	×						
Proboscidactyla flavicirrata					×		×		×						
Proboscidactyla polynema					×							×			
Proboscidactyla occidentalis									×						
Proboscidactyla ornata, var. stolonifera									×		×		×	×	
Ptychogastria polaris	×										×	×			×
Ptychogena californica									×						
Ptychogena lactea	×										×	×		×	×
Rathkea blumenbachii	×		×		×						×	×			×
Rhopalonema velatim									×	×	×				×
Sarsia coccometra									×						
Sarsia eximia	×		×						×	×	×	×			×
Sarsia flammea				×	×							×			×
Sarsia japponica		×												×	
Sarsia mirabilis				×	×		×	×	×	×	×	×			×
Sarsia princeps	×				×						×	×			×
Sarsia resplendens									×						
Scrippsia pacifica								×	×						
Sibogita simulans	×														
Slabberia brownei									×						
Slabberia catenata					×							×			
Solmissus incisa	×	×						×						×	
Solmundella bitentaculata									×	×	×	×	×	×	
Staurophora mertensii			×	×							×	×			×
Staurophora purpurea					×										

GEOGRAPHICAL DISTRIBUTION OF THE HYDROMEDUSÆ—*Continued*

	Bering Sea.	Aleutian Islands.	Alaska.	B.C. Coast, North of Vancouver I.	Vancouver Island Region.	San Juan Archipelago.	Puget Sound Region.	Cape Flattery to San Francisco.	San Francisco to Panama.	South Pacific.	East Coast of North America.	North-East Atlantic.	South Atlantic, Mediterranean.	Western Pacific.	Arctic Ocean.
Steenstrupia occidentalis									×						
Stomotoca atra				×	×	×			×	×					
Stomotoca divisa									×						
Tiaropsidium kelseyi					×				×						
Tiaropsis diademata	×		×								×	×			×
Zanclea gemmosa									×		×				

A Comparative Distribution Table.

	Total	Anthomedusæ.	Leptomedusæ.	Trachomedusæ.	Narcomedusæ.
Number of species from the entire Coast	141	51	58	21	11
Number of new species	3	1	2	0	0
Number of species new to the Coast	8	7	1	0	0
Number of species North of Vancouver Island	54	20	19	9	6
Number of species common to V.I., and North of it	25	10	12	2	1
Number in V.I., not found North of it	21	8	11	2	0
Number in V.I. Region, not found South of it	24	13	7	3	1
Number of species South of V.I. Region	101	30	48	16	7
Number common to V.I. and South of it	22	5	16	1	0
Number of species restricted to North of it	29	10	7	7	5
Number of species restricted to South of it	79	25	32	15	7
Number of species in the V.I. Region	46	18	23	4	1
Number of species common to the Northern and Southern Divisions	24	6	15	2	1
Number of species common to the entire Coast	13	4	9	0	0
Number common to the West Coast and the South Pacific	17	6	4	4	3
Number common to the Northern Division and the South Pacific	10	5	3	0	2
Number common to the Southern Division and the South Pacific	13	4	4	4	1
Number common to the East and West Coasts of North America	31	13	10	5	3
Number common to the North-East Atlantic and the West Coast	35	19	10	4	2
Number common to the South Atlantic and the West Coast	12	5	2	1	4
Number common to the Arctic Ocean and the West Coast	20	8	6	4	2
Number common to the Western Pacific and the West Coast	32	10	3	11	8
Number common to the North-East Atlantic, Northern Division, Western Pacific	11	5	2	3	1
Number common to the South Atlantic, Southern Division, Western Pacific	6	1	1	1	3
Number restricted to the West Coast	75	23	42	7	3
Number restricted to the Northern Division	5	2	1	2	0
Number restricted to the Southern Division	50	17	24	6	3
Number restricted to the Vancouver I. Region	5	1	4	0	0
Number of species contained in the Collection	34	17	13	3	1

Class **Hydromedusæ.**

Order ANTHOMEDUSAE

Family SARSIIDÆ Forbes emended.
Codonidæ Haeckel.
Genus PENNARIA Oken.

Pennaria pacifica Clarke.

Pennaria pacifica Clarke, 1907; Mayer, 1910.
Distribution— Pinco Island, Gulf of Panama (Clarke).

Pennaria species(?).

Pennaria species(?), Bigelow, H. B., 1909.
Distribution.—Acapulco Harbour (Bigelow).

Genus STEENSTRUPIA Forbes.

Steenstrupia occidentalis Fewkes.

Steenstrupia occidentalis Fewkes, 1889.
(?)*Hybocodon chilensis* (part) Mayer, 1910.
Distribution.—Santa Cruz, California (Fewkes).

Genus HYBOCODON L. Agassiz.

Hybocodon prolifer L. Agassiz.

Hybocodon prolifer Agassiz, L., 1862; Hartlaub, Cl., 1907; Mayer, 1910; Bigelow, H. B., 1913; Fraser, 1914; Hartlaub, Cl., 1917.
Distribution.—Dutch Harbour (Bigelow); Departure Bay (Fraser).

Genus MICROCAMPANA Fewkes.

Microcampana conica Fewkes.

Microcampana conica Fewkes, 1889, 1889*b*; Mayer, 1910.
Distribution.—Under the cliffs of Punta Diablo on Santa Cruz I., California (Fewkes).

Genus SARSIA Lesson.

Sarsia coccometra Bigelow.

Sarsia coccometra Bigelow, H. B., 1909; Mayer, 1910.
Distribution.—Coast of Central America (Bigelow).

Sarsia eximia (Allman).

Coryne eximia Allman, 1859.
Sarsia eximia Boehm, 1878; Hartlaub, Cl., 1907; Mayer, 1910; Bigelow, H. B., 1913; Hartlaub, Cl., 1917.
Syncoryne eximia (hydroid) Nutting, 1901; Torrey, 1902.
Distribution.—Juneau, Alaska (Nutting); Pacific Grove, California (Torrey); Dutch Harbour, Alaska (Bigelow).

Sarsia flammea Linko (Pl. 1, Fig. 1).

Sarsia flammea Linko, 1905; Hartlaub, Cl., 1907; Mayer, 1910; Bigelow, H. B., 1920.

The collection includes 24 specimens of this species, ranging in size from 2 mm. to 9 mm. in bell height, and from 1 mm. to 5 mm. in bell diameter. There are 4 tentacles with definite broken rings of nematocysts over the distal halves and with definite terminal knobs. There are no ocelli.

In some specimens the gonads cover entirely the manubrium from the base to near the mouth.

Colour of manubrium and gonads—brilliant red.

Bigelow (1920) states that "the only character which has been invoked to separate them" (*S. flammea* Linko and *S. japponica* Maas) "is the fact that in the specimens of *S. japponica* so far examined by Maas and by me (1913), the sexual products are irregularly massed, while in *S. flammea*, they occupy the whole gastric wall except for its proximal and distal extremities."

In the specimens of this collection examined, individuals were found possessing one form of gonad, that applied by Bigelow to *S. japponica*, while others showed a gonad not separable into irregular masses. Yet the shape of the tentacles and the nematocyst rings on the tentacles were quite similar; the whole shape of the bell agreed in each variety and there was no difference in colour. Preserved in formalin, they became pale brown.

S. flammea and *S. japponica* may be identical, but if not, there seem to be intergrading forms having only one character, that of the shape of the gonads, at variance. In such a case, only a knowledge of the hydroid from which they arise will show whether they are identical or belong rightfully to different species.

Six specimens in the collection, 8-10 mm. in bell height and 5-7 mm. wide, collected at Lock Bay, remained in doubt for some time. They have been placed, finally, under *S. flammea*, due to the shape of the bell, the similarity in the shape of the manubrium and radial canals. The four tentacles are in poor shape, only one being intact. In spite of its poor condition, however, it closely resembles the tentacles of *S. flammea*, described above.

The colour of the specimens in the living state was: manubrium and gonads—deep red; tentacles and radial canals—white. In the preserved state the colours became: manubrium and gonads—pale brown; tentacles and radial canals—white.

Distribution.—Cape Smyth, Point Barrow, Alaska (Bigelow); Banks Island, vertical haul, 100-0 f., 1 mile N.E. of Five Finger Island, Departure Bay, Northumberland Channel.

Sarsia japponica Maas.

Sarsia japponica Maas, 1909; Bigelow, H. B., 1913; Hartlaub, Cl., 1917.

(For discussion of *S. japponica*, see *S. flammea* Linko, above.)

Distribution.—Western Aleutian Islands (Bigelow).

Sarsia mirabilis L. Agassiz.

Sarsia mirabilis Agassiz, L., 1849.

Coryne mirabilis Agassiz, A., 1865.

Syncoryne mirabilis Torrey, 1902.
Sarsia tubulosa var. *Sarsia mirabilis* Mayer, 1910.
Coryne rosaria Agassiz, A., 1862.
Syncoryne rosaria Fewkes, 1889*b*.
Sarsia rosaria Hartlaub, Cl., 1907.
(?)*Sarsia rosaria* Mayer, 1910.
(?)*Syndictyon angulatum* (young medusa) Murbach and Shearer, 1903.
Sarsia angulata Hartlaub, Cl., 1907.
(?)*Codonium apiculum* Murbach and Shearer, 1903.
(?)*Sarsia apicula* Hartlaub, Cl., 1907; 1917.

The collection includes numerous specimens ranging in size from 2 mm. to 15 mm. in bell height and from 2 mm. to 9 mm. in bell diameter. There is a prominent apical projection present in some individuals varying considerably both in shape and size, from a well-rounded to a low, broad projection, due, in all probability, to a contraction of the bell. A stiel canal is present, varying in shape from a long, sharply-pointed to a short, rounded projection. The radial canals are narrow and smooth. The manubrium varies greatly in length. There are nematocyst cells covering the tentacles clustered at the distal ends.

One specimen in the collection, with a bell diameter of 8 mm., has 2 perradial tentacles well-developed and the other 2 only bulbs. The radial canals are narrow and smooth and where they meet the small tentacle bulbs they expand out into a triangular pad from the other angles of which the circular canal runs out. This quite probably occurs in the normal *Sarsia*, but is covered over by the upward growth of the large tentacle bulb. The manubrium is lacking, but the stiel canal and a small, swollen, transparent, circular structure above the stomach are present. This swollen, gelatinous structure above the stomach has also been noticed in normal forms of *S. mirabilis*, to which species this specimen undoubtedly belongs, being merely abnormal as regards the tentacles.

As the hydroids of *S. mirabilis* of the Atlantic and the Pacific Coasts have been pronounced identical, it seems advisable to embrace their medusæ under one species. The hydroid of *S. mirabilis* with developing medusæ has been collected at Departure Bay, attached to the piling of the wharf, so that there is no doubt but that the specimens collected are *S. mirabilis*.

Mayer (1910), in his description of *Sarsia rosaria*, states that it possesses an apical projection and nematocyst pads flanking the tentacle bulbs on either side. Unfortunately there is no figure of *S. rosaria* to substantiate this statement. Therefore, as the apical projection might be caused by contraction of the bell, as other investigators have not reported the presence of nematocyst pads, and in view of the fact that Torrey (1902) unites the hydroids of *S. mirabilis* and *S. rosaria*, it is probable that *S. mirabilis*, and *S. rosaria* are different stages of the same species. Indeed, Mayer's description fits the one specimen described above, but from this collection of *S. mirabilis* it would appear that there was too much variation and intergradation to give a distinct foundation for two separate species.

Distribution. San Francisco, California, Gulf of Georgia (A. Agassiz); Santa Barbara, hydroid (Fewkes); Puget Sound, hydroid (Calkins); Bare Island, hydroid (Hartlaub); San Francisco, hydroid (Torrey); Victoria Harbour, Puget Sound (Murbach and Shearer); San Juan Archipelago, hydroid (Fraser); Banks Island, Bull Harbour, Departure Bay, off Snake Island, 15-0 f., off Newcastle Island, north of Entrance Island, Northumberland Channel, Dodds Narrows, Round Island, Vesuvius Bay, Saltspring Island.

Sarsia princeps Haeckel.

Sarsia princeps Haeckel, 1879; Hartlaub, Cl., 1907; Mayer, 1910; Bigelow, H. B., 1913; Hartlaub, Cl., 1917; Bigelow, H. B., 1920.

Three specimens are contained in the collection whose radial canals are jagged throughout the whole length or part of the length. In size they are much smaller than those examined by Bigelow or Hartlaub, the smallest being 2 mm. and the largest 8 mm. in height. Nor is the stiel canal definite, being quite long and pointed in one specimen and short and rounded in the other two. The manubrium is long.

Distribution. Southern Bering Sea (Bigelow); Departure Bay, Dodds Narrows.

Sarsia resplendens Bigelow.

Sarsia resplendens Bigelow, H. B., 1909; Mayer, 1910.

Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Genus Ectopleura L. Agassiz.

Ectopleura dumortieri (van Beneden).

Tubularia dumortieri van Beneden, 1844.

Ectopleura dumortieri Agassiz, L., 1862; Hartlaub, Cl., 1907; Mayer, 1910.

Ectopleura ochracea Agassiz, A., 1862; Bigelow, H. B., 1909.

Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Genus Slabberia Forbes.

Slabberia brownei (Bigelow).

Purena brownei Bigelow, H. B., 1909.

Slabberia brownei Mayer, 1910.

Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Slabberia catenata Forbes and Goodsir.

Slabberia catenata Forbes and Goodsir, 1853.

Dipurena dolichogaster Murbach and Shearer, 1903.

Distribution. Victoria Harbour (Murbach and Shearer).

Family CLADONEMIDÆ.

Genus Zanclea Gegenbaur.

Zanclea gemmosa McCrady.

Zanclea gemmosa McCrady, 1857; Bigelow, H. B., 1909; Mayer, 1910.

Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Family AMPHINEMIDÆ.

Genus AMPHINEMA Haeckel.

Amphinema australis (Mayer).

Stomotoca australis Mayer, 1900.
Amphinema australis Bigelow, H. B., 1909.
Stomotoca octaedra Mayer, 1910.
Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Amphinema turrida (Mayer).

Dissonema turrida Mayer, 1900, 1910.
Amphinema turrida Bigelow, H. B., 1909.
Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Genus STOMOTOCA L. Agassiz.

Stomotoca atra L. Agassiz.

Stomotoca atra Agassiz, L., 1862; Agassiz, A., 1865; Haeckel, 1879; Mayer, 1910; Hartlaub, Cl., 1913.

Specimens of various sizes up to a bell height of 27 mm. and a bell diameter of 30 mm. are contained in the collection, the largest coming from Ikeda Bay. The number of rudimentary tentacles varies from 36-120 to a quadrant.

The colour in the living specimens was: manubrium—white; gonads—dark brown.

Distribution. Gulf of Georgia, Strait of Rosaria (Agassiz); Loredo Channel, Ikeda Bay, Departure Bay (May-July), Friday Harbour, Wash.

Stomotoca divisa Maas.

Stomotoca divisa Maas, 1897; Bigelow, H. B., 1909; Mayer, 1910.
Distribution. Bay of Panama, West Coast of Central America (Maas); Southeast of Acapulco Harbour, Coast of Mexico (Bigelow).

Family PANDEIDÆ.

Genus HALIMEDUSA Bigelow.

Following Bigelow (1916), this genus has been placed under the *Pandeidæ*, the family it seems to resemble the most.

Halimedusa typus Bigelow.

Halimedusa typus Bigelow, H. B., 1916.
Distribution. Off Amphitrite Point, Van. I. (Bigelow).

Genus ENDOCRYPTA Fraser.

This genus is placed provisionally under the *Pandeidæ* until such time as the mature medusæ have been identified.

Endocrypta huntsmani (Fraser).

Crypta huntsmani Fraser, 1911.
Endocrypta huntsmani Fraser, 1912; Fraser, 1914.

Distribution. Departure Bay, Nanoose Bay, near Clarke Rock, off Protection I., Friday Harbour (Fraser).

Genus PANDEA Lesson.

Pandea rubra Bigelow.

Pandea rubra Bigelow, H. B., 1913; Hartlaub, Cl., 1913.
Distribution. Albatross Stations 4758, 4760 (Bigelow).

Pandea violacea Agassiz and Mayer.

Pandea violacea Agassiz and Mayer, 1899; Bigelow, H. B., 1909; Mayer, 1910.
Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Genus HALITHOLUS Hartlaub.

Halitholus pauper Hartlaub (Plate I, Figs. 2, 3).

Halitholus pauper Hartlaub, Cl., 1913.

The collection includes five specimens, all small, the largest having a bell diameter of 4 mm.

There is a definite apical projection present, in the majority of cases, pointed or conical. The radial canals are moderately wide with smooth margins. There is no peduncle. Owing to their small size, the gonads are not fully developed but are beginning to arise as folds of the stomach wall, 4 to 6 in number, in that portion of the wall between each interradius and perradius. There is no connection between the 8 gonads either interradially or perradially as yet, thus corresponding more with Hartlaub's figure of *H. cirratus* (1913, p. 276, fig. 225 and p. 277, fig. 227). The manubrium extends to the velar opening. There are no mesenteries perradially connecting the manubrium with the subumbrellar wall as in *Leuckartiara*. The lips are recurved. There are 8 large tentacles present, 4 perradially and 4 interradially—with large tentacle bulbs. There are 8 adradial tentacle knobs present and, in one quadrant, subradial or secondary adradial tentacles are appearing. There is a large round ocellus in each tentacle bulb or knob.

These specimens have been included under *H. pauper*, due to the absence of peduncle and mesenteries and the presence of ocelli. They cannot be *H. cirratus* and the lack of mesenteries excludes them from *Leuckartiara* and *Neoturris*.

Distribution. North-east of Five Finger I., Departure Bay.

Genus LEUCKARTIARA Hartlaub.

Leuckartiara octona (Fleming) (Plate I, Figs. 4, 5).

Geryonia octona Fleming, 1823.
Tiara papua Bigelow, H. B., 1909.
Turris pileata Mayer, 1910.
Leuckartiara octona Hartlaub, Cl., 1913.

Several specimens are included in the collection, mostly all of which are very small, the largest having a bell diameter of 6 mm. and a bell height of 8 mm.

The specimens resemble so closely those figured by Hartlaub that there can be no doubt as to their identity. The apical projection is commonly cone-shaped, but a few specimens have globular or button-shaped projections. The manubrium extends down halfway to the velar opening, ending in a mouth with fringed lips, and is connected to the subumbrella by a mesentery. The margins of the radial canals are irregular. The gonads are horseshoe-shaped and formed of several transverse folds, irregularly arranged. The tentacles are of 2 kinds, large and small, probably rudimentary. The large tentacles number from 8 to 16 with from 8 to 16 small ones. There is a dark red ocellus in each tentacle bulb.

The colour in the living specimens and also in the preserved ones: gonads and manubrium—dark red.

Distribution. Departure Bay, North of Five Finger I., Lock Bay, Dodds Narrows, Round I., Tod Inlet.

Leuckartiara breviconis Murbach and Shearer (Plate II, Figs. 1, 2, 3).

Turris breviconis Murbach and Shearer, 1902, 1903; Mayer, 1910.

Leuckartiara breviconis Hartlaub, Cl., 1913.

The collection includes 5 specimens, 3 of which have a bell diameter of 15 mm. while the 2 smaller ones are 5 mm. in diameter.

The manubrium and bell are cubical in shape, the manubrium almost filling the bell cavity. There are definite mesenteries present connecting the manubrium with the subumbrella at the perradii. The lips are complexly folded and fringed. The gonads are confined almost wholly to the perradii, forming a horseshoe-shaped structure and consisting of folds of the stomach wall running vertically, obliquely or transversely, depending on their location. Each gonad consists of from 25-30 folds. In the interradial portion of the stomach wall between the arms of the gonad are numerous depressions in the form of pits irregularly placed. The radial canals are wide with irregular margins. These lateral diverticula are not definitely shaped or placed opposite each other as in Murbach and Shearer's figure (Plate I, Fig. 1). The circular canal is in the main regular, but here and there lateral irregularities are formed. The tentacles number from 32-35 to a quadrant and are placed in two rows arranged in a zig-zag manner. Some are large and coiled, but there are many small ones just developing. As in Murbach and Shearer's description, there are no definite tentacle bulbs but the proximal ends are laterally compressed and clasp the margin on either side. There are no ocelli distinguishable nor can any trace of their presence be found. The small specimens closely resemble the larger except that there are fewer folds in the gonad, 16, and fewer tentacles, 100. In no case was there a definite apical projection marked off, although above the stomach the gelatinous substance was quite marked.

The colour in the preserved specimens: pale yellow.

Distribution. St. Paul I., Pribyloff Is. (Murbach and Shearer); near Point Barrow, Alaska (Fewkes); Loredo Channel, Departure Bay.

Leuckartiara nobilis Hartlaub (Plate I, Fig. 6).

Leuckartiara nobilis Hartlaub, Cl., 1913.

There are 22 specimens in the collection, all collected in the one locality and ranging in size from a bell diameter of 6 mm. to that of 15 mm., and from a bell height of 5 mm. to that of 17 mm. The shape of the bell in the majority of cases is cubical while in the remainder it is spherical, widest near the base and tapering slightly toward the oral end. A definite apical projection is present. The manubrium is four-sided and, with the gonads, occupies, in the larger specimens, almost the whole of the bell cavity. It is connected with the subumbrella by a distinct mesentery. The gonads so closely resemble those of *L. nobilis*, figured by Hartlaub (1913, p. 310, Fig. 258), that unquestionably the specimens belong to this species. The two halves of each gonad are connected only at the centre by a narrow connection. They consist of 8-10 folds branched at the end. The radial canals are wide, with irregular margins. Instead of 40 tentacles, as mentioned by Hartlaub, these specimens possess only 32—4 perradial, 4 interradial, 8 adradial and 16 subradial or secondary adradial. The smaller specimens have 4 perradial, 4 interradial and 8 adradial tentacles, the adradials being merely knobs and the interradials, short tentacles, showing that the development proceeds in the regular order, perradial, interradial, adradial and subradial or secondary adradial. All the tentacle bulbs possess a dark red or dark purple ocellus while the tentacles display the peculiar construction of muscle clubs and nematocyst batteries as figured by Hartlaub (1913, p. 311, Fig. 259). The longer tentacles are coiled at their distal ends.

Colour—In the living specimens, the manubrium and gonads are dark red, the ocelli dark red or purple while the tentacle bulbs and tentacles are pale yellow. In the preserved specimens, the manubrium shows a faint tinge of red, the gonads are pale yellow, the ocelli dark red, the tentacle bulbs and tentacles pale yellow.

Leuckartiara nobilis has been reported only from Europe, in the Mediterranean and off Ireland. Yet the specimens collected so closely resemble Hartlaub's description and figures that it does not seem necessary to form a new variety even though there is a variation in the number of tentacles. Hartlaub, in his figure of the tentacles of *L. nobilis* (1913, p. 312, Fig. 260), has shown two different arrangements of tentacle formation so that there seems to be sufficient variation to include these forms from the Pacific.

Distribution. Loredo Channel.

Genus CATABLEMA Haeckel.

Catablema multicirrata Kishinouye.

Catablema multicirrata Kishinouye, 1910; Bigelow, H. B., 1913; Hartlaub, Cl., 1913.

Distribution. Orca, Prince William Sound, Alaska, Dutch Harbour, Unalaska I., Bering Sea (Bigelow).

Catablema vesicarium (A. Agassiz).

Turris vesicaria Agassiz, A., 1862, 1865

Turris vesicaria (part) Mayer, 1910.
Catablema vesicarium Haeckel, 1879; Hartlaub, Cl., 1913.
Catablema vesicaria var. *nodulosa* Bigelow, H. B., 1913.

Three specimens are included in the collection. The largest has a bell diameter of 20 mm. and a bell height of 15 mm. There are 3 large and 9 small tentacles to a quadrant. The radial canals are jagged. The apical projection consists of a broad, round, gelatinous mass almost as large as the bell itself. The gonads, consisting of linear folds, more closely resemble those of *C. vesicarium* of the North Atlantic, as figured by Bigelow (1909*c*, Plate 1, Fig. 3), than those of *C. vesicaria* var. *nodulosa* of Bering Sea (Bigelow, 1913, Plate 1, Figs. 8, 9). Bigelow states that he has found specimens in the Pacific corresponding to those of the Atlantic in the shape and structure of the gonads, so that, in all probability, this is an intergrading specimen. The smaller number of tentacles agrees with Bigelow's description of *C. vesicaria* var. *nodulosa* which Hartlaub places under *C. vesicarium.*

A smaller specimen has a bell diameter of 6 mm. and a bell height of 5 mm. The apical projection is broad and rounded, less pronounced than in the larger specimen. There are 8 tentacles, comparatively large, and 16 small bulbs. The gonads are similar in shape to those in the larger specimen.

The smallest specimen has a bell diameter of 1 mm. There are 8 large tentacles and 8 small knobs. The gonads are just developing but have the linear shape characteristic of *C. vesicarium.*

Distribution. Dutch Harbour, Bering Sea (Bigelow); Departure Bay, Dodds Narrows.

Genus NEOTURRIS Hartlaub.

Neoturris fontata Bigelow.

Turris fontata Bigelow, H. B., 1909.
Clavula fontata Mayer, 1910.
Neoturris fontata Hartlaub, Cl., 1913.

Distribution. Off the West Coast of Lower California (Bigelow).

Neoturris pelagica (Agassiz and Mayer) (Plate II, Fig. 4).

Turris pelagica Agassiz, A., and Mayer, 1902.
Neoturris pelagica Hartlaub, Cl., 1913.

There is one specimen in the collection which remained in doubt for some time. It was definitely a *Pandeid,* but as only one specimen was at hand, no definite conclusions could be drawn. It has been placed under *Neoturris pelagica,* the species it resembles the most.

Bell diameter, 4 mm. Bell height, 6 mm.

The apical projection of the exumbrella is round and dome-shaped, about half the size of the bell itself. The radial canals are moderately wide and their margins are irregular or wavy. There are 24 tentacles present, of which the perradial and interradial are long and the rest small or mere knobs. They are coiled and covered with rings of nematocysts. The tentacle bulbs are large and lack ocelli. The manubrium is quadrilateral, filling up most of the bell cavity. The mouth is large with four recurved lips. The gonads are in the form of small rounded papillae covering the sides of the manubrium. The colour in the preserved specimen is: manubrium, gonads, tentacle bulbs and tentacles—pale yellow.

The specimen does not correspond with the figure of *N. pelagica* at all closely, but the description of this species applies in every detail to the specimen in the collection.

Distribution. Pacific Coast of Lower California (Agassiz and Mayer); Departure Bay.

(?) *Neoturris pileata* (Forskal) (Plate II, Figs. 5, 6).

Medusa pileata Forskal, 1775.

Neoturris pileata Hartlaub, Cl., 1913.

The collection includes one specimen; bell diameter—7 mm.; bell height—8 mm. There is a definite apical projection present, tapering to a sharp point, into which passes a projection of the subumbrella. There is no peduncle noticeable. The gonads consist of 4 perradial rows of transverse folds with numerous pockets or depressions in the interradial area. The manubrium is wide and short, connected to the subumbrella by means of 4 perradial mesenteries. The lips are complexly folded. The radial canals are wide with irregular margins. The ring canal is irregular. The tentacles number about 60, long and coiled. There are no ocelli.

Owing to the lack of ocelli, the perradial structure, and the number of tentacles, this specimen has been placed under *N. pileata*. There is no peduncle present, it is true, but several of Hartlaub's figures show no peduncle apparent. The peculiar apical projection of the subumbrella is unusual in the family *Pandeidæ*, but it is probably only an abnormal feature.

The colour in the preserved specimen is: manubrium, gonads and tentacles—pale yellow.

Distribution. Departure Bay.

Family BYTHOTIARIDÆ Maas.

Genus Calycopsis Fewkes.

Calycopsis nematophora Bigelow.

Calycopsis nematophora Bigelow, H. B., 1913.

Distribution. Bering Sea, Western Aleutian Islands (Bigelow).

Genus Heterotiara Maas.

Heterotiara anonyma Maas.

Heterotiara anonyma Maas, 1905; Mayer, 1910; Bigelow, H. B., 1913; Hartlaub, Cl., 1913.

Distribution. Albatross Station 4759, Bering Sea (Bigelow).

Family CYTAEIDÆ L. Agassiz.

Genus Lymnorea Mayer.

Lymnorea alexandri Mayer.

Lymnorea alexandri Mayer, 1904; Bigelow, H. B., 1909.
Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Family BOUGAINVILLEIDÆ Gegenbaur.

Genus Bougainvillia Lesson.

Bougainvillia bougainvillei (Brandt).

Hippocrene bougainvillii Brandt, 1834, 1853.
(?)*Hippocrene mertensii* Murbach and Shearer, 1903.
Bougainvillia mertensii Agassiz, L., 1862; Agassiz, A., 1865.
(?)*Bougainvillia superciliaris* (part) Mayer, 1910.
Bougainvillea bougainvillei Hartlaub, Cl., 1911.
Distribution. Bering Sea (Brandt); Gulf of Georgia, San Francisco (A. Agassiz); Victoria Harbour (?), (Murbach and Shearer).

(?)*Bougainvillia britannica* Forbes.

Hippocrene britannica Forbes, 1841.
Bougainvillia britannica Forbes, 1848.
(?)*Bougainvillia britannica* Bigelow, H. B., 1920.
Distribution. Off Southern Alaska (Bigelow).

Bougainvillia fulva Agassiz and Mayer.

Bougainvillia fulva Agassiz, A., and Mayer, 1899; Bigelow, H. B., 1909; Mayer, 1910.
Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Bougainvillia glorietta Torrey.

Bougainvillia glorietta Torrey, 1904; Mayer, 1910.

Fraser (Hydroids of the Vancouver Island Region, p. 119, 1914) reports a hydroid of *B. glorietta* from Hammond Bay and has since that time secured other specimens from the vicinity of Departure Bay. Torrey states that the free medusæ are unknown.

Distribution. San Diego, California (Torrey); Hammond Bay, hydroid (Fraser).

Bougainvillia multitentaculata sp. nov. (Plate II, Fig. 7; Plate III, Figs. 1, 2).

32 specimens have been collected at Banks Island, all approximately of one size; bell height—10 mm.; bell diameter—10 mm.

The bell is well rounded at the top and the gelatinous substance is quite thick, about 3 mm. The bell wall is moderately thick. There are four clusters of marginal tentacles situated at the base of the 4 radial canals. The tentacle bulbs appear to take the shape of a wide, inverted V, and each gives rise to from

50-60 short, hollow tentacles. There is a brown ocellus at the base of each tentacle and these are arranged in a zigzag row in the tentacle bulb. The velum is well developed. There are 4 straight, narrow radial canals arising from the four corners of the stomach. There is a low, broad peduncle. The gonads are perradially situated beneath each radial canal. There are four radially-placed clusters of oral tentacles, each of which branches dichotomously 6 or 7 times, each terminal branch ending in a knob of nematocysts.

The colour in the preserved specimens is pale yellow.

The collection includes an immature form in which the gonads and manubrium are lacking. The bell diameter is 7 mm. There are four marginal clusters of tentacles, less definite in shape than those described above. Each marginal cluster possesses 27 tentacles at the base of each of which there is a dark brown ocellus.

An abnormal form of this species, *B. multitentaculata*, is contained in the collection which possesses 6 radial canals. In conjunction with these radial canals, however, there are only 5 gonads, 2 of the radial canals joining up to one gonad. Likewise there are 6 clusters of marginal tentacles, 50-60, arranged in a zigzag row, and five clusters of oral tentacles.

Distribution. Banks Island.

Bougainvillia nordgaardii (Browne) (Plate III, Figs. 3, 4).

Margelis nordgaardii Browne, 1903.

Bougainvillia nordgaardii Mayer, 1910; Hartlaub, Cl., 1911.

The single specimen of this species in the collection agrees in every respect with the description of *B. nordgaardii*, except for the fact that the markings on the gonads of *B. nordgaardii* are not mentioned. Hartlaub's figure, however, suggests exactly what is present in this specimen.

This species has not been recorded previously from the Pacific.

Colour: Manubrium, gonads and tentacle bulbs—pale brown in the preserved specimen.

Distribution. 2 miles North-East of Five Finger Island, vertical haul from 100 f.

Bougainvillia superciliaris (Gould).

Hippocrene bougainvillii Gould, 1841.

Hippocrene superciliaris Agassiz, L., 1849.

Bougainvillia superciliaris Agassiz, L., 1862; Mayer, 1910; Bigelow, H. B., 1913.

There are two specimens of the genus *Bougainvillia* in the collection which so closely resemble *B. superciliaris* that there seems to be no doubt of their position.

Bell height, 6 mm.; bell diameter, 5 mm.

Each of the 4 marginal clusters contains 21 tentacles, most of which have been broken off close to their bases. There is a black ocellus in each tentacle bulb. The 4 clusters of oral tentacles branch dichotomously 5 times. The gonads are situated interradially, and, with the manubrium, are of a dark red colour. No planulae could be seen on the side of the manubrium.

Colour: Manubrium, gonads and tentacle bulbs—reddish brown in the preserved specimens.

Fraser (Hydroids of the Vancouver Island Region, p. 119, 1914) has found a hydroid *Bougainvillia mertensii* which is common along the East Coast of Vancouver Island. Although the hydroid of *B. mertensii* is unquestionably distinct from the hydroid of *B. superciliaris* (by comparison), it is possible that the medusæ liberated by each are similar. Owing to the fact that *B. mertensii* is secured only in depth hauls, never having been found in shallow water, and as it is very fragile, it has not been possible to study its life-history. It has seldom been studied alive, as it is generally dead before it reaches the laboratory. Until the life-history is known, the problem of identifying the mature medusæ liberated by it will not be solved.

Distribution. Attu Island (Bigelow); Departure Bay.

Genus RATHKEA Brandt.

Rathkea blumenbachii (Rathke).

Oceania blumenbachii Rathke, 1835.

Rathkia blumenbachiana Brandt, 1837.

Rathkea blumenbachii Mayer, 1910; Hartlaub, Cl., 1911; Bigelow, H. B., 1913; Hartlaub, Cl., 1917.

Several specimens of this species have been collected at Departure Bay, all about 2 mm. in diameter. The marginal bulbs number 8, each bulb supporting a cluster of 3 tentacles. In no case were there more than 3 tentacles to a cluster. One case of budding occurred, corresponding with the figure given by Bigelow (1909*c*, Plate 31, Fig. 3) of *Lizzia octopunctata* Sars, which species it is commonly agreed must give way to *Rathkea blumenbachii*.

Distribution. Dutch Harbour, Bering Sea (Bigelow); Departure Bay (March and April).

Genus CHIARELLA Maas.

Chiarella centripetalis Maas.

Chiarella centripetalis Maas, 1897; Mayer, 1910.

Distribution. Gulf of California, Coast of Mexico (Maas).

Family WILLIADÆ Forbes.

Genus PROBOSCIDACTYLA Brandt.

Proboscidactyla flavicirrata Brandt.

Proboscidactyla flavicirrata Brandt, 1834; Agassiz, A., 1865; Mayer, 1910; Hartlaub, Cl., 1917.

Proboscidactyla flavicirrata+*P. brevicirrata* Haeckel, 1879.

Proboscidactyla brevicirrata Murbach and Shearer, 1903.

This species is a very common one in the Strait of Georgia, and has been collected from April to as late as November. The largest specimens have a bell height of 7 mm. and a bell diameter of 5 mm. The number of tentacles varies from 40-70 with a corresponding number of branches of the radial canals. The centripetal canals, each with a patch of nematocysts at the proximal end, are very prominent, one between each successive pair of tentacles. Ocelli are present, sometimes more than one in a tentacle bulb.

In the living specimen the stomach, gonads and the tentacle bulbs are brown.

One specimen, collected at Vesuvius Bay, Saltspring Island, has a definite apical projection of the exumbrella. This is probably only an abnormal form as another specimen from the same locality agreed with the original description.

Distribution. Kamtchatka (Brandt); Galiano I., Gulf of Georgia (A. Agassiz); Victoria Harbour (Murbach and Shearer); Bull Harbour, Departure Bay, North of Five Finger I., Berry Point, Northumberland Channel, Dodds Narrows, Round I., Vesuvius Bay, Saltspring I., Tod Inlet, Saanich Arm.

Proboscidactyla occidentalis Fewkes.

Willia occidentalis Fewkes, 1889.
Proboscidactyla occidentalis Browne, 1904.
Distribution. Island of Santa Cruz, California (Fewkes).

Proboscidactyla ornata var. *stolonifera* Bigelow.

Proboscidactyla ornata var. *stolonifera* Bigelow, H. B., 1909; Mayer, 1910.
Proboscidactyla ornata (part) Hartlaub, Cl., 1917.
Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Proboscidactyla polynema (Hartlaub) (Plate III, Figs. 5, 6, 7; Plate IV, Fig. 1).

Pochella polynema Hartlaub, Cl., 1917.

The collection includes 25 specimens, most of which are in excellent condition. In size the bell diameter varies from 2-4 mm. The manubrium is broad and four-sided with the gonads developed on each side as in Hartlaub's figures. There are 4 straight, narrow radial canals running from the corners of the stomach directly to the bell margin. From either side of each radial canal, fine, thread-like branches are given off, invisible except under the high power of the microscope, running to the tentacle bulbs. There are about 6 of these branches on each side of a radial canal. The tentacles are short and thick, almost transparent, with large, dark tentacle bulbs. There are 12 tentacles in each quadrant. No ocelli are present. There are no centripetal canals as in *P. flavicirrata*.

Hartlaub, in the discussion of *Pochella polynema*, makes mention of the resemblance of his specimens to the *Williadæ* group, presumably *Proboscidactyla*, not only in the shape and size of the bell but also in the shape and structure of the tentacles and tentacle bulbs. He has noted the absence of centripetal canals. The diverticula of the radial canals were also noticeable, some as short projections, other as blindly-ending branches. Owing to the poor condition of the specimens Hartlaub was unable to ascertain whether these branches reached the tentacle bulbs or not.

In the specimens at hand in the collection, it could be seen quite readily that the branches of the radial canal not only originated in the radial canal but were also in direct communication with the tentacle bulbs, one branch to each tentacle.

It would seem, therefore, that those specimens, studied by Hartlaub and classified as *Pochella polynema*, were really *Proboscidactyla*, and since the specimens in this collection resemble exactly Hartlaub's figures of *Pochella polynema*, the latter have been named *Proboscidactyla polynema*.

In nearly every case, *Proboscidactyla flavicirrata* was collected in the same haul as *P. polynema*.

Colour: Manubrium, gonads and tentacle bulbs—light brown.
Distribution. Departure Bay (April-June).

Order **LEPTOMEDUSÆ**.

Family THAUMANTIADÆ Gegenbaur.

Genus MELICERTUM Oken.

Melicertum campanula Oken.

Melicertum campanula Oken, 1835; Agassiz, L., 1862; Mayer, 1910.

The collection includes a number of specimens of this species. Bell diameter, 10-15 mm.; bell height, 9-12 mm. There are about 75 long, flexible tentacles. There are no marginal cirri. The manubrium and gonads are ochre yellow in colour.
Distribution. Banks I., Departure Bay (May to October).

Melicertum georgicum A. Agassiz.

Melicertum georgicum Agassiz, A., 1862, 1865; Haeckel, 1879; Mayer, 1910.
Distribution. Gulf of Georgia (A. Agassiz).

Genus ORCHISTOMA Haeckel.

Orchistoma species(?) Maas.

Orchistoma species(?) Maas, 1897.
Distribution. Gulf of Panama (Maas).

Family LAODICEIDÆ L. Agassiz.

Genus PTYCHOGENA A. Agassiz.

Ptychogena californica Torrey.

Ptychogena californica Torrey, 1909; Mayer, 1910.
Distribution. San Diego, California (Torrey).

Ptychogena lactea A. Agassiz.

Ptychogena lactea Agassiz, A., 1865; Mayer, 1910; Bigelow, H. B., 1913.
Distribution. Bering Sea (Bigelow).

Genus STAUROPHORA Brandt.

Staurophora mertensii Brandt.

Staurophora mertensii Brandt, 1838; Mayer, 1910; Bigelow, H. B., 1913.
Distribution. Norfolk Sound, off Aleutian Is. (Brandt).

Staurophora purpurea sp. nov. (Plate IV, Figs. 2-5).

Bell diameter, 20 mm. Bell height, 10 mm.

Gelatinous substance thick. Most of the tentacles have been knocked off but there are about 150 large tentacle knobs. Those few tentacles which are complete are short, the basal bulbs are quite broad; the walls of the tentacles are thick, studded with nematocysts and enclosing a cavity. No ocelli could be made out nor any trace of their presence. There are about 100 lithocysts, each containing a spherical concretion. They do not seem to follow any definite order of arrangement, but are placed irregularly around the margin, about 25 to each quadrant.

The most striking characteristic of this specimen is the great development of the lips. These consist of 4 folded masses, curtain-like in appearance, hanging down almost to the bell margin. The lips are fringed around the margin. The mouth is a long, moderately wide slit, opening at each corner into a radial canal. The connection between the mouth and the radial canals could be distinctly seen but the radial canals were not open for any appreciable length. Along each side of each radial canal depended curtain-like structures, extending from the mouth to the bell margin, but these showed no marked connection with the lips. They are longer than the length of the radial canals and are thrown into sinusoidal folds. There are no diverticula projecting out from the radial canals as shown in Mayer's figure of *Staurophora mertensii*. A broad, low peduncle is present but the shape of the bell would indicate that this was caused by contraction.

Colour: In the living specimen, gonadal folds, lips and radial canals—purple; in the preserved specimen, lips—dark brown; gonads—pale brown; tentacles and radial canals—white.

As there is only one specimen in the collection, it is rather hard to form definite conclusions as to its exact specific characters. Mayer describes a *Staurophora mertensii* at a stage of 20 mm., in which the mouth has extended half-way down the radial canals. He mentions the fact that the lateral diverticula of the radial canals are developed only in the adult. This would explain their absence in this specimen discussed. But the absence of ocelli definitely excludes it from the species *S. mertensii* or *S. falklandica* Browne. Therefore, it has been given a new specific name, the characters of which are lack of ocelli, less rapid development of the slit-like mouth and definite purple colour.

Distribution. Off Entrance I., in plankton net down to 200 f.

Family POLYORCHIDÆ A. Agassiz.

Genus Polyorchis A. Agassiz.

Polyorchis penicillata A. Agassiz.

Polyorchis penicillata Agassiz, A., 1862; 1865; Fewkes, 1889; Mayer, 1910.
Melicertum penicillatum Eschscholtz, 1829.
Polyorchis pinnatus+*P. penicillatus* Haeckel, 1879.
Polyorchis minuta Murbach and Shearer, 1903; Mayer, 1910.

Mayer reports a *P. penicillata* whose dimensions are about 50-60 mm. high by 30-40 mm. wide. In the specimens which have been studied, the largest had a diameter of 40 mm. and a height of 42 mm. A slight apical projection was present. As against the 36-40 tentacles in Mayer's description, the average number possessed by the large ones in the collection was 64, or 16 to a quadrant. Their basal bulbs are elongated and spindle-shaped and possess a purple ocellus but the ocelli vary in their position according to the length of the tentacle bulb, each ocellus being situated where the tentacle becomes detached from the exumbrellar surface. The velum is strong and about 2 mm. in breadth. In Mayer's description the "4 radial canals give rise, each, to 15-25 pairs of simple, short and unbranched, blindly-ending, lateral diverticula." Those specimens examined showed the lateral diverticula to number 35-40 on each radial canal and these diverticula had simple, forked or club-shaped ends, according to the state of development. A. Agassiz, in his original description, states that the diverticula have "knotty, club-shaped" ends so that there appears to be a variation in the shape of the ends of these diverticula. The size of the peduncle likewise differs from that of Mayer's specimens in that, in the larger forms, it is quite extensive, having a width of about 8 mm. and a depth of about 4 mm. In many forms, the diverticula are scattered along the radial canals in that portion from which the gonadal sacs depend, but they are few in number and quite small.

Colour: Gonads, manubrium and tentacle bulbs—purple.

Polyorchis minuta, Murbach and Shearer, seems to be a young form of *P. penicillata*. There is a decided similarity in the number of tentacles and their method of development. The stomach, manubrium and lips correspond with the specimens of *P. penicillata*. The number of lateral diverticula on the radial canals agrees and the fact that they are simple and unbranched and do not have club-shaped endings is due to the fact that they are not fully developed. Specimens of the same size have been examined which possessed simple diverticula but corresponded to *P. penicillata* in every other respect. Their position and method of growth corresponds. Therefore, as there seems to be considerable variation in the development of *P. penicillata*, as there is a definite similarity between *P. minuta* and *P. penicillata*, and as Murbach and Shearer base their new species on size alone, a doubtful difference, it is believed that *P. minuta* is only a young form of *P. penicillata*.

There follows a tabular list of specimens examined, in which a definite gradation seems to occur, according to the size of the individuals:

Bell diameter in mm.	Bell height in mm.	Number of tentacles	Branches of radial canals	Gastric filaments	Lips	Peduncle, width by depth in mm.
2.5	2	4	None	None	Simple	Beginning
3	4	4	30-35	None	"	"
4	5	4	30	2	"	1 by .5
4	5	6	30	2	"	.5 by .5
5	6	8	30	2	recurved	1 by 1
5	6	10	30	3-4	"	"
6	7	12	30-35	5	"	"
6	7.5	8 (small)	40	4-6	folded	"
7	7	16 "	35-40	5	"	1 by 1.5
7	8	8 (large)	35-40	5	"	"
8	9	12	40	5	complexly folded	2 by 1.5
8	10	12	35-40	4	"	1.5 by 1.5
10	10	12-14	36-40	4	"	"
11	13	14	40	7	"	"
12	15	17	35-40	6	"	"
14	15	16	35	4	"	4 by 2
16	18	17-18	35	5	fringed	"
18	18	18	35	6	"	5 by 3
20	20	16-18	30-35	8	"	6 by 3
20	21	17	37	6	"	"
20	22	18	35	6	"	6 by 4
22	23	18	20	8	"	7 by 3
22	24	19	35-40	7	"	8 by 2
23	23	21	30-38	7	"	7 by 2
26	26	16	35-40	8	"	8 by 4
33	25	16	35-40	8	"	10 by 4
28	24	21	32-38	9	"	11 by 5
40	42	30	35-40	10	"	......

From a study of this series, it is clear that the gonadal sacs increase in number as the individual grows. This applies also to the length of these sacs, although there seems to be a variation in the method of growth, that is, the same gonadal sac does not always appear the longest. In some cases the middle sac is the longest; in other cases, the sac nearest the stomach has the greatest length, while in a third case the second gonadal sac from the distal end is the longest. In any case, there is the regular gradation in growth and development, those gonadal sacs at either end being smallest while generally those near the centre of the row are the longest. They are, in the beginning, mere knobs; in the largest forms they extend to or beyond the velar opening.

The lips also appear to increase in size and shape, developing from simple to complexly folded or fringed.

The number of lateral diverticula on each radial canal, that is, on each margin of each radial canal, seems to be fairly constant, 30-40, for small as well as large specimens. A difference is seen, however, in the length of the diverticula.

In the youngest specimens, they are either not noticeable or barely so as very small projections or notches. From this they gradually increase until, in the larger forms, they are several times the width of the radial canal and definitely branched or possessing club-shaped ends. Very few of them are directly opposite. In one form, 20 mm. in diameter and 22 mm. in height, there were 5 diverticula directly opposite; the remainder were irregularly placed. Some were bent over until they almost touched the next diverticulum below. Those diverticula towards the centre of the radial canal are always longer than those at the ends, the latter being mere projections at the extreme ends of the canals.

An increase in the size of the peduncle is also noticeable.

Distribution. San Francisco, Gulf of Georgia (Agassiz); Santa Bara, Santa Cruz, San Francisco (Fewkes); Puget Sound (Murbach and Shearer); Bull Harbour, Departure Bay, Newcastle I., Sea Otter Cove, Grants Landing (West Coast).

Genus SCRIPPSIA Torrey.

Scrippsia pacifica Torrey.

Scrippsia pacifica Torrey, 1909; Mayer, 1910.

Distribution. La Jolla, San Francisco (Torrey).

Family MITROCOMIDÆ Haeckel.

Genus MITROCOMA Haeckel.

Mitrocoma discoidea Torrey.

Mitrocoma discoidea Torrey, 1909; Mayer, 1910.

Four specimens are included in the collection. Bell diameter, 6 mm.; bell height, 4 mm. All are in excellent condition. There are from 100 to 140 tentacles with thick conical basal bulbs and coiled distal ends. Between each two tentacles there is a short, transparent cirrus. The lithocysts number from 2 to 4 to each quadrant, each containing several concretions. There are no ocelli. The radial canals are narrow and straight and are thrown into folds along their upper margin. The gonads are narrow and linear, extending along the entire length of the radial canals, leaving only the ends free. There is no peduncle. There are four prominent, recurved lips.

The specimens resemble *M. discoidea* in many respects and inasmuch as the description given by Torrey is of a very large individual, and as the specimens here described differ in details which are subject to change in development, they have been considered as specimens of *M. discoidea*.

Colour: In preserved specimens, manubrium, gonads and tentacle bulbs—dark brown.

Distribution. San Diego, California (Torrey); Depature Bay.

Mitrocoma sinuosa sp. nov. (Plate IV, Fig. 6).

Bell diameter, 4 mm. There are about 50 tentacles with thick, conical basal bulbs. Between each successive pair of tentacles there are from 3 to 5 transparent marginal cirri. The velum is well developed. There are 12 lithocysts present, 3 in each quadrant, consisting of open folds or pockets on the subumbrellar side of the velum. There are no ocelli. The radial canals are narrow and straight. The gonads are prominent, lying in two rows, one on each side of the radial canal, thrown into sinusoidal curves. They are confined to the distal half of the radial canal, not quite reaching the circular canal. There is no peduncle. The stomach is wide and quadratic. The manubrium is short, ending in a large, wide mouth with four large recurved lips.

This specimen differs from *M. discoidea* in the number of lithocysts, the number of tentacles and marginal cirri and in the shape and length of the gonads. It is much smaller than *M. discoidea* and yet the gonads seem to be quite mature.

Colour of preserved specimen—very pale brown.

Distribution. North of Five Finger Island.

Genus CAMPELICIUM Torrey.

Campelicium medusiferum Torrey.

Campelicium medusiferum Torrey, 1902; Mayer, 1910.

Distribution. Long Beach, California (Torrey).

Genus HALISTAURA Bigelow.

Halistaura cellularia (A. Agassiz) (Plate V, Figs. 1, 2).

Laodice cellularia Agassiz, A., 1865.

Thaumantias cellularia Haeckel, 1879; Murbach and Shearer, 1903; Mayer, 1910.

Halistaura cellularia Bigelow, H. B., 1913.

Numerous specimens are included in the collection, ranging in size from 7 to 70 mm. in bell diameter and from 6 to 30 mm. in bell height. The tentacles range from 180 to 300 in number. There are sense pits on the subumbrellar side of the velum and produced as pockets between the tentacles, projecting from the exumbrellar side of the velum. The variation in these sense pits is as follows:

Bell diameter	Tentacles per quadrant	Number of sense-pits per quadrant
60 mm.	75	6
60	75	4
60	75	15 (abnormal)
60	75	5
60	75	4
44	70	5
17	54	4
7	50	4-6
50	78	4

Most of the sense-pits are semicircular or crescentic in shape, but some, probably contracted, are almost quadrilateral. In no case could anything resembling otocysts or otoliths be found, even in the live specimens.

Distribution. Gulf of Georgia, Port Townsend (A. Agassiz); Puget Sound, Victoria Harbour, Friday Harbour (Murbach and Shearer); Southern Alaska, Puget Sound (Bigelow); North of Five Finger I., Departure Bay, Rocky Bay, Gabriola I., Tod Inlet, Saanich Arm, Friday Harbour.

Genus TIAROPSIS L. Agassiz.

Tiaropsis diademata L. Agassiz.

Tiaropsis diademata Agassiz, L., 1849; Mayer, 1910; Bigelow, H. B., 1913.
Distribution. Dutch Harbour, Agattu Island, Bering Sea (Bigelow).

Genus TIAROPSIDIUM Torrey.

Tiaropsidium kelseyi Torrey (Plate IV, Fig. 7).

Tiaropsidium kelseyi Torrey, 1909.

Tiaropsis kelseyi Mayer, 1910.

Bell diameter, 50 mm.; bell height, 30 mm.

The specimen corresponds with Torrey's figure and description except that there are 8 rudimentary tentacles between each large tentacle and each pigmented otocyst. The pigment of the endodermal pit is black. The gonads are curtain-like, much folded and about 4 mm. in width. At the proximal end of each radial canal, between the end of the gonad and the manubrium are located numerous tentacular processes. In three of the quadrants, they are damaged considerably and only three complete processes could be distinguished but, in the fourth quadrant, there were 20 of these hollow, coiled processes formed from the ectoderm of the radial canal. In their development, they have pushed out the subumbrellar wall so that the inner layer of the tentacular process is formed from the endoderm of the radial canal while the outer layer is formed from the ectoderm of the subumbrellar wall. Torrey has not noted the occurrence of these peculiar processes, but as all his specimens were damaged, it is possible that they were knocked off.

As the specimen agrees so well with Torrey's description, it does not seem necessary to form a new genus or species inasmuch as there is only one specimen at hand which may be a variety and as the structures may have been present in Torrey's specimens.

Colour: Manubrium and gonads—pale yellow.

Mayer considers it inadvisable to differentiate generically between rudimentary tentacles and developing tentacles, but as the specimen is quite mature, the small tentacles are unquestionably rudimentary. The presence of the tentacular processes would also prove a generic difference.

Distribution. San Diego, between San Diego and Monterey, California (Torrey); Tod Inlet, Saanich Arm.

Family EUCOPIDÆ Gegenbaur.

Genus Obelia Peron and Lesueur.

Obelia borealis Nutting.

Obelia borealis Nutting, 1901; Mayer, 1910; Fraser, 1911, 1914.

Distribution. Yakutat, Alaska (Nutting); off Massett, Naden Harbour, Bull Harbour, Ucluelet, San Juan Archipelago (Fraser).

Obelia commissuralis McCrady.

Obelia commissuralis McCrady, 1858; Torrey, 1902; Fraser, 1911.

(Hydroids only.)

Distribution. San Francisco Bay (Torrey).

Obelia corona Torrey.

Obelia corona Torrey, 1904; Mayer, 1910; Fraser, 1911.

(Hydroids only.)

Distribution. San Diego, California (Torrey); San Juan Archipelago (Fraser).

Obelia dichotoma (Linnaeus).

Sertularia dichotoma Linnaeus, 1758.

Obelia dichotoma Hincks, 1868; Mayer, 1910; Fraser, 1911, 1914.

(Hydroid only.)

Distribution. Bremerton (Calkins); Sitka, Berg Inlet, Orca, Alaska (Nutting); San Pedro to Coronado Is., San Diego, California (Torrey); Alert Bay, off Protection I., off Matia I., off Waldron I., Departure Bay, San Juan Archipelago (Fraser).

Obelia dubia Nutting.

Obelia dubia Nutting, 1901; Mayer, 1910; Fraser, 1911, 1914.

(Hydroid only.)

Distribution. Orca, Alaska (Nutting); Queen Charlotte Is., Snake I., Departure Bay, Dodds Narrows, Neck Pt., Northumberland Channel, Gabriola Pass, Ucluelet, San Juan Archipelago, Friday Harbour (Fraser).

Obelia fragilis Calkins.

Obelia fragilis Calkins, 1899; Mayer, 1910; Fraser, 1911.

(?)*Obelia fragilis* Fraser, 1914.

(Hydroid only.)

Distribution. Port Townsend (Calkins).

Obelia geniculata (Linnaeus).

Sertularia geniculata Linnaeus, 1758.

Obelia geniculata Allman, 1864; Torrey, 1902, 1904; Mayer, 1910; Fraser, 1911.

Distribution. San Francisco, Catalina Is., Coronada I. (Torrey).

Obelia gracilis Calkins.

Obelia gracilis Calkins, 1899; Mayer, 1910; Fraser, 1911, 1914.

(Hydroid only.)

Distribution. Scow Bay, Port Townsend (Calkins); San Juan Archipelago, Port Townsend (Fraser).

Obelia griffini Calkins.

Obelia griffini Calkins, 1899; Mayer, 1910; Fraser, 1911, 1914.

(Hydroid only.)

Distribution. Puget Sound (Calkins); Departure Bay, Ucluelet, Dodds Narrows, Gabriola Pass, Porlier Pass, Friday Harbour, off Sucia Is., Port Townsend, West Seattle (Fraser).

Obelia longissima (Pallas).

Sertularia longissima Pallas, 1766.

Obelia longissima Hincks, 1868; Clarke, 1876; Mayer, 1910; Fraser, 1911, 1914.

Specimens of this species are quite common in Departure Bay during the summer months.

Distribution. Unalaska (Clarke); Banks I., Lasqueti I., Nanoose Bay, Dodds Narrows, Gabriola Pass, Sucia Is., Friday Harbour, San Juan Archipelago, West Seattle, Port Townsend, Griffin Bay, Clayoquot Sound (Fraser); Departure Bay.

Obelia multidentata Fraser.

Obelia multidentata Fraser, 1914.

(Hydroid only.)

Distribution. Friday Harbour (Fraser).

Obelia plicata Hincks.

Obelia plicata Hincks, 1868; Nutting, 1899, 1901; Calkins, 1899; Fraser, 1911, 1914.

Obelia (?) *plicata* Mayer, 1910.

Distribution. Puget Sound (Nutting); Puget Sound (Calkins); Orca, Alaska (Nutting); Departure Bay, San Juan Archipelago, Port Townsend (Fraser).

Obelia purpurea Torrey.

Obelia purpurea Torrey, 1909; Mayer, 1910.

Distribution. San Diego, California (Torrey).

Obelia surcularis Calkins.

Obelia surcularis Calkins, 1899; Fraser, 1911, 1914.

(Hydroid only.)

Distribution. Scow Bay, Port Townsend (Calkins); Kanaka Bay (Fraser).

Obelia species(?).

Obelia species(?), Bigelow, H. B., 1913.

Distribution. Dutch Harbour, Alaska (Bigelow).

Obelia species(?).

Bell diameter, 1 mm. 10 tentacles are present in each quadrant. There are 8 otocysts. The gonads are at the distal ends of the radial canals.

Colour: Manubrium and gonads—bright green.

Distribution. Dodds Narrows.

Genus CLYTIA Lamouroux.

Clytia attenuata (Calkins).

Campanularia attenuata Calkins, 1899.
Clytia attenuata Fraser, 1911, 1914.

(Hydroid only.)

Distribution. Port Townsend, Scow Bay (Calkins); San Juan Archipelago (Fraser).

Clytia cylindrica Agassiz.

Clytia cylindrica Agassiz, L., 1862; Nutting, 1901; Fraser, 1912, 1914.

(Hydroid only.)

Distribution. Off Pt. Richardson, near Friday Harbour (Fraser).

Clytia edwardsi (Nutting).

Campanularia gracilis Calkins, 1899.
Campanularia edwardsi Nutting, 1901; Torrey, 1904.
Clytia edwardsi Fraser, 1911, 1914.

Distribution. Port Townsend (Calkins); San Diego (Torrey); very extensively distributed throughout the region; found at Banks I., China Hat, Lasqueti I., Nanoose Bay, several points near and in Departure Bay, North of Gabriola I., Northumberland Channel, Dodds Narrows, Pylades Channel, Gabriola Pass, Porlier Pass, Whaleboat Passage, Friday Harbour, San Juan Channel, Deer Harbour, Port Townsend (Fraser); Departure Bay, Strait of Georgia, great quantities in July.

Clytia hendersoni Torrey.

Clytia hendersoni Torrey, 1904; Fraser, 1911.

Distribution. San Diego, California (Torrey).

Clytia inconspicua (Forbes).

Thaumantias inconspicua Forbes, 1848; Wright, 1862; Fraser, 1911.
Campanularia inconspicua Calkins, 1899.
Clytia inconspicua Fraser, 1914.

Distribution. Puget Sound (Calkins); Banks I., Departure Bay, Whaleboat Passage, San Juan Archipelago (Fraser).

Clytia johnstoni (Alder).

Campanularia johnstoni Alder, 1856; Calkins, 1899.
Clytia johnstoni Clarke, 1876; Fraser, 1911, 1914.

Clytia bicophora Torrey, 1902.

Distribution. Puget Sound (Calkins); North of Gabriola I., Gabriola Pass (Fraser).

Clytia kincaida Nutting.

Campanularia kincaida Nutting, 1899; Fraser, 1911.
Clytia kincaida Fraser, 1914.

(Hydroid only.)

Distribution. Puget Sound (Nutting); Dodds Narrows, Nanoose Bay, off Clarke Rock, Gabriola Pass, off Matia I., Friday Harbour (Fraser).

Clytia universitatis Torrey.

Clytia universitatis Torrey, 1904; Mayer, 1910; Fraser, 1911.

(Hydroid only.)

Distribution. San Pedro Bay, California, San Diego Bay (Torrey).

Genus PHIALIDIUM Leuckart.

Phialidium discoida (Mayer).

Oceania discoida Mayer, 1900.
Phialidium discoida Bigelow, H. B., 1909.
Phialidium discoidum Mayer, 1910.
Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Phialidium languidum (Agassiz).

Oceania languida Agassiz, A., 1862; Agassiz, A., 1865.
Phialidium languidum Haeckel, 1879; Murbach and Shearer, 1903; Mayer, 1910.
Phialidium lomae Torrey, 1909.

As noted in the description below of *P. languidum* var. *gregarium*, there seem to be differences between the common Atlantic form, *P. languidum*, and the common Pacific form. Yet there are intergrading forms, such as *P. languidum* Murbach and Shearer and *P. lomae* Torrey which have characteristics common to both species and thus are united to the older species.

Distribution. Victoria Harbour (Murbach and Shearer); San Diego, California (Torrey).

Phialidium languidum var. *gregarium* (Agassiz).

Oceania gregarium Agassiz, L., 1862; Agassiz, A., 1865.
Phialidium gregarium Haeckel, 1879; Murbach and Shearer, 1903; Mayer, 1910.

These medusæ are very common in the waters of the Strait of Georgia, especially during the summer months.

The forms from the Pacific and those from the Atlantic Coast have always been classified as separate species, the former as *P. gregarium* and the latter as *P. languidum*. Of late, however, the correctness of this classification has been questioned. To determine to what extent the two species differed, specimens of both were examined, those from the Pacific collected alive, and those from the Atlantic, kindly sent by Dr. Huntsman, Director of the Dominion Biological Station at St. Andrews, N.B.

Murbach and Shearer cite as a difference between the two species, the shape of the stomach. This is rather misleading for specimens have been found of both species the shape of whose stomachs shows a great variation, caused, no doubt, by the contraction of the bell, which variations not only correspond with Murbach and Shearer's description but give the reverse result.

Regarding the number of tentacles, the Atlantic forms possess, on an average, 32 tentacles whereas the Pacific forms have 64, a difference which cannot be caused by any difference in the state of development for all the forms are of approximately the same bell diameter, 12 mm.

There is a decided contrast between the lips of the two species. Those of the Atlantic are simple or recurved, while those of the Pacific are longer and complexly folded or fringed.

There is a difference also in the number of otocysts. The Atlantic specimens, in every case, showed a greater proportion of 2 otocysts between each successive pair of tentacles, the average for 15 specimens being 20 spaces between tentacles, containing 2 otocysts; 5 spaces with one otocyst; and one space containing 3. The Pacific forms, on the other hand, showed a greater proportion of 1 otocyst between each successive pair of tentacles, the proportion being 29.5 : 3.5.

Moreover, the gelatinous substance of the bell is much greater, that is, much thicker, on the aboral surface in the Pacific forms than in the Atlantic.

It is interesting to note that, of about 100 specimens of the Pacific form, collected at Friday Harbour, 20 which were examined showed a predominance of 2 otocysts between successive pairs of tentacles, while several others possessed more spaces with one otocyst, the proportion being 26 : 18. In all other respects, these specimens are similar to those collected in Canadian waters.

These latter specimens, thus, seem to be intergrading forms between the species from the two coasts. For this reason, that of intergradation of forms, it would seem advisable to consider the Pacific form of *Phialidium* a variety of the Atlantic form, *P. languidum*, since the latter has precedence over *P. gregarium*.

Distribution. Gulf of Georgia (Agassiz); Puget Sound, Victoria Harbour (Murbach and Shearer); Bull Harbour, Five Finger I., Departure Bay, North of Entrance I., Northumberland Channel, Round I., Friday Harbour.

Genus PHIALIUM Haeckel.

Phialium duodecimalis (A. Agassiz).

Eucheilota duodecimalis Agassiz, A., 1862; Agassiz, A., 1865; Mayer, 1910.
Phialium duodecimale Haeckel, 1879.
Phialium duodecimalis Bigelow, H. B., 1909.

Bigelow states: "It is best to retain Haeckel's genus as distinguished from *Eucheilota*, inasmuch as it is separated from the numerous species with eight

otocysts (*Eucheilota*), not only by the number of these organs, but also by the limited number of developed tentacles (four radial) and by the extreme development of the gonads."
Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Genus PHIALOPSIS Torrey.

Phialopsis diegensis Torrey.

Phialopsis diegensis Torrey, 1909; Mayer, 1910.
Distribution. San Diego, California (Torrey).

Genus PHIALUCIUM Maas.

Phialucium comata Bigelow.

Phialucium comata Bigelow, H. B., 1909; Mayer, 1910.
Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Genus EUCHEILOTA McCrady.

Eucheilota bakeri (Torrey).

Phialium bakeri Torrey, 1909.
Eucheilota bakeri Mayer, 1910.

Torrey declares that "the interradial position of the statocysts of the young prevents an easy transition to *Eucheilota*," but Mayer considers it a form of *Eucheilota*, as it "recalls the condition seen in *Eucheilota dipleuron* from the Atlantic Coast."
Distribution. Oceano, San Diego (Torrey).

Genus EUTIMA McCrady.

Eutima levuka Agassiz and Mayer.

Eutima levuka Agassiz, A., and Mayer, 1899; Bigelow, H. B., 1909; Mayer, 1910.
Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Genus EUTIMALPHES Haeckel.

Eutimalphes brownei Torrey.

Eutimalphes brownei (part) Torrey, 1909.
Eutima brownei Mayer, 1910.

Ten specimens out of the 90 examined by Torrey possess marginal cirri between the tentacles. Following Haeckel's classification, these 10 would be classed as *Eutimalphes brownei*, the other 80 as *Eutonina brownei*.

Genus EUTONINA Hartlaub.

Eutonina brownei (Torrey).

Eutimalphes brownei (part) Torrey, 1909.
Eutima brownei Mayer, 1910.

Those 80 specimens, out of 90 examined and classified by Torrey as *Eutimalphes brownei* and by Mayer as *Eutima brownei*, having no cirri, come under

the genus *Eutonina* Hartlaub. As they possess more than four tentacles, they are not included under *Eutima* Haeckel. For explanation of genera, see Systematic Discussion.
Distribution. San Diego, California (Torrey).

Eutonina indicans (Romanes).

Tiaropsis indicans Romanes, 1876.
Eutonina socialis Hartlaub, 1897.
Eutonina indicans Hartlaub, 1897; Bigelow, H. B., 1913.
Eutimium socialis, Mayer, 1910.

Numerous specimens are included in the collection, varying in size from 8 mm. in bell diameter to 4 mm. in bell diameter. In the large specimens, the tentacles number 40-45 per quadrant.

Following Bigelow, the two species of *Eutonina*, *E. indicans* and *E. socialis* are combined as *E. indicans* as there seems to be little doubt but what the two species are identical.
Distribution. Dutch Harbour (Bigelow); Bull Harbour, Departure Bay (March-October), off Snake Island.

Eutonina scintillans (Bigelow).

Eutimalphes scintillans Bigelow, H. B., 1909.
Eutimium scintillans Mayer, 1910.

As these specimens, according to Bigelow, possess no cirri and from 29 to 36 tentacles, unquestionably they should be placed under the genus *Eutonina* Hartlaub.
Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Genus EIRENE Eschscholtz.

Eirene medusifera Bigelow.

Eirene medusifera Bigelow, H. B., 1909; Mayer, 1910.
Distribution. Common in Acapulco Harbour, Coast of Mexico (Bigelow).

Eirene mollis Torrey.

Irene mollis Torrey, 1909.

Mayer includes *Irene mollis* in the species *Eirene viridula* (vol. 2, p. 311, 1910), but as there is a difference in the number of tentacles, number of statocysts and in the length of the gonads, there seems to be ground for a specific difference.
Distribution. San Diego, California (Torrey).

Family AEQUORIDÆ Eschscholtz.

Genus OCTOCANNA Haeckel.

Octocanna polynema Haeckel.

Octocanna polynema Haeckel, 1879; Bigelow, H. B., 1909; Mayer, 1910.
Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Genus AEQUOREA Péron and Lesueur.

Aequorea aequorea (Forskål).

Medusa aequorea Forskal, 1775.
Aequorea forskalea Péron and Lesueur, 1809.
Crematostoma flava Agassiz, A., 1862, 1865.
Aequorea ciliata Eschscholtz, 1829; Agassiz, L., 1862; Agassiz, A., 1865.
Mesonema victoria Murbach and Shearer, 1902, 1903.
Aequorea forskalea Mayer, 1910.
Aequorea aequorea Bigelow, H. B., 1913.

Aequorea aequorea is perhaps the commonest medusa in the Strait of Georgia. It is found in great numbers throughout the whole year.

The bell diameter of the large specimens in the collection averages about 35 mm. bell diameter and 25 mm. bell height. The number of tentacles, including bulbs, is 120. The number of radial canals totals 60.

Distribution Northwest Coast of North America, Lat. 41° to 51° North (Eschscholtz); Gulf of Georgia, Straits of Fuca (A. Agassiz); Victoria Harbour, Esquimalt Harbour, Pleasant Beach (Murbach and Shearer); Dutch Harbour, Union Bay, Friday Harbour, Puget Sound (Bigelow); Strait of Georgia.

Aequorea coerulescens (Brandt).

Mesonema (*Zygodactyla*) *coerulescens* Brandt, 1838.
Zygodactyla coerulescens Agassiz, A., 1865.
Aequorea coerulescens Torrey, 1909; Mayer, 1910.

Distribution 1,600 miles west of San Diego (Mertens); entrance of Straits of Fuca (A. Agassiz); Unalaska I. (Torrey); San Diego (Torrey).

Aequorea rugosa (Nutting).

Campanulina rugosa Nutting, Harriman, 1901; Fraser, 1911, 1914.

As the medusæ of *Campanulina forskalea* have been given the name *Aequorea aequorea*, it seems necessary to call the medusæ of the hydroid *Campanulina rugosa*, *Aequorea rugosa*. Its relationship to the common *Aequorea* of the Coast, *A. aequorea* is not known.

(Hydroid only.)

Distribution. Juneau, Alaska (Nutting); West Seattle (Fraser).

Order **TRACHOMEDUSÆ**.

Family OLINDIINÆ Browne (sens. em.).

Genus EPERETMUS Bigelow.

Eperetmus typus Bigelow.

Eperetmus typus Bigelow, H. B., 1915, 1920

In the collection are several specimens of this species, varying in size from 5 mm. to 45 mm. in bell diameter, all of which correspond exactly with Bigelow's description.

The centripetal canals agree in 2 specimens, numbering, 4, 4, 4, 5 per quadrant and in all the remaining specimens, there is a variation in the number to a quadrant from 4 to 6. In 3 specimens, there were 6 centripetal canals in each quadrant Bigelow describes his type specimen as possessing 4, 4, 4, 5 per quadrant.

Bigelow states that "the total number of tentacles is 107, *i.e.*, 28, 22, 24, and 29 in each quadrant besides the four radials, of various sizes, and evidently of various ages." In the specimens here described, the tentacles varied similarly in each quadrant. In the smallest specimens there were, to a quadrant, 4 large tentacles, situated some distance up from the bell margin, 4 smaller tentacles, situated nearer the bell margin, and at the bell margin, 15-18 small tentacles. In the largest specimen, the number of tentacles, in positions similar to those just enumerated in the smallest, was 9, 15, 45 respectively. The otocysts numbered, roughly, one between each successive pair of tentacles.

Colour: In the living specimens, the manubrium, gonads and tentacles are a delicate pink, while the tentacle knobs are a deep pink. In the preserved specimens, the manubrium, gonads and tentacles are a pale yellow.

Distribution. 2 miles off Mary I., Southern Alaska, 1905, (?)Port Clarence, Alaska, 1913 (Bigelow); off Snake I., Departure Bay, Northumberland Channel, Dodds Narrows, Tod Inlet, 100-0 f.

Genus Gossea L. Agassiz.

Gossea brachymera Bigelow.

Gossea brachymera Bigelow, H. B., 1909; Mayer, 1910

Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Genus Gonionemus A. Agassiz.

Gonionemus agassizii Murbach and Shearer.

Gonionemus agassizii Murbach and Shearer, 1902, 1903; Mayer, 1910.

Distribution. Found in a small salt lake at Unalaska, Aleutian Is. (Murbach and Shearer).

Gonionemus vertens A. Agassiz.

Gonionemus vertens Agassiz, A., 1862, 1865; Murbach and Shearer, 1903; Bigelow, H. B., 1909; Mayer, 1910.

This species is common among the sea weed along the Strait of Georgia.

Distribution. Gulf of Georgia (A. Agassiz); Victoria Harbour, Matsmets Bay, Puget Sound (Murbach and Shearer); Ballinac I., Departure Bay, Mudge I., Round I., Cardale Point.

Family PTYCHOGASTRIDÆ.

Genus Ptychogastria Allman.

Ptychogastria polaris Allman.

Ptychogastria polaris Allman, 1878; Mayer, 1910; Bigelow, H. B., 1913.

Distribution. Bering Sea (Bigelow).

Family TRACHYNEMIDÆ.

Genus Rhopalonema Gegenbaur.

Rhopalonema velatim Gegenbaur.

Rhopalonema velatim Gegenbaur, 1856; Bigelow, H. B., 1909; Mayer, 1910.
Distribution. Off the Coasts of Lower California, Mexico, Salvador and Guatemala (Bigelow).

Genus Colobonema Vanhöffen.

Colobonema typicum (Maas).

Homoeonema typicum Maas, 1897; Mayer, 1910.
Colobonema typicum Maas, 1905; Bigelow, H. B., 1913.
Distribution. Pacific Coast of Central America (Maas).

Genus Pantachogon Maas.

Pantachogon haecklii Maas.

Pantachogon haecklii Maas, 1893; Mayer, 1910; Bigelow, H. B., 1913.
Distribution. Bering Sea, Unalaska I. (Bigelow).

Genus Crossota Vanhöffen.

Crossota brunnea var. *norvegia* (Vanhöffen).

Crossota norvegia Vanhöffen, 1902.
Crossota brunnea (part) Bigelow, H. B., 1909.
Crossota norvegia Mayer, 1910.
Crossota brunnea var. *norvegia* Bigelow, H. B., 1913.
Distribution. Albatross Stations—4758, 4759, 4760, and Bering Sea (Bigelow).

Crossota pedunculata Bigelow.

Crossota pedunculata Bigelow, H. B., 1913.
Distribution. 46° 26′ N., 124° 26′ W. (just North of the Mouth of the Columbia River) (Bigelow).

Genus Aglaura Péron and Lesueur.

Aglaura hemistoma Péron and Lesueur.

Aglaura hemistoma Péron and Lesueur, 1809; Bigelow, H. B., 1909; Mayer, 1910.
Aglaura hemistoma var. *prismatica* Mayer, 1910.
Aglaura prismatica Maas, 1897.
Distribution. Gulf of Panama (Maas); off the West Coast of Lower California, off the Entrance to the Gulf of California, off the Coast of Mexico, and Central America (Bigelow).

Genus Aglantha Haeckel.

Aglantha digitale (Müller).

Medusa digitale Müller, O. F., 1766; Fabricius, 1780

Aglantha digitalis Haeckel, 1879.
Aglantha digitale Mayer, 1910; Bigelow, H. B., 1913, 1920.
Trachynema camtschatica Agassiz, A., 1865.

The collection includes about 150 specimens varying in size from 1.5 to 10 mm. in bell diameter and from 2.5 to 14 mm. in bell height. In all of these, however, the tentacles have been broken off close to the base so that only knobs are left. These, in the larger individuals, numbered from 50-80. It was impossible to make out the otocysts in the preserved specimens but, in one specimen examined alive, these numbered 16 to a quadrant.

Mayer has described a specimen about twice the size of the largest in this collection and it possessed from 80 to 100 tentacles and 4 lithocysts. Another individual, he states, possessed as many as 8 lithocysts. Bigelow also records specimens possessing tentacles from 68 to 124 in number but with only 8 otocysts at the most. Otherwise the specimens correspond with Mayer's description.

Distribution. Galiano I., Gulf of Georgia (A. Agassiz); Albatross Stations—4758, 4759, 4760, Dutch Harbour, 4762, Bering Sea, 4785, 4793, 4797 (Bigelow); Station 21*a*, *b*, *c*, Lat. 68° 30′ N., Long. 166° 32′ W., off Cooper I., Alaska (Bigelow); East of Newcastle I., Departure Bay, N.E. of Five Finger I., North of Entrance I., off Berry Point, Tod Inlet.

Aglantha digitale var. *intermedia* Bigelow.

Aglantha digitale var. *intermedia* Bigelow, H. B., 1909.

Distribution. At Entrance to Gulf of Panama, off Coasts of Guatemala, Salvador, Nicaragua (Bigelow).

(?)*Aglantha proboscifer* (Maas).

Melicertum proboscifer Maas, 1897.
Melicertum(?) *Aglantha*(?) *proboscifer* Mayer, 1910.

Distribution. Gulf of Panama (Maas).

Genus Amphogona Browne.

Amphogona apsteini (Vanhöffen).

Pentachogon apsteini Vanhöffen, 1902.
Amphogona apsteini Browne, 1904; Bigelow, H. B., 1909.

Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Family HALICREASIDÆ.

Genus Halicreas Fewkes.

Halicreas papillosum Vanhöffen.

Halicreas papillosum Vanhöffen, 1902; Bigelow, H. B., 1909, 1913; Mayer, 1910.

Distribution. West Coast of Panama, Bering Sea (Bigelow).

Genus Botrynema Browne.

Botrynema ellinorae (Hartlaub).

Alloionema ellinorae Hartlaub, 1909.

Botrynema ellinorae Bigelow, H. B., 1913.
Distribution. Albatross Stations—4760, Bering Sea (Bigelow).

Family GERYONIDÆ.

Genus Liriope Lesson.

Liriope indica Bigelow.

Liriope indica Bigelow, H. B., 1904; Mayer, 1910.
Liriope hyalina (immature?) Agassiz, A., and Mayer, 1899.
Distribution. N. Lat. 9° 57′ W., Long. 137° 47′ (Agassiz and Mayer).

Liriope rosacea (Eschscholtz).

Geryonia rosacea Eschscholtz, 1829.
Liriope rosacea Gegenbaur, 1856; Maas, 1897; Mayer, 1910.
Distribution. West Coast of North and South America (Maas).

Liriope tetraphylla (Chamisso et Eysenhardt).

Geryonia tetraphylla Chamisso, A., et Eysenhardt, C. G., 1821.
Liriope tetraphylla Gegenbaur, 1856; Bigelow, H. B., 1909; Mayer, 1910.
Distribution. West Coast of Lower California and Central America (Bigelow).

Liriope species(?) Bigelow.

Liriope species(?) Bigelow, H. B., 1909.
Distribution. West Coast of Lower California, Coast of Salvador (Bigelow).

Genus Geryonia Péron and Lesueur.

Geryonia proboscidalis (Forskål).

Medusa proboscidalis Forskål, 1775.
Geryonia proboscidalis Eschscholtz, 1829; Bigelow, H. B., 1909; Mayer, 1910.
Geryones mexicana+*Carmaris rosea* (young medusa), Agassiz, A., and Mayer, 1902.
Distribution. Off Coast of Mexico (Agassiz and Mayer); off West Coast of Lower California (Bigelow).

Order **NARCOMEDUSÆ**.

Family CUNINIDÆ.

Genus Cunoctantha Haeckel.

Cunoctantha octonaria (McCrady).

Cunina octonaria McCrady, 1857.
Cunoctantha octonaria Haeckel, 1879; Bigelow, H. B., 1909; Mayer, 1910.
Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Cunoctantha tenella Bigelow.

Cunoctantha tenella Bigelow, H. B., 1909; Mayer, 1910.
Distribution. Acapulco Harbour, Coast of Mexico (Bigelow).

Genus CUNINA Eschscholtz.

Cunina globosa Eschscholtz.

Cunina globosa Eschscholtz, 1829; Haeckel, 1879; Bigelow, H. B., 1909.
Distribution. Just West of Acapulco Harbour, Coast of Mexico (Bigelow).

Cunina peregrina Bigelow.

Cunina peregrina Bigelow, H. B., 1909.
Distribution. Just North of the Entrance to the Gulf of California (Bigelow).

Genus SOLMISSUS Haeckel.

Solmissus incisa (Fewkes).

Solmaris incisa Fewkes, 1886.
Solmissus incisa Bigelow, H. B., 1909, 1913; Mayer, 1910.
Distribution. Albatross Stations—4759, 4760, Bering Sea (Bigelow).

Family ÆGINIDÆ.

Genus ÆGINA Eschscholtz.

Ægina citrea Eschscholtz.

Ægina citrea Eschscholtz, 1829; Haeckel, 1879; Bigelow, H B., 1909, 1913.
Distribution. San Francisco, California (Bigelow).

Ægina rosea Eschscholtz.

Ægina rosea Eschscholtz, 1829; Bigelow, H. B., 1913.
Ægina alternans Bigelow, H. B., 1909.

Nineteen specimens were collected in a vertical haul North-East of Five Finger I., Nov. 25th, 1918. All approximated a size of 4 mm. in bell height and 4 mm. in bell diameter. There are 4 tentacles about three times the bell height in length; 4 gastric pouches divided interradially, but there were no signs of adradial notches There were from 4 to 6 lithocysts to a quadrant. Mayer states that there are typically 8 marginal sensory organs, 2 to a quadrant. Vanhöffen has found 16 in one quadrant.

The largest specimen has a bell height of 7 mm. and a bell diameter of 7 mm. It was collected in a plankton net off Five Finger I., July 10, 1915.

Distribution. Albatross Stations—4761, 4774 (Bigelow); North of Five Finger I., 40-0 f., 2 miles N.E. of Five Finger I., 100-0 f., off Berry Point, 10-0 f

Ægina species(?) Bigelow.

Ægina species(?) Bigelow, H. B., 1913.

"In these young *Æginas*, the 8 gastric pouches (all have 4 antimeres) are not divided secondarily, and in our present comparative ignorance of the growth-stages of the genus, it is impossible to be certain whether they belong to *A. rosea* or *A. citrea*. None of them are in good enough condition for me to count the otocysts."—Bigelow, 1913.

Distribution. Albatross Stations—4762, 4785, 4793, 4797, 4805, 4806 (Bigelow).

Genus ÆGINURA Haeckel.

Æginura grimaldii Maas.

Æginura grimaldii Maas, 1904; Bigelow, H. B , 1913.

Distribution. Albatross Stations—4764, 4766, 4768, 4780, 4953, 5058, 5084 (Bigelow).

Genus ÆGINOPSIS Brandt.

Æginopsis laurentii Brandt.

Æginopsis laurentii Brandt, 1838; Agassiz, A., 1865; Mayer, 1910; Bigelow, H. B., 1920.

Distribution. Bering Sea (Brandt); Laurent Bay, Bering Sea (Mertens); off Collinson Point, Alaska (Bigelow).

Genus SOLMUNDELLA Haeckel.

Solmundella bitentaculata (Quoy and Gaimard).

Charybdea bitentaculata Quoy et. Gaimard, 1833.

Solmundella bitentaculata Maas, 1906; Bigelow, H. B., 1909; Mayer, 1910.

Distribution. West Coast of Lower California and Mexico (Bigelow).

BIBLIOGRAPHY.

(Only those papers referred to in the synonymy or in the text are listed.)

AGASSIZ, A.

1862. The Acalephan fauna of the southern coast of Massachusetts (Buzzard Bay). Proceedings of the Boston Society of Natural History, vol. 8, 224 pp.

1865. North American Acalephae. Illustrated Catalogue of the Museum of Comparative Zoology at Harvard College, No. 2, pp. xiv+234, 360 figs.

AGASSIZ, A., and MAYER, A. G.

1899. Acalephs from the Fiji Islands. Bulletin of the Museum of Comparative Zoology at Harvard College, vol. 32, pp. 157-189, 17 plates.

1902. Reports on the Scientific Results of the Expedition to the Tropical Pacific in charge of Alexander Agassiz by the U.S. Fish Commission Steamer *Albatross*, from August, 1899, to March, 1900 III. Medusæ, Memoirs of the Museum of Comparative Zoology at Harvard College, vol. XXVI., pp. 139-176, 14 plates.

Agassiz, L.

1849. On the Naked-eyed Medusæ of the Shores of Massachusetts in their perfect state of development. Contributions to the Natural History of the Acalephae of North America. Memoirs of the American Academy, new series, vol. 4, pp. 221-316, 8 plates.

1862. Contributions to the Natural History of the United States of America. Boston, vol. 4, pp. 1-372, plates 20-35.

Alder, J.

1856. A notice of some new genera and species of British hydroid zoophytes. Annals and Magazine of Natural History, 2nd series, vol. XVIII, London.

Allman, G. J.

1859. Notes on the Hydroid Zoophytes. Annals and Magazine of Natural History, series 3, vol. 4, pp. 137-144.

1864. Notes on the Hydroida. Annals and Magazine of Natural History, series 3, vol. XIV.

1878. Hydrozoa: in Capt. Sir G. S. Nares' Narrative of a Voyage to the Polar Sea during 1875-76, in H.M. Ships *Alert* and *Discovery*. London, vol. 2, pp. 290-292.

Beneden, P. J. van

1844. Mémoire sur les Campanulaires de la Côte d'Ostende, considérés sous le rapport physiologique, embryogénique et zoologique. Nouvelle Mémoires de l'Académie Royal, Bruxelles, tome XVIII, 42 pp.

Bigelow, H. B.

1904. Medusæ from the Maldive Islands. Bulletin of the Museum of Comparative Zoology at Harvard College, vol. 39, pp. 245-269, 8 plates. Cambridge.

1909*a*. Reports on the Scientific Results of the Expedition to the Eastern Tropical Pacific, in charge of Alexander Agassiz, by the U.S. Fish Commission Steamer *Albatross*, from October, 1904, to March, 1905. XVI. The Medusæ. Memoirs of the Museum of Comparative Zoology at Harvard College, vol. 37, 243 pp., 48 plates. Cambridge.

1909*c*. Coelenterates from Labrador and Newfoundland, collected by Mr. Owen Bryant from July to October, 1908. Proceedings of the United States National Museum, vol. 37, pp. 301-320, plates 30-32. Washington.

1913. Medusæ and Siphonophoræ collected by the U.S. Fisheries Steamer *Albatross* in the Northwestern Pacific, 1906. Proceedings of the United States National Museum, vol. 44, 119 pp., 6 plates. Washington.

1915. Eperetmus, a new genus of Trachomedusæ. Proceedings of the United States National Museum, vol. 49, pp. 399-404, plate 59. Washington.

1916. Halimedusa, a new genus of Anthomedusæ. Transactions of the Royal Society of Canada, series III, vol. X, section iv, pp. 91-95, 1 plate. Ottawa.

1920. Medusæ and Ctenophoræ. Report of the Canadian Arctic Expedition, 1913-1918. Southern Party, 1913-1916, vol. VIII, part H, 22 pp., 2 plates. Ottawa.

Boehm, R.

1878. Helgolander Leptomedusen. Jena Zeitschrift für Naturw. Bd. 12, pp. 68-199, plates 2-7.

Brandt, J. T.

1834. Prodromus Descriptionis Animalium ab H. Mertensio in orbis terrarum circumnavigatione observatorum. Fascic. 1, in Récueil Actes séances publique Academie Imperial de Science. St. Pétersbourg, 1833-34, 76 pp., 1 plate.

1837. Remarques sur quelques modifications dans l'arrangement de l'ordre des Acalèphes discophores ou ombrellifères. Bulletin de scientifique Academie Imperial de Science, St. Pétersbourg, vol. 1, pp. 185-191.

1838. Ausführliche Beschreibung der von C. H. Mertens auf seiner Weltumsegelung beobachteten Schirmquallen. . . . Mémoires Academie St. Pétersbourg, series 6, vol. 4, Sci. Math. et Nat., tome 4, pp. 237-411, plates 1-31.

Browne, E. T.

1903. Report on some Medusæ from Norway and Spitzbergen. Bergens. Mus. Arbog. No. 4, 36 pp., 5 plates.

1904. Hydromedusæ, with a Revision of the Williadæ and Petasidæ. Fauna and Geography of the Maldive and Laccadive Archipelagoes, vol. 2, pp. 722-749, plates 54-57.

Calkins, G. N.

1899. Some hydroids from Puget Sound. Proceedings of the Boston Society of Natural History, vol. 28, No. 13, pp. 333-367. Boston.

Chamisso, A. de, and Eysenhardt, C. G.

1821. De Animalibus quibusdam e Classe Vermium Linneana. . . . Fasc. 2. Acad. Caes. Leop., Nova Acta, 1821, vol. X, pp. 343-374, plates 24-33.

Clarke, S. F.

1876. Report of the Hydroids on the Coast of Alaska and the Aleutian Islands, collected by W. H. Dall, from 1871 to 1874. Proceedings of the Academy of Natural Sciences of Philadelphia, pp. 205-238.

1907. Reports on the Scientific Results of the Expedition to the Eastern Tropical Pacific . . . vol. VIII. The Hydroids. Memoirs of the Museum of Comparative Zoology at Harvard College, vol. 35, 18 pp., 15 plates.

Eschscholtz, Fr.

1829. System der Acalephen. Eine aüsführliche Beschreibung aller Medusenartigen Strahlthiere. Berlin. 196 pp., 16 plates.

Fabricius, O.

1780\. Fauna Grönlandica. Hafniae, 8°, 452 pp., 1 plate.

Fewkes, J. W.

1886\. Report on the Medusæ collected by the U.S. Fish Commission Steamer *Albatross* in the Region of the Gulf Stream in 1883-84. U.S. Commission of Fish and Fisheries. Report of the Commissioner for 1884, pp. 927-980, plates 1-10.

1889\. New Invertebrata from the Coast of California. Bulletin of the Essex Institute, Salem, vol. 21, pp. 99-146, 7 plates.

1889*b*. On a few Californian Medusæ. American Naturalist, vol XXIII, pp. 591-602, plates 25-28, 10 figures in the text.

Fleming,

1823\. Gleanings of Natural History, gathered on the Coast of Scotland during a voyage in 1821: Edinburgh Philosophical Journal, vol. VIII, pp. 294-303.

Forskal, P.

1775\. Descriptiones animalium . . . quae in itinere orientale observavit, post mortem ededit Carstem Niebuhr. Hauniæ, pp. 20+xxxiv +16, 1 map.

1776\. Icones rerum naturalium quas in itinere orientale depingit curavit Petrus Forskal . . . edidit Carstem Niebuhr. Hauniæ, 15 pp., 43 plates.

Forbes, E.

1841\. Contributions to British Actinology. American Magazine of Natural History, vol. VII, pp. 81-85.

1848\. A Monograph of the British Naked-eyed Medusæ. London, Ray Society, 104 pp., 13 plates.

Forbes, E., and Goodsir.

1853\. On some remarkable Marine Invertebrata new to the British Seas. Transactions of the Royal Society of Edinburgh, vol. XX, pp. 307-315, plates 9, 10.

Fraser, C. McLean.

1911\. The Hydroids of the West Coast of North America with special reference to those of the Vancouver Island Region. Bulletin of the Laboratories of Natural History, State University of Iowa, vol. VI, No. 1, pp. 1-91, 8 plates. Iowa City.

1912\. Endocrypta huntsmani, Science, vol. XXXV, p. 216.

1912\. Some Hydroids of Beaufort, North Carolina. Bulletin of the Bureau of Fisheries, vol. XXX, 1910, pp. 339-387. Washington.

1914\. Some Hydroids of the Vancouver Island Region and Notes on some Alaskan Hydroids. Transactions of the Royal Society of Canada, section iv, vol. VIII, third series, pp. 99-222, 37 plates. Ottawa.

Gegenbaur, C.

1856\. Versuch eines system der Medusen, mit Beschreibung neuer oder wenig gekannter Formen . . . Zeit. wiss. Zool., vol. VIII, pp. 202-273, plates 7-10.

Goto, S.

1903. The Craspedote Medusa Olindias and some of its Natural Allies. Mark Anniversary volume, Cambridge, pp. 1-22, plates 1-3.

Gould, A. A.

1841. Report on the Invertebrates of Massachusetts. 372 pp., 14 plates. Cambridge.

Haeckel, E.

1879. Das System der Medusen. Theil I. System der Craspedoten. Jena Denkschriften, vol. 1, 360 pp., atlas of 40 plates.

1880. System der Acraspedoten. Zweite Hälfte des Systems der Medusen. Jena Denkschriften, vol. 1, 2 abth., pp. 361-672.

Hartlaub, Cl.

1897. Die Hydromedusen Helgolands. Beitrage zu Meeresfauna von Helgoland. X. Wissenschaftliche Meeresuntersuchungen, herausgegehen von der Kommission zur Untersuchung der deutschen Meere in Kiel und der Biologischen Anstalt auf Helgoland, vol. 2, pp. 451-512, plates 14-23. Kiel and Leipzig.

1907. Craspedote Medusen. 1 Teil, 1 lieferung, Codoniden und Cladonemiden. Nordisches Plankton, sechste Lieferung, No. XII, 135 pp., 126 figuren.

1909. Méduses, in Duc d'Orleans Crosière Océanographique, accomplée à Bord de la Belgica dans la Mer du Grönland, 1905, 18 pp., plates 76-77. Bruxelles.

1911. Craspedote Medusen. 1 Teil, 2 lieferung, Margelidae. Nordisches Plankton, Funfzehnte Lieferung, No. XII, pp. 137-235, figuren 127-199.

1913. Craspedote Medusen. 1 Teil, 3 lieferung, Tiaridae, Nordisches Plankton, Siebzehnte Lieferung, No. XII, pp. 237-363, figuren 200-311.

1917. Craspedote Medusen. 1 Teil, 4 Lieferung, Williadae, Index, Figuren-Verzeichnis, Literatur-Verzeichnis, Nordisches Plankton, Neunzehnte Lieferung, No. XII, pp. 365-479, figuren 312-347.

Hincks, T.

1868. A history of the British Hydroid Zoophytes, 2 volumes. London.

Kishinouye, K.

1910. Some Medusæ of Japanese Waters. Journ. Coll. Sci. Tokyo, vol. 17, art. 9, 35 pp., 5 plates.

Linnaeus, C. von.

1758. Systema naturae . . . Ed. 10, vol. 1, 823 pp.

Linko, A.

1905. Zoologische Studien im Barents-Meere. Vorl. Mittlg. Hydromedusen. Zoologische Anzeiger. Bd. 28, pp. 210-220.

Maas, O.

1893. Die Craspedoten Medusen der Plankton Expedition. Ergeb. der Plankton-Expedition der Humboldt-Stiftung, vol. 2, K.c., 107 pp., 6 plates, 2 maps.

1897. Reports on an Exploration off the West Coasts of Mexico, Central and South America, and off the Galapagos Islands, in charge of Alexander Agassiz, by the U.S. Fish Commission Steamer *Albatross* during 1891. XXI. Die Medusen. Memoirs of the Museum of Comparative Zoology at Harvard College, vol. XXIII, No. 1, 92 pp., 15 plates. Cambridge.

1904. Méduses provenant des Campagnes des Yachts Hirondelle et Princesse-Alice (1886-1903). Résultats des Camp. Sci., etc., par Albert 1er, Prince Souverain de Monaco. . . . Fasc. 28, 71 pp., 6 plates.

1905. Die Craspedoten Medusen der Siboga-Expedition. Uit. kom. op. Zool. Bot., Oceanogr. en Geol. Gebied. Siboga-Expedition. Monograph X, 84 pp., 14 plates.

1906. Méduse d'Amboine (Voyage de M. Bedot et C. Pictet dans l'Archipelago Malais). Revue Suisse Zool., tome 14, pp. 81-107, plates 2, 3.

1909. Japanische Medusen. F. Döflein, Beitrage zur Naturgeschichte Ostasiens. Abhandl. math. phys. Klasse K. Bayr. Akad. Wiss. 1 suppl. vol., 52 pp., 3 plates.

Mayer, A. G.

1900. Some Medusæ from the Tortugas, Florida. Bulletin of the Museum of Comparative Zoology at Harvard College, vol. 37, pp. 13-82, 44 plates.

1904. Medusæ of the Bahamas. Memoirs of the Natural Science Museum of the Brooklyn Institute of Arts and Science, vol. I, 33 pp., 7 plates.

1910. Medusæ of the World, 3 vols., 734 pp., 76 plates. Carnegie Institute, Washington, publication No. 109.

Müller, O. F.

1776. Zoologiae danicae prodromus, seu animalium Daniae et Norvegiae indigenarum characteres, nomina et synonyma imprimis popularium, Hauniæ, 8°.

Murbach, L., and Shearer, C.

1902. Preliminary Report on a Collection of Medusæ from the Coast of British Columbia and Alaska. Annals and Magazine of Natural History, series 7, vol. 9, pp. 71-73.

1903. On the Medusæ from the Coast of British Columbia and Alaska. Proceedings of the Zoological Society of London, part 2, pp. 164-192, plates 17-22.

McCrady, J.

1857. Gymnophthalmata of Charleston Harbour. Proceedings of the Elliott Society, vol. 1, pp. 103-221, plates 8-12.

Nutting, C. C.

1899. Hydroids from Alaska and Puget Sound. Proceedings of the United States National Museum, vol. XXI, pp. 741-753. Washington.

1901. The Hydroids of the Woods Hole Region. U.S. Fish Commission Bulletin for 1899, vol. XIX, pp. 325-386. Washington.

1901. Papers from the Harriman Alaska Expedition. XXI. The Hydroids. Proceedings of the Washington Academy of Sciences, vol. III, pp. 157-216. Washington.

OKEN,

1835. Allgemeine Naturgeschichte für alle Stände, Bd. V. Stuttgart.

PALLAS, P. S.

1766. Elenchus Zoophytorum. Haag.

PÉRON, F., and LESUEUR, C. A.

1809. Histoire Générale et Particulière de tous les Animaux qui composent la famille des Méduses. Annals Mus. Hist. Nat., vol. 14, pp. 218-228.

QUOY ET GAIMARD.

1833. Zoologie: in Voyage de découvertes de l'Astrolabe, etc., . . . de M. J. Dumont D'Urville. Paris, vol. 4, 390 pp. Atlas Zool., vol. 2, Zoophytes, 26 plates.

RATHKE, M. H.

1835. Beschreibung der *Oceania blumenbachii* einer bei Sevastopol gefundenen leuchtenden Meduse, in: Mem. Acad. Imp. Sci. St. Pétersbourg, vol. 2, pp. 321-329, 1 plate.

ROMANES, G. J.

1876. An account of some New Species, Varieties and Monstrous Forms of Medusæ. Journ. Linn. Soc. London, vol. 12, pp. 524-531.

TORREY, H. B.

1902. The Hydroida of the Pacific Coast of North America. University of California Publications in Zoology, vol. 1, 104 pp., 11 plates. Berkeley.

1904. The Hydroids of the San Diego Region. University of California Publications, Zoology, vol. 2, Nos. 1 and 2, 51 pp., 1 plate. Berkeley.

1909. The Leptomedusæ of the San Diego Region. University of California Publications, Zoology, vol. 6, No. 2, pp. 11-31, text figures 1-11. Berkeley.

VANHÖFFEN, E.

1902. "Die Craspedoten Medusen der deutschen Tiefsee-Expedition." ("Valdivia"), 1898-99. I. Trachomedusen. Wissen. Ergebnisse, Bd. III, pp. 53-86. Taf. IX-XII.

WRIGHT, T. S.

1862. On the reproduction of Thaumantias inconspicua. Quarterly Journal of Microscopic Science, new series, vol. II, London.

PLATE I.

Fig. 1. *Sarsia flammea.* Immature form. Found at Lock Bay. Free-hand sketch.

Fig. 2. *Halitholus pauper.* Manubrium and gonad. Camera lucida.

Fig. 3. Aboral view, showing cross formation of gonads.

Fig. 4. *Leuckartiara octona.* Mature form, showing the structure of the gonads. Camera lucida.

Fig. 5. Camera lucida drawing of another entire form.

Fig. 6. *Leuckartiara nobilis.* Free-hand sketch of mature form, showing the structure of the gonads.

PLATE II.

Fig. 1. *Leuckartiara breviconis.* Free-hand sketch of a mature form, showing the structure of the gonads, pits in the stomach wall and the general shape.

Fig. 2. Portion of bell margin to show the structure and position of the tentacles. Camera lucida.

Fig. 3. Camera lucida drawing of a perradial region, showing the structure of the radial canal and the position and shape of the gonads and pits.

Fig. 4. *Neoturris pelagica.* Camera lucida drawing. The markings on the manubrium and stomach are elevations, not depressions.

Fig. 5. *Neoturris pileata*(?). Camera lucida drawing.

Fig. 6. Enlarged drawing of the side of the manubrium to show the shape of the gonads.

Fig. 7. *Bougainvillia multitentaculata.* Camera lucida drawing of one side of the manubrium to show the shape of the gonads and the oral tentacles.

PLATE III.

Fig. 1. *Bougainvillia multitentaculata.* Camera lucida drawing. Mature specimen.

Fig. 2. A marginal cluster of tentacles.

Fig. 3. *Bougainvillia nordgaardii.* Camera lucida drawing.

Fig. 4. A marginal cluster of tentacles. Free-hand.

Fig. 5. *Proboscidactyla polynema.* Camera lucida drawing.

Fig. 6. A side view of another specimen. Camera lucida drawing.

Fig. 7. High-power drawing to show the radial canal and its branches.

PLATE IV.

Fig. 1. *Proboscidactyla polynema.* Enlarged drawing of a quadrant to show the direction of the branches of the radial canals and the structure of the tentacles.

Fig. 2. *Staurophora purpurea.* Aboral view showing the shape of the mouth and the connection to the radial canals.

Fig. 3. Free-hand sketch of entire specimen.

Fig. 4. Portion of bell margin showing two tentacle knobs and three lithocysts.

Fig. 5. Portion of bell margin showing the shape of the tentacle knobs.

Fig. 6. *Mitrocoma sinuosa.* Free-hand drawing.

Fig. 7. *Tiaropsidium kelseyi.* Oral view showing the tentacular processes of the radial canal.

PLATE V.

Fig. 1. *Halistaura cellularia.* Camera lucida drawing of a sense pit.

A = Exumbrellar surface of velum.

B = Columnar cells of exumbrellar ectoderm.

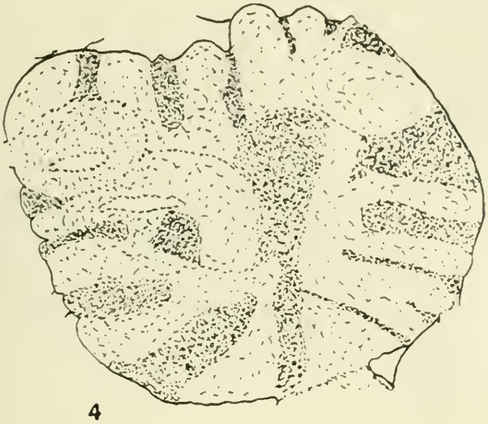
C = Cells of subumbrellar layer.

D = Columnar cells of exumbrellar ectoderm bordering the marginal ring.

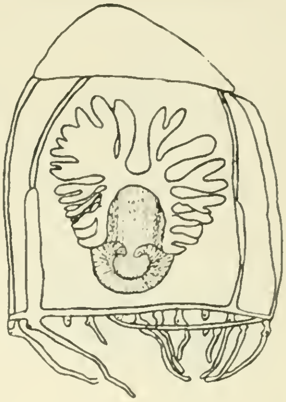
E = Exumbrellar cells bordering the marginal ring.

Fig. 2. Camera lucida drawing showing the relative position of sense pits and tentacles. Vel. = velum. Marg. = marginal ring. S.P. = sense pit. Tent. = tentacles.

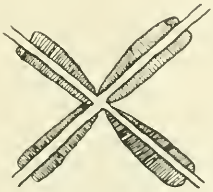
PLATE I.



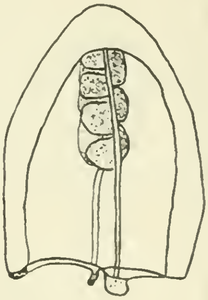
4



6

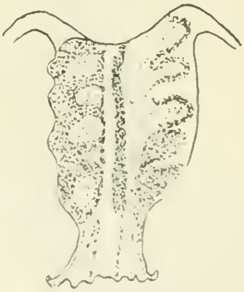


3



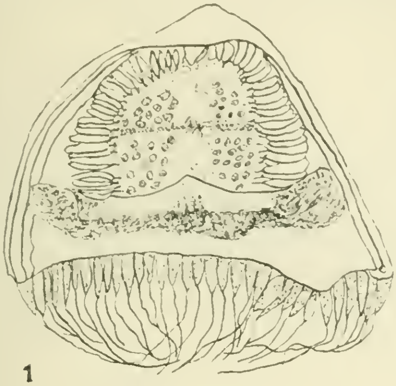
1

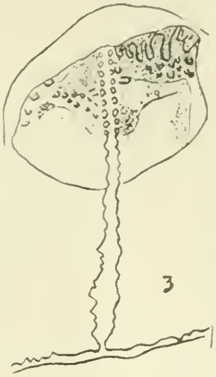
5

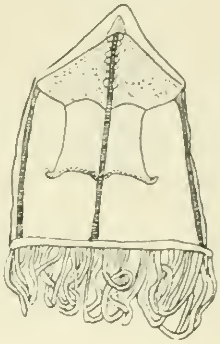


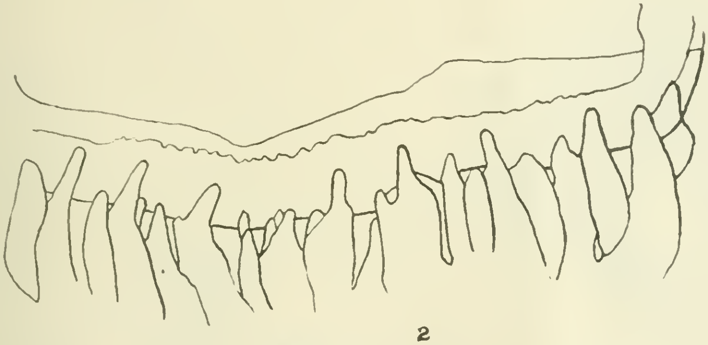
2

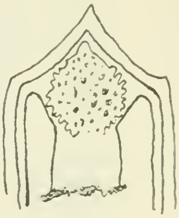
PLATE II

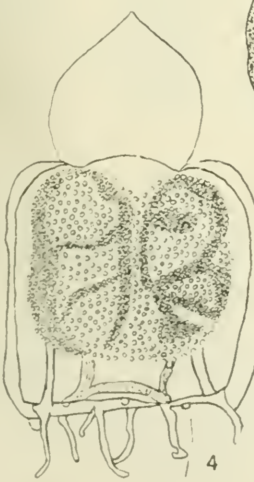

1


3


5

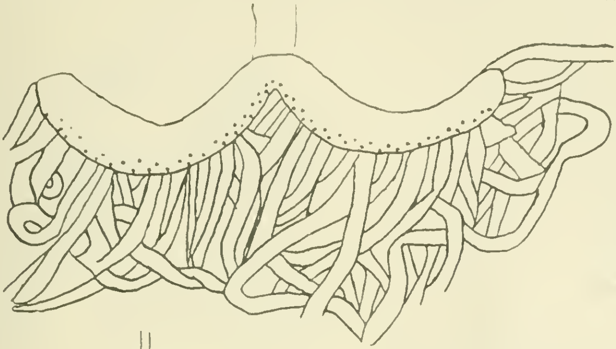

2

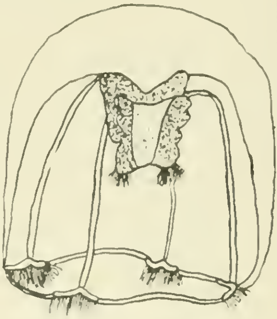

6

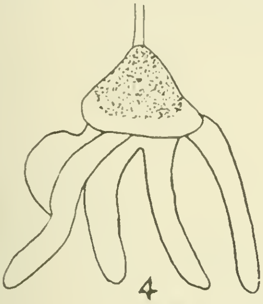

4

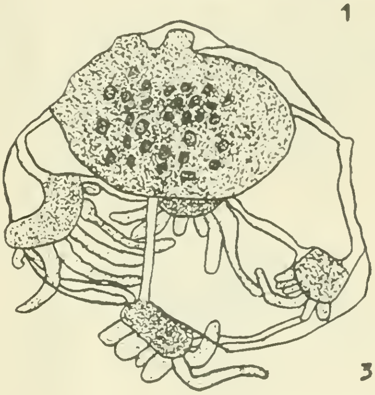

7

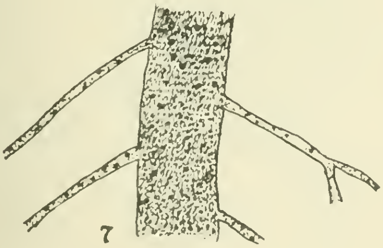
PLATE III.

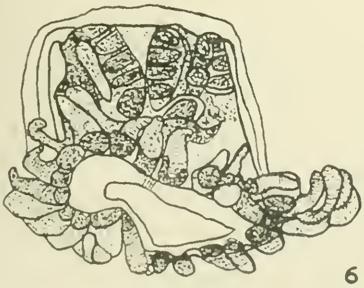

2


1


4


3


7


6

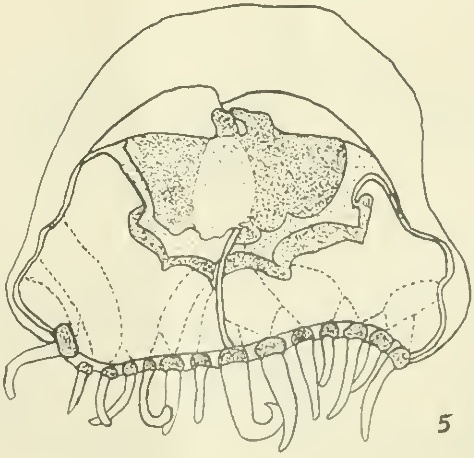
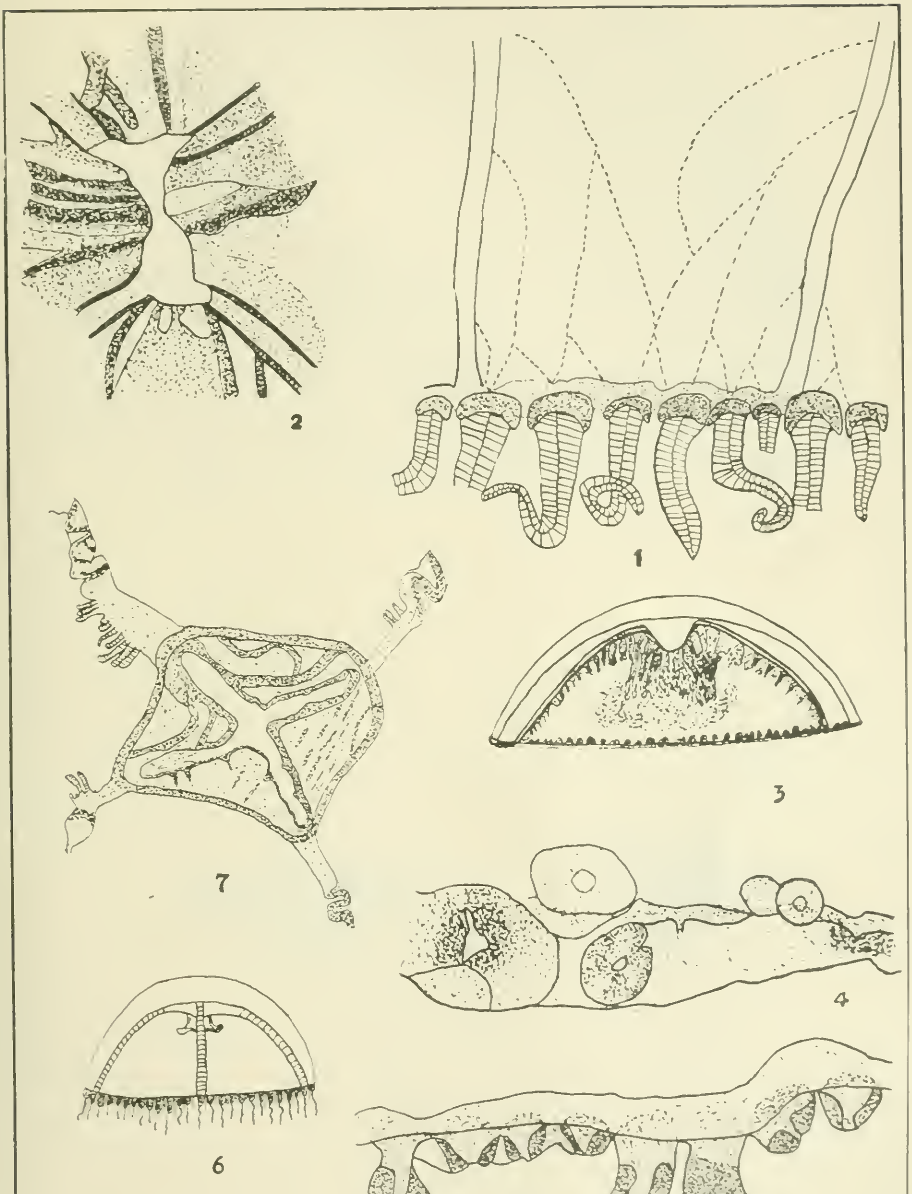
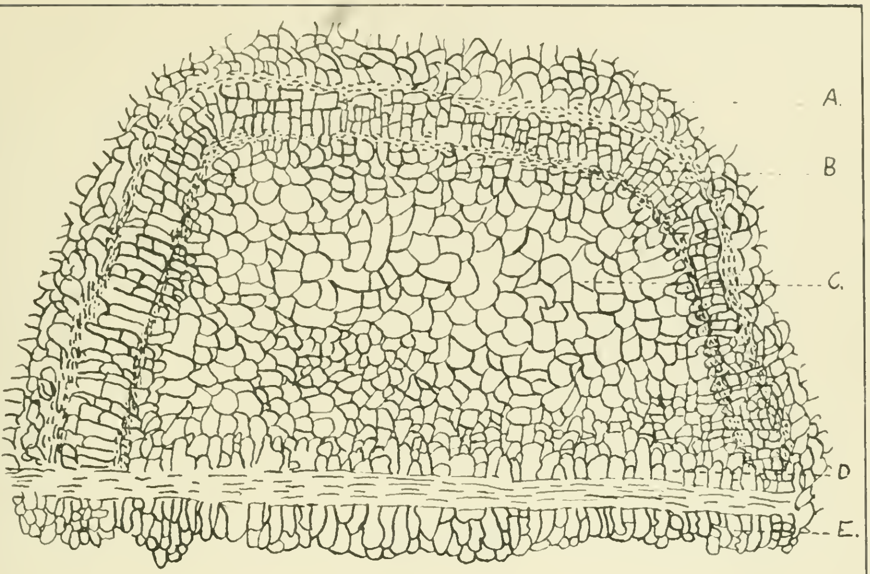
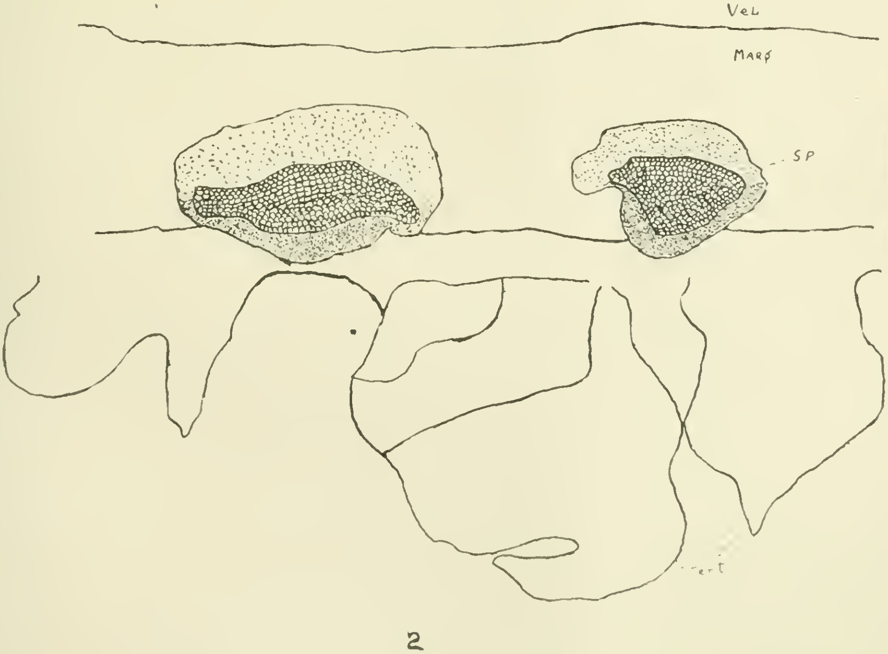

5

PLATE IV





1



2

No. 13

RUSTY HERRING

BY

F. C. HARRISON, D.SC., F.R.S.C.
Macdonald College, P.Q.

Rusty Herring

By F. C. Harrison, D.Sc., F.R.S.C.

Macdonald College, P.Q.

The trouble known as "Rusty Herring" occurs only on pickled fish and is characterized by the appearance of a reddish brown discoloration on the exterior surface of the herring. The colour resembles iron rust, and hence the common name "rusty". Not only is the appearance of the fish spoiled by this semblance of rustiness, but the flavour of such fish is not so good, and they seem to deteriorate more rapidly than normal pickled fish.

Many packers consider this trouble a serious one for the fish trade, and a few quotations concerning it from a number of correspondents in the fish trade will serve to explain the views of packers and others as to its cause.

"I do not believe the trouble is due to a microbe, but rather is the effect of lack of moisture or rather pickle, since the rust usually occurs when the packages containing herring lose their pickle and become dry. This condition prevails to a greater extent in warm weather, and our experience has been that during the winter months there is not so much danger of rust, because the pickle becomes frozen and does not leak from packages so readily.

"It is a fact that herring will show rust during warm weather if exposed to the heat, and it is our contention that this condition is due to the oil in the fish."

"We have always known of this trouble with salted herring and particularly fat and oily herring, but we have never taken the matter seriously, as it has been our impression that any time pickled herring becomes rusty it was caused by the fact that the pickle had been allowed to run off the herring, and we have always believed that the rust was the oil from the herring. If fat herring are kept covered with pickle, they remain in good condition, but I cannot say for what length of time. Herring are usually sold in barrels in pickle, and when the pickle is allowed to run off the packages, they invariably become rusty after a very short while."

"We would say that the cause of pickled fish rusting is lack of pickle. Any fish that is kept fully covered with pickle will not rust, hence the necessity of pickled fish being contained in perfectly tight barrels. Unfortunately Canadian packages as used for pickled fish usually leak to a more or less extent, so that unless the barrels are carefully watched and filled up with pickle from time to time, the fish will rust at whatever point the pickle is lacking. A dishonest packer may mix in rusty fish in the barrel when he is packing, the fish having deteriorated when he has been curing them; also owing to his not keeping the container in which the fish have been cured filled up with pickle. Fat fish rust more quickly and to a greater extent than fish that have a small proportion of fat. Spring herring and mackerel that have very little fat will stand out of pickle for some time without rusting, whereas these fish caught later in the season will start to turn rusty within three or four days."

"We have not had many rusty herrings this season. In our opinion, the cause of this defect in the fish is due to lack of pickle in the barrels after the herrings have been cured. Sometimes the barrels leak and the pickle runs out, and as soon as fish get in touch with high temperatures, this rust sets in."

"We have had quite a lot of experience with herring and other fish. We believe that rust on herring is due to the oxidation of the oil or fat of the herring and occurs when the fish are not kept covered with pickle. Leaky packages are to blame for its occurrence. We have kept fat herring to the third summer by keeping plenty of strong pickle on them and keeping the barrels covered after being open for use.

"The best herring, our fat July fish, are more liable to rust than the poorer qualities which are not so fat."

The above extracts from letters received from some of the largest packers in Canada reveal the situation; and to these excerpts may be added a few clauses from the "Fish Inspection Act as amended 1920". Clauses 1 to 20 are concerned with specifications regarding barrels, their size, strength and capability of retaining pickle. Clause 28 states in part that herring shall be thoroughly cured, bright in colour, and free from rust. Provided that if the owner of any container of herring furnishes an inspection with a statutory declaration that such herring are for shipment to the West Indies, they may be exempted from the two latter requirements.

Clauses to the same effect are given for alewives.

To summarize the facts given by the packers, we may note:

1. That rusty herring is a serious trouble.
2. That nearly all packers agree that the trouble occurs only when the barrels leak or are not kept full of pickle and the fish completely immersed.
3. That herring pickled in July are more liable to rustiness than those caught earlier or later.
4. That the cause of rustiness is the oxidation of the oil from the herring after they have become exposed to air.

Legislation requires sound barrels, well filled with pickle and excludes rusty herring except for export to the West Indies.

EXPERIMENTAL INQUIRY

We have received samples of rusty herring from a number of packers in the Maritime Provinces. These herring were quite representative of the trouble. Cultures were made from the rusty material from different parts of the fish, on 16% salt codfish agar and other fish media with varying but large percentages of salt. All cultures were incubated at blood heat, and also at room temperatures. Three weeks later practically all these cultures showed a marked red growth around the rusty material with which they had been inoculated, and from some, in which the growth was most advanced, it was possible to transfer to other tubes material which proved on subsequent inoculation to be in pure culture. Repeated examinations of the cultures thus obtained showed that the red organism named *Pseudomonas salinaria*, and fully described in my paper on "The Red Discoloration of Codfish," was responsible for the red colour of the cultures obtained from the rusty herring.

However, in order to prove that rusty herring could be produced by the red organism, it was necessary to inoculate fresh herring with a culture of the red organism. Several lots of herring were placed in large glass dishes, and salted. After the brine had formed, a number of the herring were smeared with a culture, the second transfer from the original isolation from rusty herring. The inoculated fish were kept at room temperature and in two weeks the characteristic rusty red appearance was manifest, and which increased progressively with age. From these experimental fish transfers were made to various salt media when red growth appeared, which on cultural and microscopical examination proved to be a pure culture of *Ps. salinaria*, the red organism of discolored codfish.

As this organism has been shown to be present in solar or tropical salt, another batch of fresh herring were salted with a tropical salt (Turks Islands), which was known to contain the red organism. In due time rustiness developed, and again the red organism was isolated on appropriate culture media without difficulty. Other fresh herring salted with Liverpool Salt remained fresh and bright, and no rustiness developed.

One point needs further explanation. Why does *Ps. salinaria* produce *red* colour on cod, hake, pollack and cusk, and rusty colour on *herring?*

From a number of experiments made by mixing masses of the red growth taken from salt codfish media with the oil and exudate coming from pickled herring, a rusty coloured material is obtained, and it seems evident that the herring oil modifies the production of colour. Experimentally one can obtain a redder colour if pains are taken to exclude oil from the growth, and when abundant oil is present well mixed with salt, the colour is distinctly that of rusty iron.

The scientific facts obtained are in accord with the experience of packers. The red organism is *salt loving, requires free oxygen, refusing to grow beneath the surface of pickle*, or in any condition which deprives it of free oxygen, and its *growth* is *favoured* by *warm temperatures*. All these points have been discussed at length in my report to the Scientific and Industrial Council on "The Red Discoloration of Cured Codfish," and hence inadvisable to repeat; but, briefly, the extraordinary life history of the red organism accounts for the practical experience of the packers, and these are:

1. Ability of the organism to grow in large amounts of salt;
2. Appearance of "rustiness" in fish only out of pickle;
3. Greater "growth" of rustiness in warm weather.

Remedial measures have been discussed in the publication referred to, and this investigation emphasizes the necessity of controlling the use of solar or tropical salts, by either sterilizing them before use, or by prohibition of sale, until it is shown that such salt is free from the red organism.

There is also need for packers to be more particular about the proper filling up with pickle of barrels and kegs, so that fish are kept immersed in the liquid. Such precautions will prevent the growth of the red organism.

REFERENCES.

HARRISON, F. C. and KENNEDY, MARGARET. The Red Discolouration of Cured Codfish. *Trans. Roy. Soc. Can.* Vol. XVI, p. 101, 1922. Idem. *Hon. Advis. Council for Sci. and Indust. Research Report No. 11.* Ottawa, 1922.

No. 14

ICHTHYOLOGICAL NOTES

BY

C. MCLEAN FRASER

Ichthyological Notes

By C. McLean Fraser

During the last ten years numerous observations on various species of fish in the waters in the neighbourhood of the Biological station, Nanaimo, have been noted, but as some of these have had no direct bearing on any of the questions discussed in published papers no reference has been made to them. It might be a long time before the observations on any one species would justify the preparation of a paper, yet it seems worth while to record them even if this record has to be put in the disconnected form of "Ichthyological notes." These notes come under two main topics: food and spawning.

FOOD OF FISHES

The stomachs of many fish have been examined to see the nature of the food eaten and observations have been made on the live fish as well, in many instances.

The Dogfish.—*Squalus sucklii.* During the summer months young herring and young salmon are commonly seen in large shoals in the shallow water near the station wharf, and with them there may be sticklebacks and sand launces. The fish in these shoals are often attacked by young dogfish. On two successive evenings, May 29 and 30, 1916, these young dogfish were in such unusually large numbers that the waters were all in a commotion. As the tide was high at the time it was an easy matter to spear them off the wharf. On these two occasions only the young herring were abundant and they evidently were digested very rapidly after being swallowed for although the dogfish were taken right in the attack on the herring, in ten individuals examined only three complete fish were obtained and in most cases they were past recognition.

The mature dogfish feed extensively on the mature herring. On countless occasions they have been observed in the herring schools, apparently taking a fish whenever they felt inclined. This is most noticeable when the herring, forming very large schools, move along near shore to feed on the nauplius and cypris larvæ of the barnacles. The herring are too wary to be caught with a dipnet, hence if a few are required for examination it is often easier to spear a dogfish or as many as are required and open them to get the herring. As many as six fullgrown herring have been obtained from one dogfish, all apparently fresh and sound. As the meat of the mature herring is much firmer than that of the fingerlings digestion of it does not take place so rapidly. On occasion it is an easy matter to spear the dogfish from the landing float at the station. When the herring are spawning in shallow water the dogfish will come right in shore and may even be left temporarily stranded by a wave. Even out in the deeper water farther from shore, when the herring are near the surface feeding, the characteristic commotion of the water, indicative of the presence of dogfish, may often be observed.

Gulls have an insatiable appetite for herring and it is often possible to locate spawning schools of herring from a distance by the action of the innumerable gulls in the vicinity. On March 14, 1917, while looking for herring spawning areas to the southward and eastward of Gabriola island, numerous excited gulls were noticed around a little bay in the most easterly of the Flattop islands. On reaching the spot there was no evidence of herring spawning but as the water was clear it was readily possible to see numerous large dogfish following up the herring, that, in trying to escape, went into the shallow waters of the rocky pools where they fell a prey to the waiting gulls (for, of course, gulls cannot dive and hence they can only obtain herring when they are near the surface). It would be more correct to say that although the gulls were always waiting they did not always get satisfaction, because several bald eagles were also aware of the panic of the herring and at times they decided to become active participants. Then the gulls had to scatter but they gave voice to their discomfiture and returned to the feast at the first opportunity. The dogfish on this occasion as on many others accounting for the destruction of many more herring indirectly than directly and since dogfish are so numerous in coastal waters even the direct destruction is bad enough.

Herring, large and small, are not the only fish eaten by the dogfish. It is possible that any fish small enough to be swallowed will serve. Young salmon, sticklebacks, sand launces and pipefish have been taken from their stomachs. When the capelin come in to spawn in the sand along shore,—early in October,—the dogfish follow them in and take a large toll. As in the case of the pursuit of the herring they may become temporarily stranded on the beach.

Apart from fish, cephalopods, both squid and octopi, evidently are often eaten, although usually only the undigested beaks are found in the stomach. Schizopods, too, have been found, but one can scarcely surmise that these would be worth bothering with except when collected in large numbers as when they appear in the water as "pink feed."

The most surprising stomach content that has been obtained was the medusa *Æquorea*. These jelly fish could surely supply very little nourishment but possibly they might serve as a condiment.

THE SPRING SALMON. *Oncorhynchus tschawytscha*. In papers on the spring salmon attention has been called to its food, but it is even more varied than has been indicated:—fish, crustacea, molluscs and annelids. Of the fish, herring takes precedence and it apparently makes little difference whether the herring are small or large. Five full sized, undigested herring were found in an 18-pound salmon. Young herring, sticklebacks and sand launces may be taken in large numbers; 27 undigested sticklebacks were found in an 8-pound salmon. The approach of the capelin to the inshore spawning ground is usually indicated by the number of these fish found in the stomachs of the salmon, but the salmon does not follow up into such shallow water as the dogfish does. It may be only when other food is scarce but at times salmon are eaten as well and these are likely to be of the same species. Two spring salmon 7 or 8 inches long were found in the stomach of a three-year-old spring.

Of the crustacea, schizopods predominate but many shrimps are also eaten; crabs and amphipods are seen occasionally.

With the spring salmon as with many other fish, cephalopod molluscs, both squid and octopi, are desirable as food although not always obtainable. In the stomach of an 11-pound salmon, 5 squid, *Loligo opalescens*, were obtained.

Annelids of the Nereid type are not uncommon in the food supply but it has not yet been determined whether these are taken from the sea-bottom or from near the surface when they come up to spawn. The latter would seem to tally better with the feeding habits of this species than the former.

THE SOCKEYE SALMON. *Oncorhynchus nerka*. It is a generally accepted statement that nothing is to be found in the stomachs of the Fraser river sockeye after they enter the strait of Fuca, and that no doubt is true for the great majority of them, but evidently there may be exceptions. Last summer, Fisheries Overseer R. M. Colvin of Cowichan bay, came across one of these exceptions, the first he had seen in a long experience of sockeye fishing. The contents were not of great bulk, about 20 cc. in all, consisting of crab larvæ in the megalopa stage, nearly all fresh and undigested. The fish was caught in a purse seine off South Pender island about July 12th. It was a female, about 24 inches in length, weighing 6 pounds.

COHO SALMON. *Oncorhynchus kisutch*. The feeding habits of the coho are similar to those of the spring salmon, although not quite so wide a variety of food has been noticed. The only species of fish found in the coho's stomach, not found in a spring's, was a young ling cod, *Ophiodon elongatus*, but it is quite probable that these also are eaten by the spring salmon.

VIVIPAROUS PERCH *Embiotocidæ*. Three species of perch are common around the wharf and float, viz., *Phanerodon furcatus*, *Tæniotoca lateralis* and *Cymatogaster aggregatus*. All of them have mouths too small to take anything whole unless it is minute. In consequence the food material in the stomach is seldom recognizable. After the herring have spawned, herring eggs have been found in their stomachs. Much of the time they appear to feed on barnacles or the parts of these that are extruded when the valves of the shell are opened, for there is no indication that they are able to break open the shells. It is probable that they get some of the annelids that live among the mussels and barnacles as well.

LING COD. *Ophiodon elongatus*. Fish and crustacea serve as the chief diet of the ling cod. Herring and viviparous perch are eaten and possibly other small fish. The crustacea are mainly crabs, not only such forms as *Cancer productus*, but also spider crabs and hermit crabs. Probably the females do not take food at spawning time for, although they are caught with bait at other times, they will not take bait at that period. The males do eat at that time, however, as herring, hermit crabs, etc., have been found in their stomachs and they can be caught with bait.

Hexagrammus decagrammus. This fish feeds on much the same kind of food as *Ophiodon elongatus* does, but as it is a much smaller fish the size of the species eaten is more restricted. The small blennid, *Anoplarchus atropurpureus*, is the only fish that has been found in the stomach. Various species of crabs are common and herring eggs are eaten during the short time they are available.

ALASKA OR GRAY COD. *Gadus macrocephalus.* This species is not as common in the neighbourhood of Nanaimo as it is farther north and few have been examined. The food of a 20-inch fish taken on Dec. 22, 1913, is quite typical of these. It had two specimens of the viviparous perch, *Phanerodon*, two of the pipe fish, *Siphostoma*, and several shrimps.

BUFFALO FISH. *Enophrys bison.* This shallow water species lives on crabs, mainly the small shore crab, *Hemigrapsus*, mussels, beach fleas and other amphipods and the smaller fishes, e.g., young herring, salmon, viviparous perch and sand launces. Its method of attack on these swiftly moving species can readily be observed in the shallow water. When it lies still in the rocky or muddy bottom its colour harmonizes perfectly with its surroundings, as it remains motionless until its prey is well within striking distance. Then it makes a sudden dart, but one only, whether the prey is secured or not, after which it returns to the bottom to digest the fish caught or to a suitable position to lie in wait for another chance.

MOTTLED SCULPIN. *Scorpænichthys marmorata.* This large species of the general bull-head type likes plenty of variety in fish, crustacea and eggs of any kind. Like most of the bottom fish it is able to take in a large supply for a meal and then lie around sluggishly while this is being digested. One example will indicate this. On December 23, 1913, a female 23½ inches long and weighing 16 pounds, was caught near the station in a shore seine. In the stomach there was a red sculpin (*Hemilepidotus*), 12½ inches long, weighing 17 ounces, several small viviparous perch, some of three species of crabs (*Epialtus*, *Cancer* and *Hemigrapsus*), several shrimps of different species and a large mass,—about half a pound,—of fish eggs, developed as far as the eyed stage. The fish measured 7 inches across the broadest part of the head and the red sculpin's head was 4 inches across.

RED SCULPIN. *Hemilepidotus hemilepidotus.* The red sculpin is also a bottom form, feeding mainly on crabs, shrimps, barnacles and mussels. The one mentioned in the preceding paragraph contained several shrimps in good state of preservation. On Feb. 18, 1914, about five o'clock in the evening, a specimen was caught and the stomach examined. It contained a good specimen of *Cancer productus* in berry, as well as some shore crabs (*Hemigrapsus*) and some mussel remains. The specimen of *Cancer* was taken into the laboratory and about 8 o'clock that evening it was found to be still alive and again active.

FLATFISH. *Pleuronectidæ.* The various flatfish examined,—*Lepidopsetta bilineata, Platichthys stellatus, Pleuronichthys cœnosus, Parophrys vetulus, Hippoglossoides elassodon, Limanda aspera* and other species not determined at the time of observation,—evidently used much the same kind of food. This consists of annelids, usually of the *Nereis* type, small crabs, shore crabs and hermit crabs, shrimps and clams.

7

FISH AS FOOD

It should not be amiss here to record some observations of instances where fish were used as food by other animals. Many instances are of common occurrence or have been recorded at various times and there is no need to refer to these.

THE BALD EAGLE. This bird is familiar to everyone who has travelled any considerable distance along the coast of British Columbia and his fish eating proclivities are well known. Objections are raised at times to the amount of toll he exacts from such food fishes as salmon and herring. His food, however, is not restricted to food fishes. On June 29, 1916, while on the deck of a launch going north on Fitzhugh sound, a shadow passed across the boat. This shadow was due to a bald eagle, not far above, with a moderate-size, wriggling, dogfish (probably 7 or 8 pounds) in its talons. With field glasses it was watched in its flight away to the woods to the eastward. Apparently it tired with the effort, but not sufficiently to prevent the satisfactory completion of its flight. Almost immediately after the disappearance a second shadow indicated a second eagle, possibly the mate, that had been similarly successful in a dogfish attack, this dogfish being much of the same size as the former one. The flight was made in the same direction as the previous one. This was in the sockeye season, hence it would seem that the catching of dogfish was a matter of choice rather than one of necessity. If such a choice is an everyday matter the bald eagle must be an extremely useful coast inhabitant.

THE GRAY SEA-LION. In the 1917 Sea-lion Report (Contr. to Can. Biol.) an account was given of stomach contents of sea-lions killed during the herring season on Barkley sound. In July, 1919, the stomach of a sea-lion, killed during the sockeye season in Rivers inlet, was sent to the station by Mr. W. D. Stewart, Manager of the cannery at Wadhams. It contained the remains of five salmon, three of which were recognizable as sockeye, the other two could not be determined. There was flesh of a white-fleshed fish like the ling cod, but no bones or scales could be found to identify it. There were the remains of five squid and the beak only of another.

THE HAIR SEAL. Like the sea-lion the hair seal apparently catches and eats whatever fish are most readily obtained. When the salmon are running they are followed even far up into the fresh water, but when these are not so plentiful others serve. During the season when the herring are in shallow water the hair seals are plentiful in their midst. When neither salmon nor herring are to be obtained readily, rock cod or any other species found near the surface or in shallow water may be attacked. Cephalopod molluscs may also be used when they are available.

THE MEDUSA. *Gonionemus vertens.* The three species above quoted are all of economic importance on account of the effect on the supply of food fishes. One instance of an entirely different sort will serve to complete this part of the paper. *Gonionemus vertens* is widely distributed in the vicinity of the station. On June 8, 1918, a specimen was found among the eel grass in Hammond bay with a partly digested herring fry in its stomach, or more correctly partly in its stomach. The fry was about one and a half inches long while the medusa was not more than half that in either vertical or transverse diameter. There is no means of knowing whether the fry was living, dying or dead when it was attacked by the jelly fish. It is conceivable that the stinging cells of the jelly fish are powerful enough and the young fish sensitive enough to be narcotized by the poison of the stinging cells but the probability that this is so is another matter.

SPAWNING

Except in the cases of species that have been considered in papers already published, the observations on spawning and early development of any one species have not been extensive, but even a record of the spawning time may be useful and in most cases little more than that can be given here.

Dogfish. Although thousands of unborn dogfish have been seen as yet no definite attempt has been made to follow up the early development, largely because in one day's catch of dogfish there are found embryos of so many different sizes. Since the species is viviparous and the young are relatively so large when they are born they can be studied only by cutting open the parent fish, and since one fish caught in a gill net may have embryos bearing no particular relation in size to those in other fish caught in the same net in the same day, there is no definite means of comparison.

On first consideration, when only a few dogfish were seen at a time and in each there were some well developed embryos, it seemed possible that one female might give birth to more than one lot of embryos during the year. Later when the fish were seen in large numbers and the variation in one day was noted, the only explanation possible seemed to be that there was no definite spawning season as in the case of most other fishes. Coupled with that is the possibility that they are not all nearly the same size when they are born. Some measurements have been made and these would indicate, if they are typical, that fertilization takes place in the spring and liberation from the parent in the winter succeeding. The smallest embryo so far obtained was 6 mm. long, taken on March 20, 1915. On March 11, 1914, over 20 embryos were measured. These varied from 8 mm. to 22 mm., the 8 mm. one having 38 or 39 somites. On Nov. 13, 1914, some pups measured were about 4 inches long, but on the same day one female was examined in which the pups were already liberated. On the following day another was examined in which the young were just ready for liberation as the yolk had been drawn into the body cavity, leaving only a mark on the ventral surface. There were four young in each uterus, 5 of the 8 being female. They were all practically the same length, 9½ inches from the tip of the snout to the end of the body, not including the projecting part of the anal fin. They weighed two ounces each.

Skate. *Raja binoculata*. Evidently the eggs of *Raja binoculata* are laid early in the year for although an occasional empty case is dredged during the summer, no live embryos were obtained until April 18, of this year, when a case was picked up on the beach at English Bay, Vancouver, where it had probably been washed in by the tide after being detached from the seaweed at the bottom by a storm, a few days previous. The case was 24 cm. long, without the corner tendrils, 14 cm. wide, with a cavity inside, measuring 13.2 cm. long, 11.4 cm. wide and 5 cm. deep. In the case there were three live embryos, measuring as follows:

16.8 cm. long (the free tail being 9.8 cm.), 7.4 cm. from tip to tip of fins, with each "ocellus" 12.5 mm. in diameter;

15.5 cm. long (the free tail, 9.0 cm.), 6.8 cm. broad, with "ocellus" 12 mm.;

14.3 cm. long (the free tail 8.8 cm.), 5.3 cm. broad, with "ocellus" 10 mm.

The remaining yolk was oval, 3.7, 3.6 and 2.5 cm. respectively in long diameter.

SKATE. *Raja* sp. Another species of skate of which eggs and egg-cases are much more frequently dredged is evidently a much smaller species, as the egg case is so much smaller. In contradistinction to the egg-cases of *Raja binoculata*, no case of this species has been obtained with more than one developing embryo. The empty cases are dredged much more often than cases containing embryos.

On Aug. 12, 1921, when dredging north of Thetis island in 15-25 fathoms, two cases were obtained each of which contained an embryo, about 4 cm. long, the tail supplying about two-thirds of the length. The yolk was 1.8 cm. by 1.1 cm.

When the yolk is all absorbed and the young fish is ready to escape, the body is 6 cm. long and the tail 10.5 cm., giving a total length of 16.5 cm. Measured from tip to tip of the fins, the breadth is 9 cm. Since the fins are folded over the back and the tail is wound partly around the body, up the right side, then over to the left, in front of the head, it may be accommodated in the pocket of the case although that pocket is only about 6 cm. by 4.5 cm. As such embryos have been found early in August, there must be an extended spawning season for these.

VIVIPAROUS PERCH. As the young viviparous perch are relatively of large size when they are liberated, the period of development within the body of the mother extends over several months. The exact period for any species has not been determined. An earlier stage has been observed in *Tæniotoca lateralis* than in any other, but even these were far past the earliest stage of development. The embryos from the same parent are quite uniform. A female caught on March 22, 1915, had 25 embryos, 21 mm. each in total length. There may be a difference in the time of development in different fish, or probably in different years. On April 22, 1913, 35 embryos taken from a fish, were each 25 mm. in length, although taken a month later than the preceding. Going back to the year 1915, on May 12, 44 embryos were taken from a fish and these measured 40 mm. in total length. At this time the fins were very large, out of all proportion to the rest of the body; the caudal fin increased the length of the fish from 28 mm. to 40 mm. Except for the brain and the heart, the body is almost transparent and the circulation of the blood can readily be observed, particularly that part of the circulation that occurs in the arteries and veins connecting up the fimbriated margins of the large fins with the body circulation. The young fish are born early in August, at which time they are about 7 cm. in total length, but the fins are not nearly so large in proportion. In fact the caudal fin is little longer than it was in the 4 cm. embryo.

The young of *Phanerodon furcatus* are born about the same time and are of much the same size as those of *Tæniotoca lateralis*. Probably the period of prenatal development is similar, but no stages as early as the earliest stages of *Tæniotoca* have been examined.

Ophiodon elongatus. Some account of the spawning of this species and of the stage of development in the embryo at the time of hatching has previously been given (Trans. Royal Can. Inst. 1916, p. 13). Numerous observations since that time have confirmed the conclusion that in the vicinity of Departure bay, all, or nearly all, spawning takes place between January 15 and March 1. On Feb. 12, 1915, an opportunity was afforded to make a comparison in the weight of the spawn to the weight of the fish. A female, 34 inches long, that weighed 16 pounds after spawning, produced 6 pounds of spawn, the number of eggs being approximately 170,000.

Sebastodes. The various species of *Sebastodes* or rock cod, orange cod, etc., found in the vicinity, give birth to embryos when these are still very small. No information is available as to when the eggs are fertilized, but embryos less than half a centimetre long have been observed during February and early March. Unlike such species as the viviparous perch and the dogfish that give birth to embryos well developed, the number of embryos in the species of *Sebastodes* is very large. A specimen of *Sebastodes pinniger*, 18 inches long and weighing 6 pounds, caught on March 2, 1915, had approximately 600,000 eggs or rather, young embryos.

Several other species spawn at much the same time as *Ophiodon elongatus*. Some definite date records are:

Alaska cod, *Gadus macrocephalus*. Feb. 10, 1915.

Hexagrammus decagrammus. Jan. 26, 1915.

Scorpænichthys marmorata. Feb. 9, 1915.

SINGING FISH. *Porichthys notatus*. Porichthys eggs are laid attached to the under surface of rocks on a shingly beach that may be largely uncovered at low tide, during the latter half of May, May 12 being the earliest date on which they have been found. They are hatched out about July 15, at which time they are 10 mm. long. The yolk with its sucker is entirely absorbed so as to set the young fish free early in August, when they have reached a length of 25 mm.

PIPE FISH. *Siphostoma*. In the genus *Siphostoma* the eggs are incubated in a longitudinal fold or pouch in the body of the male. On August 7, 1918, a male pipe fish, in which the embryos were escaping from the fold, was obtained.

EXPLANATION OF PLATE

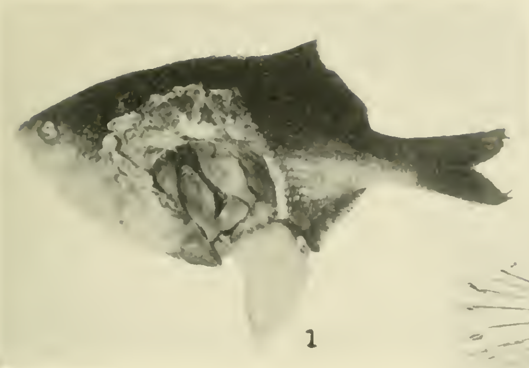
Fig. 1. *Phanerodon furcatus.*
Female dissected to show embryos in situ.
(Dissection by Dr. A. P. Knight.)

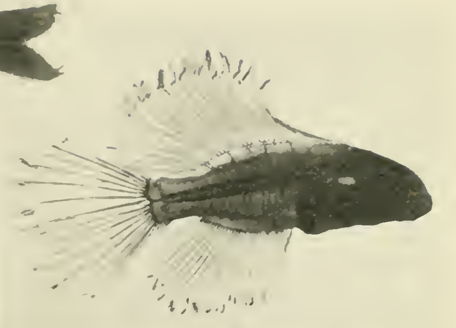
Fig. 2. *Tæniotoca lateralis.*
Embryo 40 mm. long, showing large median fins with fimbriated margin and circulation. (Photo taken with transmitted light.)

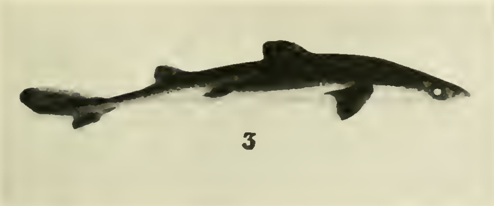
Fig. 3. *Squalus sucklii.*
Embryo at time of birth.

Fig. 4. *Raja* sp.
Egg case cut open to show embryo as it appears just before escaping from the case.

Fig. 5. *Porichthys notatus.*
Embryos just after hatching, with yolk attached to surface of rock by a sucker.


1


2


3


4


5

No. 15

THE FREEZING OF FISH—FAILURE AND SUCCESS

BY

F. SLATER JACKSON,
McGill University, Montreal.

The Freezing of Fish—Failure and Success

By F. Slater Jackson,
McGill University, Montreal

Our frozen fish trade is for several reasons a most important one. The fishing regions are far from the large markets, the demand in our own country is not for cured, but rather for frozen fish, and, while the fishing season for each species is for the most part short, the market is to be satisfied only by a more or less continuous supply.

While the freezing of fish has been practised for a great many years, entire success has never been attained. More or less deterioration in the quality of the fish is observed after long periods of storage, and at times heavy losses have resulted from the fish coming out of cold storage in an unsalable condition. It cannot be too frequently stated that fish cannot be improved by freezing and subsequent cold storage. If spoiling has commenced, as may be the case when freezing is used to save an overabundant catch, that cannot be handled in other ways, the decomposition is, it is true, nearly or altogether arrested by the freezing, but the fish are certain to come out of cold storage in a worse condition than that in which they went in, and, on thawing, they spoil with extreme rapidity.

All kinds of fish are not frozen successfully with equal ease. Halibut, salmon, and herring may be mentioned as species which have been handled with general success in this way. The cod-like fishes have been less satisfactory in this respect, and most conspicuous have been the failures that have attended attempts made some years ago to develop a market for frozen hake (*Urophycis*).

A few years ago a Canadian firm shipped a lot of frozen hake to New York for Philadelphia. The fish had an excellent appearance and sold well, but the orders were never repeated. Complaints were made that the fish were tough, tasteless, and like paper. During the war frozen hake was shipped to England and disposed of in the markets there. Similar complaints were made and the matter was brought to the attention of the British Department of Scientific and Industrial Research, who referred it to the Canadian Council for Scientific and Industrial Research.

Hake frozen commercially in air is very plump and attractive. When, however, it is thawed out and cut, it loses a large quantity of juice, particularly if it is pressed slightly, and cavities easily visible to the naked eye can be seen to permeate the flesh. A piece of the flesh may be squeezed to a much smaller volume, and when the pressure is released it at once regains its original shape and size, like a sponge.

In the autumn of 1918 fresh hake were frozen in a mixture of ice and salt at the Atlantic Biological Station, St. Andrews, N.B., and shipped to St. John, where they were stored in the refrigerators of the N.B. Cold Storage Company, through the courtesy of the manager. Later they were shipped in a refrigerator car to Toronto, Ont., and there put in cold storage by the kindness of Mr. F. T. James. After a lapse of about two months from the time of freezing, they were still in excellent condition, and on being thawed were in no wise spongy like the commercial fish.

This success proved that hake can be satisfactorily frozen. The method employed was such as to freeze the fish very rapidly, much more rapidly than in the ordinary commercial freezing, which is carried out in pans in air, and usually on the refrigerating coils of pipe. From such knowledge as we possess regarding the nature of the freezing process in animal tissues, it seemed probable that the failure reported had resulted from too slow freezing, hake being particularly liable to undergo unfavourable changes.

These changes may be explained in the following way. It is known that when sea water freezes, the ice that forms is almost pure, and when melted yields fresh water. This means that when salt water is slowly frozen, pure ice at first separates out in large crystals, and a stronger brine is left, which finally freezes at a lower temperature, yielding a weak mass of pure ice crystals and frozen brine. If, however, the freezing of the salt water is sufficiently rapid, no ice crystals are formed, and a strong, clear, homogeneous block of ice is produced.

In a somewhat similar fashion slow freezing of the flesh or muscle of the fish permits of the formation from the watery substances of the fibres constituting the muscle, of large crystals of ice. These crystals may become so large as to rupture the fibres and so permit practically all of the soluble and savoury substances of the fish to escape with the juice when the fish is thawed. Also the formation of the ice crystals separates so much water permanently from the flesh that only a solid, tough material remains. This material naturally occupies all the spaces between the ice crystals, and, if the latter be large, forms a coarse network of strands or sheets, quite similar to that of a sponge. This, then, is the explanation of the tough, spongy, tasteless character of the flesh of slowly frozen hake.

During the summers of 1920 and 1921 a series of experiments was conducted in order to ascertain just what changes take place in fish muscle as a result of freezing under different conditions. These experiments were made on several of the most important food fishes, viz.: hake, cod, haddock, herring and flounder. In every case extremely thin sections were made through the muscle, which was cut lengthwise and crosswise, in order to show the microscopic changes in the fine fibres of which the muscle is made up. The sections were stained in various ways so as best to bring out these changes, and were studied, and in many cases photographed under the microscope.

Fresh muscle in good condition, when cut through, presents a fine, even grain, as shown in Fig. 1, which is a cross-section through the tail of a fresh hake.

When this fresh muscle is cut into extremely thin sections in such a direction as to be parallel to the fibres of which it is composed, it shows, under very high power of the microscope, if properly stained, the condition represented in the photograph (Fig. 2). Note in this the even character of the fibres, each one enclosed by a delicate membrane along which the nuclei, shown as dots, are scattered. Note also the delicate and regularly arranged cross markings of the fibres.

Three methods of freezing were employed, viz.:

1. In air.
2. In brine.
3. With ethyl chloride, a fluid which freezes in a few seconds, and is commonly used by surgeons for freezing the skin in small operations.

1. *Air freezing.*—In air-frozen fish it was found that the muscle fibres were largely destroyed and widely separated by the large ice crystals which form in and between them.

On thawing, the condition shown in Fig. 3 is to be seen, the muscles exhibiting a loose, spongy appearance.

Under the microscope the muscle showed a very loose, spongy structure, with large spaces from which the melted ice crystals had escaped (Fig. 4). It is to be noted that the material of the muscle fibre is so altered by condensation as to fail to show the delicate cross markings. Since these ice crystals are formed from the fluid part of the muscle substance, it is easy to understand that, as the fluid oozes out on thawing, most of the tasty and nutritious part of the fish is lost, and only the tough and tasteless parts remains.

If such a muscle is cut crosswise of the fibres and observed under the microscope, the appearance exhibited in Fig. 5 is to be seen. When ends of fibres are cut, as shown by the small size, the original form is largely retained, but when cut toward their centres the fibres are seen to be greatly altered, exhibiting a relatively enormous space in the centre of each, with the material of the fibre pressed against the enclosing membrane.

2. *Brine freezing.*—Fish frozen in brine presents an appearance much more like that of fresh fish, the reason being that the employment of brine permits of a more rapid freezing, owing to its absorbing more heat than does air, and only one-tenth or one-fifteenth of the time taken in air freezing is required.

The appearance of such muscle, when cut into thin sections, crosswise of the fibres, and observed under the microscope, is to be seen in Fig. 6.

As compared with muscle frozen in air, the fibres are but little altered, showing only small spaces inside the fibres, and this in only a few of the fibres.

This is the only reason for the employment of brine—which does not penetrate, and is thus not in any sense used as a pickle. In this, as in every case, the more rapid the freezing, the smaller are the ice crystals, and in this lies the explanation of the success of brine freezing. Since the ice crystals form so rapidly and are so small, they cause little change in the muscle fibre. They are not large enough to rupture the fibre or the delicate sheath by which it is surrounded, but form between the very small fibrils of which the fibre is composed. Thus the more fluid and nutritious juice of the muscle is retained and does not escape on thawing, so that the appearance and taste of brine-frozen fish are hardly distinguishable from those of fresh fish.

3. *Ethyl chloride freezing.*—Freezing experiments with ethyl chloride were made in order to afford additional proof that the more rapid the freezing the less change occurs in the muscle. Small pieces were frozen in a few seconds,

and under the microscope could scarcely be distinguished from fresh muscle (Fig. 7).

It will be seen that the fibres are but little altered as compared with fresh muscle, the delicate cross markings being still quite distinct.

All fish do not stand freezing equally well, probably owing to differences in their chemical composition. Of three kinds examined, hake appears to suffer most, cod less, and haddock least of all. The results of this study show that the more rapid the freezing the more perfect the results. In practice the most rapid method of freezing that is (commercially) practicable should be employed.

FIG. 1
Cross section of tail of fresh hake.

FIG. 3
Cross section of tail of hake frozen slowly in air.

FIG. 2.—Thin section of fresh muscle cut lengthwise and photographed under a very high power of the microscope.

Fig. 4.—Thin section of muscle frozen slowly in air, cut lengthwise and photographed highly magnified.

Fig. 5.—Thin section of muscle frozen slowly in air, cut crosswise and photographed highly magnified.

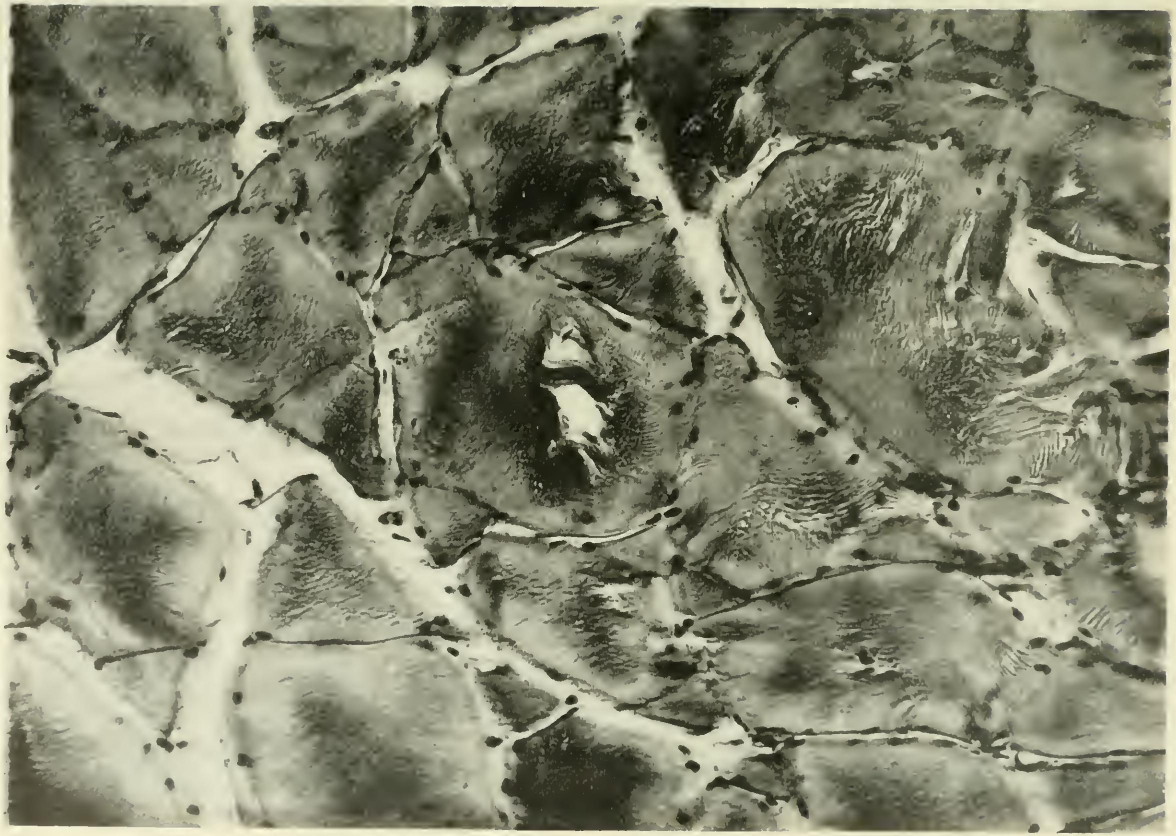


FIG. 6. Thin section of muscle frozen quickly in brine, cut lengthwise and photographed highly magnified.

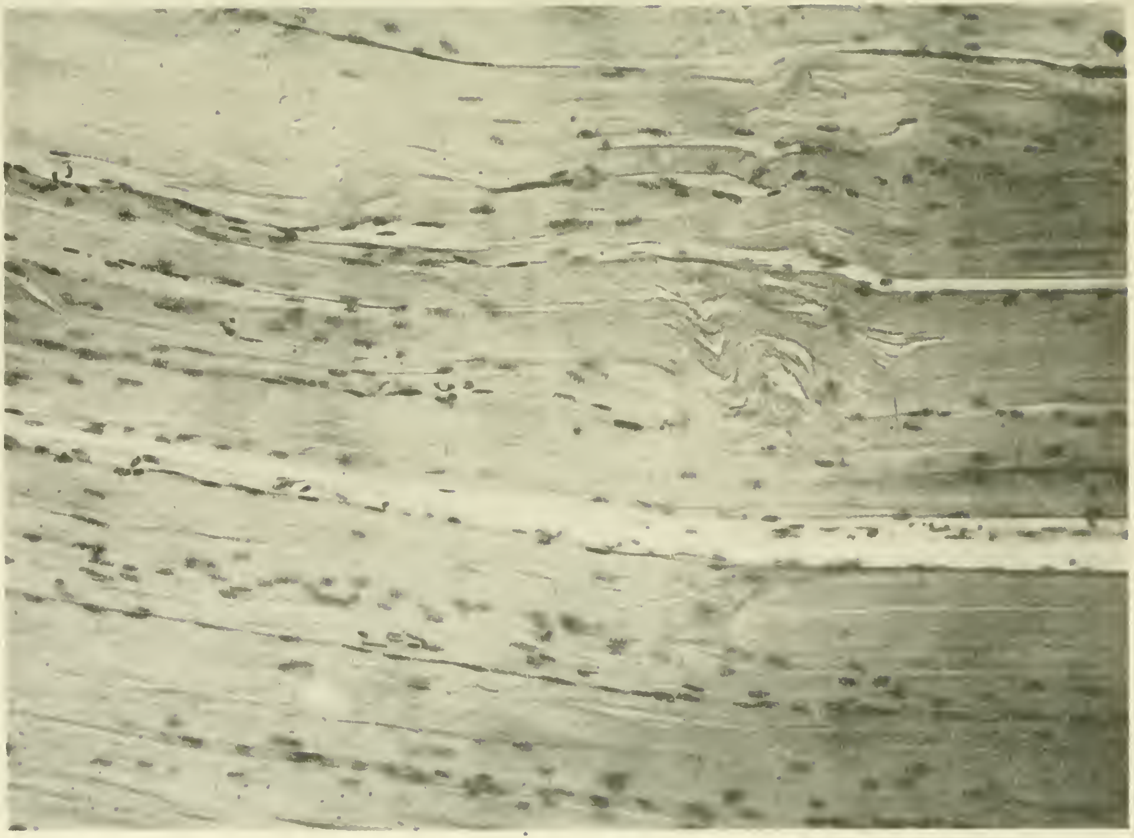


Fig. 7.—Thin section of muscle frozen quickly with ethyl chloride, cut lengthwise, and photographed highly magnified.

No. 16

NOTES ON THE DISTRIBUTION OF FREE-LIVING COPEPODA IN CANADIAN WATERS

BY

PROFESSOR A. WILLEY
(*McGill University, Montreal*)

Notes on the Distribution of Free-living Copepoda in Canadian Waters

By Professor A. Willey
(*McGill University, Montreal*)

The material upon which this contribution is based has been derived from five sources, under the authority of the Biological Board of Canada There are several well-marked species to be described for the first time, several others not previously recorded from North America, and some new to Canada. The names of those who have procured the material are: Mr. A. H. Leim of Toronto University in connection with his work on the shad in Nova Scotia; Mr. Frits Johansen in his expedition to Hudson Bay; Dr. A. G. Huntsman from the Miramichi River, New Brunswick, and from the Quill Lakes, Saskatchewan. At the end of May, 1920, I accompanied Dr. Huntsman to the Quill Lakes, and in the same year I continued my studies on these forms at the Biological Station, St. Andrews, N.B.

Mr. Leim's collection from the Shubenacadie River includes many Ostracoda, but these belong to two species only. Copepoda, Cladocera and Ostracoda are three orders of entomostracan Crustacea, the members of which are of insignificant size and occur regularly in nearly all natural waters, their distribution depending on various factors connected not only with existing currents and water courses, but with former relations of land and water during the glacial period. A certain amount of dispersion by the agency of birds and of winds is probable, but this fact does not exclude other agencies of a more remote influence, though it undoubtedly suggests caution in drawing conclusions.

I. QUILL LAKES, SASKATCHEWAN.

The two lakes show no marked difference in their faunal characters, the bulk of the plankton being obtained from Little Quill Lake, where the facilities for collecting samples of the water and its inhabitants from a boat were greater. The water is saline, but fit to drink for cattle; when it evaporates on the mud flats a white, flocculent, insipid precipitate is left behind, known colloquially as "potash." This is derived, as I learn from Dr. D. B. Dowling, by seepage from the Cretaceous shales through the overlying boulder clay. Besides the Copepoda, some notes were made on the Cladocera, whose empty winter-egg-cases (ephippia) were strewn in windrows along the lake side.

On May 29, 1920, the surface plankton at Little Quill Lake showed the following entomostracan content:

Diaptomus sicilis	55 per cent.
Cyclops parcus	29 " "
Laophonte calamorum n. sp.	1 " "
Daphnia longispina	15 " "
	100

The *Laophonte* will be described below. Its presence is remarkable as being in accordance with some of the phytoplankton records, and because the numerous species of the family Laophontidae hitherto described are strictly marine. In the ponds or "sloughs" beside the lakes there were abundant swarms of *Diaptomus sicilis*, sufficiently dense to constitute a pabulum for a flock of Wilson's Phalaropes. These birds alighted upon the water and commenced whirling about in an extraordinary manner, ever and anon dipping their beaks into the water. Their behaviour first drew our attention, on wading out to the scene, to the dense streaks of *Diaptomus* which were clearly visible by the red colour of the fatty contents of their little bodies, and could be dipped up in unlimited quantity by a net held in the hand. After two years in formalin, the brick-red coloration is still retained in full strength.

The pirouetting of the Phalaropes has been observed and described at least once before, by F. M. Chapman. In May, 1903, there was witnessed an unusual demonstration of Phalaropes (Northern and Red) on the coast at Monterey, California. These "seafarers among the snipe" had been delayed by the violence of a northwest gale in the voyage to their Arctic summer homes: "All the quiet bodies of water contained Phalaropes, a large pond in the city of Monterey being fairly speckled with them. As I [Chapman] approached its margin, I was not a little astonished to observe that apparently one-half of the Phalaropes in it were spinning about in the most remarkable manner. It required only a few moments' watching to learn that the revolving birds were feeding. The lobed feet were moved alternately in such a manner that the birds spun around in the same spot, making a complete revolution in about two seconds, and from three to four to as many as forty turns without stopping. A rotary movement of the shallow water was thus created, bringing to the surface small forms of aquatic life which the Phalaropes eagerly devoured, their slender bills darting rapidly two or three times during each revolution" (Chapman, 1908).

Cyclops parcus Herrick is treated by G. O. Sars (1913) as a synonym of *C. lucidulus* Koch. It is one of a group of North American species, the others being *C. brevispinosus* and *C. americanus*, which C. D. Marsh (1910) puts as varieties of *C. viridis*, defining the latter as follows: Spinous armature of the third joints of the outer branches (Re 3) of the four pairs of swimming-feet (p 1 to p 4) having the formula 2, 3, 3, 3 or 3, 4, 4, 4; the third joint of the inner branch (Ri 3) of *p 4* may have an ectal spine or an ectal bristle; the small ental spine of the second joint of *p 5* may be separated by an articulation or not. The following is a tabulation of the three varieties according to the data supplied by Marsh:

	americanus Marsh	*brevispinosus* Herrick	*parcus* Herrick
Re 3 (spines)	3, 4, 4, 4	3, 4, 4, 4	2, 3, 3, 3
p 4 Ri 3 se	seta	spine	seta
C st e	seta	spine	seta
p 5 si	articulated	not articulated	articulated

C st e refers to the outer terminal caudal seta.

The word *seta* is frequently used to signify a flexible, plumose bristle; a spine is a rigid *seta*, needle-like, sometimes sparsely ciliate, pectinate or denticulate. There is an intermediate form, half spine, half *seta*.

The *Cyclops parcus* (or "*viridis*") of Quill Lake exhibited at least nine kinds of fluctuation in the spinous armature of *Re 3*. The flexible setae on the inner margin of the ramus showed no variation; they are the natatory setae. The spines give increased strength with economy of surface to the natatory feet, and may be named supporting setae; they are the variable elements in the feet.

Spinous armature of Re 3 in Cyclops parcus (female) from Little Quill Lake:

Right foot				Left foot				Number
p 1	p 2	p 3	p 4	p 1	p 2	p 3	p 4	
2	3	3	3	2	3	3	3	6
2	3	3	3	2	4	4	3	1
2	3	3	3	3	3	3	3	1
2	3	3	3	3	4	3	3	1
2	4	3	3	2	4	3	3	2
2	3	4	3	2	3	4	4	1
2	4	4	3	3	4	4	4	1
3	4	3	3	3	4	3	3	1
3	4	4	3	3	4	4	3	1
								15

Miss Esther F. Byrnes independently suggested the close relationship between *C. americanus* and *C. parcus*, as indicated by their general points of agreement, and in addition by the occasional finding of an adult Cyclops in which most of the swimming-feet agree with *C. americanus* in having three outer spines on the terminal segments of the outer rami, while others are in the condition of *C. parcus*, having only two. In Quill Lake such variations are uncommonly frequent, as the table above demonstrates. For further discussion of the *C. viridis* complex, the article by E. B. Forbes (1897) may be consulted. (Fig. 1.)

Laophonte calamorum n. sp. may be diagnosed as follows: Length of female, 0.5 mm., ovisac not observed and no males found. The segments of the body

1.

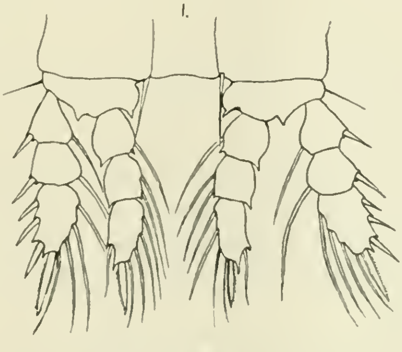


Fig. 1.—*Cyclops parcus* Herrick, second pair of swimming feet (*p 2*). Little Quill Lake.

are defined with thickened projecting rims characteristic of the family; the genital segment, above and at the sides, but not below, is as sharply divided as the rest. At the lateral posterior edges of the second and third abdominal segments, there is a little triangular lappet appearing, when seen from above, as two pairs of blunt, spur-shaped protuberances tipped with minute spinules. The anal operculum has a smooth margin, but a row of spinules extends across the middle of it above. The rostral projection is not conspicuous; in dorsal view it terminates the head with a straight edge from which it is angularly deflexed, ending in a bluntly rounded free border, finely ciliated. The caudal rami are smooth, twice as long as broad, without any setae on the proximal three-fourths of the outer border; the dorsal seta (not shown in the figure) arises nearly in the same plane with the more proximal of the two lateral setae; the distal lateral seta is inserted near to the apical margin; from the latter arise three setae, a middle one, long and strong, flanked on each side by a very small seta, the outer one being minutely serrulate and closely appressed to the middle seta (Fig. 2). The anterior antennae are five-jointed, the proximal part consisting of three segments, the distal of two; the terminal segment is seven-eighths the length of the composite third joint, and three times the length of the penultimate joint (fourth joint) (Fig. 3). The first feet conform to the *Laophonte* type, both rami two-jointed, the inner much larger than the outer, terminating in a prehensile claw; the second joint of the outer branch carries five setae (Fig. 4). The fifth feet carry three marginal setae on each lobe, and in addition a strongly exserted lateral seta on the basal lobe. In the second, third and fourth feet Ri 1 is achaetous; Re 1 has 1 se 0 si; Re 2 has 1 se 1 si. The remaining joints may be tabulated:

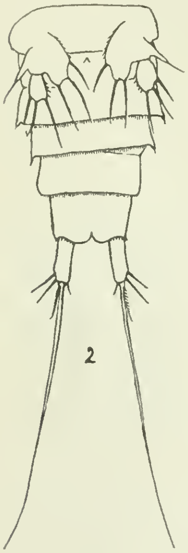
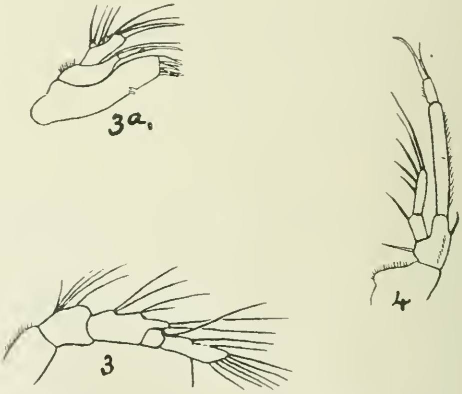


Fig. 2.—*Laophonte calamorum* n. sp. Fifth pair of feet and urosome from below.
Little Quill Lake.



Figs. 3, 3*a* and 4.—*Laophonte calamorum* n. sp.
3. Anterior antenna.
3*a*. Maxilla.
4. First foot.

	P 2	P 3	P 4
Ri 2:	0 se 2 as 2 si	1 se 2 as 3 si	trisetose
Re 3:	3 se 1 st 2 si	3 se 1 st 2 si	2 se 1 st 2 si

The terminal setae on Ri are referred to as apical setae (*as*); the terminal seta of *Re* is indicated by the letters *st*.

Out of fifty-eight species of Diatoms identified from the Quill Lakes, Professor Bailey found that six of them belong to marine types. In discussing the question of regarding these marine forms as relict species or as bird-droppings, he points out the difficulties in the way of accepting the theory of bird-dispersion to account for their presence. He adds that the only other supposition is that they are survivals of a time when the sea covered that region, possibly in an interglacial period. This would seem to agree well with Sir William Dawson's views concerning the nature of the glacial period in Canada, where, as he thought, floating glaciers or icebergs existed in an interglacial sea (in a spatial sense) rather than a continuous ice-sheet at any one time.

II. SHUBENACADIE RIVER, NOVA SCOTIA.

The collections were made by Mr. A. H. Leim in 1919 and 1920. The Shubenacadie River opens into Cobequid Bay which in turn opens into the Basin of Minas at the head of the Bay of Fundy. At Shubenacadie, as I am informed by Mr. Leim, the water is brackish and tidal; at Milford Station, at Enfield and at Elmsdale it is fresh and above the tides. The summer plankton at the fresh water stations was very scanty and in 1919 only summer gatherings were made. The spring plankton, up to the middle of June, was fairly copious, the greatest quantity being obtained at Elmsdale on May 18, 1920, and the next on May 25.

At Elmsdale on May 18, at 7.22 p.m., the surface tow, with the fine net, registered 90 per cent. of *Diaptomus minutus* and 10 per cent. of *Cyclops*, with a few Cladocera (*Bosmina longirostris*). Twenty minutes later (at 7.43 p.m.) the gathering, consisting of several hundreds of small Copepods, contained about 76 per cent. of *Diaptomus minutus*, males and females; the remainder consisted mainly of a species of *Cyclops* which proved, according to my determination, to be *Cyclops scutifer*, males and females, but none with ovisacs. There were also a few Cladocera and Acarina.

At the same place on May 25, at 4.50 p.m., there was the same percentage (76) of *Diaptomus minutus*, together with many female and some male *Cyclops scutifer*, one ovigerous *Cyclops serrulatus*, and many immature *Cyclops* sp. This gathering also contained some *Daphnia* and *Bosmina longirostris*.

Cyclops scutifer has not previously been recorded from North America, hence the grounds of the determination must be mentioned briefly. To begin with, it belongs to the group of species of which *C. strenuus* is the type, distinguished by the spinous armature of the natatory legs. One member of this group is recorded from America, namely, *C. strenuus* itself, but, according to Marsh, from one spot only, a pond in the Adirondacks. The form collected by Mr. Leim agrees precisely with *C. scutifer* G. O. Sars in the following characters, so that no doubt is possible regarding the identification: Total length, 1.22 mm.; fifth feet practically indistinguishable from those of *C. strenuus;* the shield-like expansion of the lateral parts of the last two trunk-segments (th4 and th5); the shape of the divergent spermatophores; the length of the caudal rami and interrelative lengths of the caudal setae; the tumid form of the seta on the inner margin of the first basal joint of the fourth foot; the vestigial outer apical spine of the inner ramus of the fourth foot, not easy to find, from barely one-fifth to nearly one-third the length of the inner apical spine to which it is closely applied.

C. scutifer was again present, accompanied by *C. leuckarti*, in material from Lake Utopia, N.B., collected June 4, 1921, at 4.45 p.m., in a fifteen minute tow at 18-23 metres. The bulk of the gathering, which was sent to me by Dr. Huntsman, consisted of Cladocera (*Daphnia longispina, Leptodora hyalina, Holopedium gibberum* and one *Polyphemus pediculus*). Of thirteen *Cyclops*, three were *C. leuckarti*, one of which was ovigerous, and ten were *C. scutifer*, of which three were ovigerous and none carried spermatophores. In the same gathering there were nine *Epischura lacustris*, of which one was a male, and several of the others carried a spermatophore, all typical.

At Enfield, June 8, 1920, at 3.08 p.m., the vial contained a male *Epischura nordenskioldi* and a large Cladoceran, *Eurycercus lamellatus*. An hour later (4.09 p.m.) there was no *Epischura* in the tow, but a male *Diaptomus* and several *Cyclops*, including a female *C. scutifer* with the ends of the spermatophores projecting beyond the borders of the urosome in dorsal view.

At Elmsdale, June 11-12, 1920, in an all-night setting, only two female *Epischura nordenskioldi* were obtained. This species has been recorded from near St. Johns, Newfoundland. It is characterized in the female by a straight abdomen and five spines on the end-joint of the fifth foot. On June 14 there were several *Epischura*, male and female, two of the latter bearing an annular spermatophore, that is, a slender cylinder wrapped quite half-way round the genital segment from left to right, so that when viewed from the right side it appears to encircle the body. This disposition of the spermatophore is characteristic of *E. nordenskioldi* and is mentioned by De Guerne and Richard (1889, p. 148). On June 28, a female *Epischura* was present having a straight abdomen and six spines on the end-joint of the fifth foot; this should be *E. nevadensis*. Accompanying it was a male *E. nordenskioldi*. On July 5, at the same station, a male of *E. lacustris* was obtained, together with *Cyclops serrulatus*.

The synopsis of a night-gathering at Elmsdale, July 9-10, 1920 (8 p.m. to 9 a.m.), may be taken as a sample of the summer plankton at that spot:

Cyclops ater	6	(females)
Cyclops albidus	18	(females)
Epischura lacustris	2	(male and female)
Epischura nordenskioldi	2	(females)
Eurycercus lamellatus	1	
Ophryoxus gracilis	1	
Total	30	

An all-night setting at Elmsdale, July 15-16, yielded fifteen Entomostraca all told and all females:

Cyclops albidus	6
C. viridis (*brevispinosus*)	4
C. ater	5
	15

It should be noted that Sars treats *Cyclops brevispinosus* as a distinct species under the name *C. robustus.*

As the summer advances the gatherings become still more impoverished. On July 19, 10.17 a.m., the surface net yielded only two copepods, a *Cyclops albidus* and one *C. serrulatus* with ovisacs, the posterior end of each ovisac pointed and marked by an opercular ring. The latter species is named *Leptocyclops agilis* (Koch) by Sars. A few Ostracods, *Candona parallela,* were taken at Elmsdale on this date.

At Milford Station, August 4, 1919, towing in the current with the fine surface net at 9.55 p.m. yielded three *Cyclops serrulatus* only. At Elmsdale, August 9, 1919, there were two copepods only in the vial, *Cyclops serrulatus* and *Diaptomus minutus.*

Finally at Elmsdale, on August 27, 1919, 8.42 p.m., the tow in the current at a depth of ten feet yielded a single damaged specimen of *Cyclops fuscus.*

At Shubenacadie there is to be found a mixture of fresh, brackish and salt water species. The brackish water form discovered here is a species of a genus of Harpacticoid copepods new to North America, *Canuella canadensis* n. sp. On May 28, 1920, the gathering was wholly freshwater, comprising eleven individuals:

Cyclops viridis (*brevispinosus*)	2
Cyclops serrulatus	1
Cyclops leuckarti	3
Diaptomus minutus	5
	11

On July 3, 1920, 4.42 p.m., the Shubenacadie vial contained fifteen Entomostraca:

Centropages hamatus	1
Eurytemora hirundoides	5
Cyclops viridis (*brevispinosus*)	4
Canuella canadensis	1
Cypria ophthalmica	4
	15

Less than an hour later, at 5.34 p.m., there was a typical and relatively copious *Canuella* plankton. Many of the *Canuella* females carried the two ovisacs characteristic of the genus, but I have no record of the male:

Canuella canadensis	84 per cent.
Cyclops viridis (*brevispinosus*)	9 " "
Eurytemora hirundoides	1 " "
Cypria ophthalmica	6 " "
	100

On July 31, 1919, a similar swarm of *Canuella* was encountered at the surface in the ebbing tide at 9.30 p.m. In this gathering, which included several hundreds of Entomostraca, the approximate percentage was:

Canuella canadensis	75 per cent.
Eurytemora hirundoides	5 " "
Cypria ophthalmica	20 " "
	100

On the same evening at 10.10 p.m. in the ebbing tide at a depth of 12 feet, using a coarser silk net, the complete catch comprised 130 *Eurytemora hirundoides*, 1 *Acartia tonsa*, 1 *Cyclops viridis* (*americanus*), 12 *Canuella canadensis.*

Many of the *Eurytemora* females had spermatophores, many carried an ovisac, and nine were males.

On the following evening (August 1, 1919) at high tide (8.45 p.m.), there were 41 *Eurytemora hirundoides*, 1 *Canuella*, and 1 young *Cyclops*. At the turn of the tide (9.10 p.m.) there were 16 *Eurytemora*, 13 *Cyclops viridis* (*s. l.*) and 3 *Canuella*. These numbers illustrate the reciprocal relations between tidal and fluviatile species in the surface plankton at Shubenacadie. The absence of the Ostracods (*Cypria ophthalmica*) which are frequently taken with the *Canuella*, is noticeable.

Canuella canadensis n. sp. differs from *C. perplexa* Scott by unit characters touching especially the spinous armature in the fourth pair of swimming feet and in the caudal furca. It agrees with the European species in the short, five-jointed anterior antennae, densely setose, carrying about eight coarsely spicate spines in addition to a number of slender, flexible, plumose setae and a couple of sensory setae; and in the seven-jointed outer branch of the posterior antennae. The mouth-parts are essentially the same, differences being hard to detect. I have observed that the outer branch of the mandibular palp is three-jointed, being figured as unjointed in *C. perplexa;* and the outer branch of the maxillary palp carries eight setae (instead of ten).

TABLE OF DIFFERENCES IN P 4.

	C. perplexa.	*C. canadensis*
Re 1.	1 se 0 si	1 se 0 si
Re 2.	1 se 1 si	1 se 0 si
Re 3.	3 se 1 st 1 si	2 se 1 st 1 si
Ri 1.	0 se 1 si	0 se 1 si
Ri 2.	0 se 1 si (vestigial)	0 se 0 si
Ri 3.	2 se 1 st 1 si	2 se 1 st 1 si (Fig. 5) [or 1 se 2 as 1 si]

The feature of these differences, trivial as they may appear, lies in their constancy; and the same remark holds good for the caudal furca, the branches of which are ciliated on their outer and inner margins, without any lateral seta outside, this seta being situated at the apex alongside the terminal setae. On the inner margin of each furcal ramus, a group of two slender setae occurs at three-fourths of the distance from base to apex (Fig. 6). The fifth feet are vestigial, a generic character. Total length, 1.21 mm.

Of the two species of *Canuella* found off the coast of Norway, *C. perplexa* was taken at the depth of a few fathoms on a sandy bottom partly overgrown by algae at a spot outside the Christiania Fjord; while *C. furcigera* occurred in the upper part of the Christiania Fjord, not far from the town, at the depth of a few fathoms on a muddy bottom. The former would therefore belong to the Laminarian zone, the latter to the sublittoral zone. *Canuella canadensis* clearly belongs to the estuarine zone, occurring as it does in association with fresh-water as well as marine species of Entomostraca.

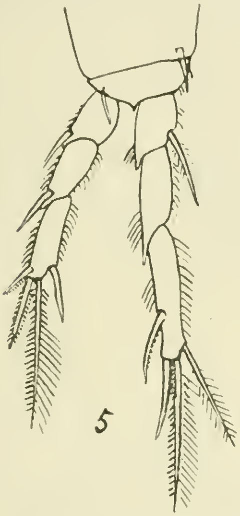


Fig. 5.—*Canuella canadensis* n. sp. Fourth pair of swimming feet (*p 4*). Shubenacadie.

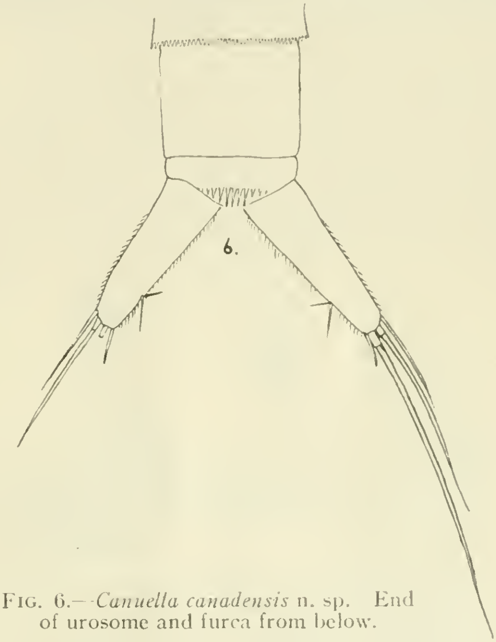


Fig. 6.—*Canuella canadensis* n. sp. End of urosome and furca from below.

III. SHAD STOMACH CONTENTS.

The contents were taken by Mr. A. H. Leim from the stomachs of shad (*Alosa sapidissima*) in 1920. The shad were caught in a weir near the low tide level at Scotsman Bay, N.S. This is separated from Minas Basin by Cape Split. Owing to the heavy tides (38 feet), there is much mixing of the water, the salinity being estimated at 30 pro mille, and the temperature 14.4°C. The first sample I received was from a shad 26 centimetres long, July 28, 1920, aged two years. The material was a copious chyme composed almost entirely of *Acartia clausi*. In addition there were present in subequal numbers, two species of *Eurytemora*, namely, *E. herdmani* Thompson and Scott, and *E thompsoni* n. sp. Many *Harpacticoids* (*Leimia vaga n. gen. et sp.*) were sprinkled throughout the mass, and some Mysid shrimps (*Neomysis*).

Eurytemora thompsoni is near to *E. affinis* Poppe, differing in the following points. The ental spur or unguiform process of the penultimate joint of the fifth legs of the female is ciliate on both edges, especially on the inner edge. The apical setae of these legs are long, flexible, not very unequal. The penultimate joint itself presents a constriction about the middle, often quite marked. The thoracic pleurae of the fifth segment are obtusely pointed, not wing-like as they are in *E. herdmani* and in *E. hirundoides* (Fig. 7). The furcal rami and anal segment are finely spinulose above; inner margins of the rami longiciliate; the insertion of the lateral seta divides the ramus into unequal proximal and distal portions in the proportion of 10:5; the terminal setae are as long as, or longer than, the ramus; the latter is six to seven times as long as broad. In the male there are spines on joints 8 to 12 of the right anterior antennae; taking the length of the spine on joint 9 as unity, the following are the approximate interrelative lengths:

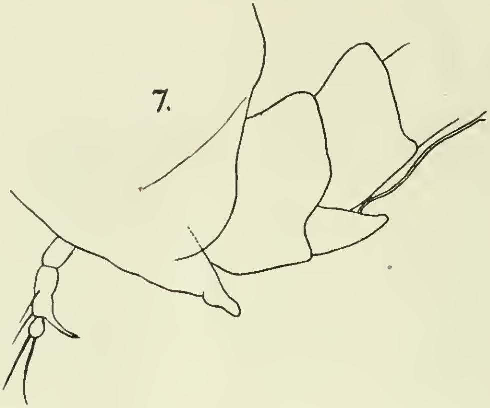


FIG. 7.—*Eurytemora thompsoni* n sp., showing end of thorax and front of urosome in side view, with the fifth foot *in situ* and part of the long stalk of a spermatophore behind the genital lobe.

Joint	*Herdmani*	*Hirundoides*	*Thompsoni*
8	¾	very small	½
9	1	1	1
10	0	1	½
11	0	1	¾
12	2	2½	1⅓

By this character the males of *E. herdmani* and *E. thompsoni* are readily separable, without further dissection.

Leimia vaga n.g. et sp. is a small Harpacticoid which strays, sometimes in no inconsiderable numbers, into the food of the shad. It is not easily placed in its proper family, since it exhibits a commingling of characters, with a balance in favour of the Canthocamptidæ. It seems to effect a link between the freshwater types and the marine types of adjoining families, but not especially between fresh-water and marine Canthocamptidæ. It has the caudal furca, antennary exopodite, natatory feet and even the fifth feet of species of the fresh-water genus *Attheyella* (Canthocamptidæ); the first foot (p 1) is almost that of a *Danielssenia* (Tachidiidae); the reduced antennae of *Cletodes*; and the sharply marked segmentation of *Laophonte*.

The *anterior antennae* are short and thick, six-jointed, the terminal joint large and blunt; the *posterior antennae* are two-jointed, and the outer branch, though uniarticulate, is large and conspicuous, standing out sideways in a dorsal view of the head (prepared out), exceeding half the length of the terminal joint, and carrying four large setae, as in *Attheyella crassa* G. O. Sars. On the inner (convex) border of the proximal joint of the posterior antennae, that is, on the side opposite to the insertion of the outer branch, there are two setae of which the distal one is much the larger, rather more than twice the length of the outer branch. In *Attheyella crassa* these setae are subequal and about half the length of the outer branch. The distal joint of the posterior antennae has four spines and two geniculate setae interspersed; the terminal spine has a flexible distal portion, giving it an intermediate character, so that it might be described as subgeniculate. The *mandibular palp* is simple and bipartite, the distal portion narrower than the proximal and set at a slight angle. When seen slantwise the shoulder of the wider basal portion causes a deceptive appearance of an obvious articulation, as in the figure. When mounted perfectly flat the articulation is not so obvious and it appears that the two parts are imperfectly divided. The basal portion carries a seta inside and outside, the former very strong and exserted (Figs. 8 and 9).

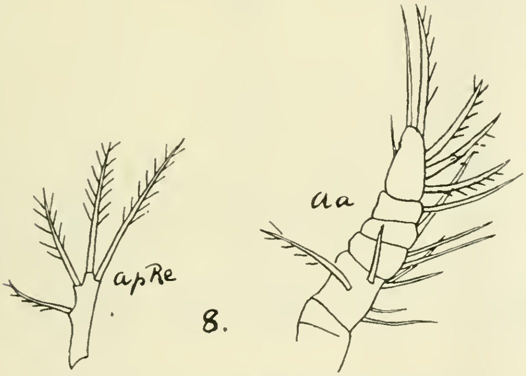


FIG. 8.—*Leimia vaga n. g. et sp.* Anterior antenna (*Aa*) and outer branch of posterior antenna (*Ap Re*).
Shad stomach, Scotsman Bay, N.S.

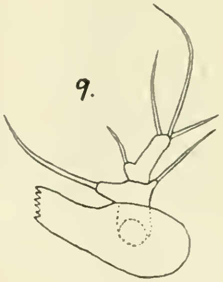


FIG. 9.—*Leimia vaga.* Mandible.

The *maxilla* is of the *Canthocamptus* type; its basal portion is occupied by the lobe carrying the manducatory setae; the distal portion is the palp which is devoid of branches, the obsolete outer branch being represented by a couple of setae arising close together from the front of the base of the palp; opposite to these setae, that is, from the inner side of the base of the palp, there arises a small internal lobe carrying two setae; the larger, main or distal lobe of the palp may be called the unguiferous lobe, since two of the setae are fairly strong and claw-like. The appendage, as a whole, is closely similar to the figure by Sars in *Canthocamptus staphylinus.*

The first maxilliped also agrees with *Canthocamptus* in having "only two digitiform lobules inside the unguiferous joint" (Sars); the first of these inner lobes is trisetose. The second *maxillipede* has a simple hand ciliated on the inner border, at least in its wider proximal portion, bearing a very delicate claw drawn out into an extremely fine though rigid point.

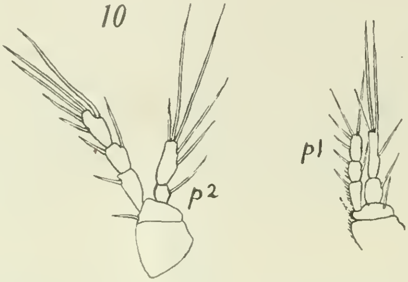


FIG. 10.—*Leimia vaga.* First swimming foot *(p 1)* and second swimming foot *(p 2).*

The four pairs of swimming feet, including *p 1*, which is natatory and not prehensile, have a three-jointed outer and a two-jointed inner branch. In the first feet the branches are subequal in length; in the rest the inner branch is much shorter than the outer. The following points are common to all the swimming feet (*p 1* to *p 4*): Re 1 has 1 se 0 si; Re 2 has 1 se 1 si; Ri 1 has 0 se 1 si (Fig. 10).

SYNOPSIS OF THE SETAE ON THE TERMINAL JOINTS.

	p 1	p 2	p 3	p 4
Re 3.	2 se 1 st 1 si	2 se 1 st 2 si	2 se 1 st 2 si	2 se 1 st 3 si
Ri 2.	1 se 2 as 1 si	1 se 2 as 2 si	1 se 2 as 2 si	1 se 1 as 1 si

Not only the number but also the insertion and size of the setae have to be noted. To do this thoroughly would require more figures than can be afforded and more text than can be allotted. In the first foot there are no geniculate setae; the *st* and *si* of *Re 3* are side by side, apical in position and subequal in length; Ri 2 carries three setae side by side at its apex, namely, an *se* and two long equal apical setae; and one *si* with central insertion. The second and third feet are alike; the proximal inner seta (*si 1*) of *Re 3* occupies a distal position and is the longest and stoutest of all the setae on the joint, this relation being accentuated in the third foot. The six setae of *p 4 Re 3* are all inserted distad of the middle of the joint, and in fact are crowded around the broad stunted apex (Fig. 11).

The segments of the urosome are fringed with short spinules above and long filaments below. The basal lobe of the fifth foot is produced outside to carry the long exserted seta; its inner expansion is low, with five marginal setae; distal lobe with four setae. The caudal furca is longer than the anal segment, attenuating from base to apex in side view, with two lateral setae outside, one proximal and one distal; the dorsal seta is inserted remote from the apex, nearly at the level of the proximal lateral seta, arising from a small pedicle. The two longer caudal setae are coarsely ciliated and the outer margin of each furcal ramus is coarsely spinulose (Fig. 12).

The total length is 0.80 mm.; the ovisac is single; no male has been observed.

The presence of *Leimia vaga* in the same stomach contents with *Acartia clausi*, *Eurytemora herdmani* and *Eurytemora thompsoni* completes an ecological assemblage of distinct individuality sufficient to give character to that region. The generic name is suggested in compliment to Mr. A. H. Leim, whose intensive studies of the Nova Scotian shad fishery have already yielded substantial results.

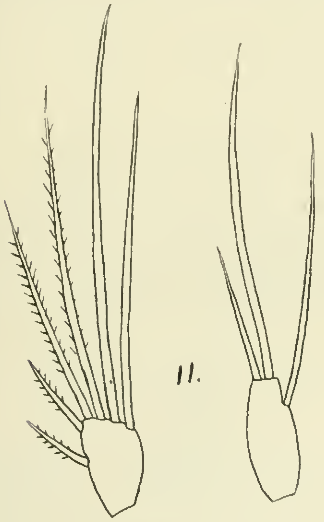


Fig. 11. *Leimia vaga*. Third joint of outer branch of fourth foot (*p 4 Re 3*) and second joint of inner branch of same foot (*p 4 Ri 2*). The latter is trisetose.

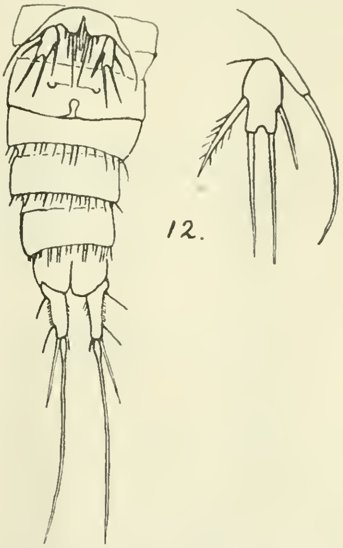


Fig. 12. *Leimia vaga*. Urosome and fifth pair of feet, from below.

The family of the Peltidiidae, with flattened, shield-shaped bodies, like miniature woodlice which, as noted by Claus, they further resemble in their ability to roll the body into a ball, is represented by *Alteutha purpurocincta* Norman. According to G. P. Farran this is the name by which the species entered by Sars as *Alteutha depressa* Baird is henceforth to be known. Under the latter name it is listed at Woods Hole, Mass. There are some features of importance in the fourth pair of feet: in the third joint of the inner branch (Ri 3) the external seta and the two apical setae are spiniform as in the type figured by Sars (1904, Pl. XXXVIII); the corresponding setae are also spiniform in the third foot in both sexes in our material. In the second joint of the inner branch (*p 4 Ri 2*) the first seta on the inner border (si 1) is only spiniform in the female, as in Sars's figure, not in the male. Lastly, the *si 2* of *p 4 Re 3* is a powerful serrate spine in both sexes. This feature has not been mentioned anywhere to my knowledge. The *si 1* of the same joint is a normal seta in close juxtaposition with the modified *si 2*, arising seemingly from the same acetabulum (Fig. 13).

There is the purple band across the middle of the body and my preparations further agree with the type in the absence of an inner seta on *p 1 Ri 2* and in the absence of an inner seta on the *Re 1* of the three middle legs (*p 2* to *p 4*). On the other hand the inner setae of *p 2 Re 3* are inserted more as in Sars's figure of *Alteutha interrupta* than as in his figure of *A. purpurocincta* (*depressa*); thus the *si 1* arises near the proximal end of the joint opposite to the proximal interspace; *si 2* arises nearly midway between *si 1* and the apex of the joint, opposite to the interval between *se 1* and *se 2* (middle interspace). These slight differences are worth noting in conjunction with the special features of the fourth pair of feet.

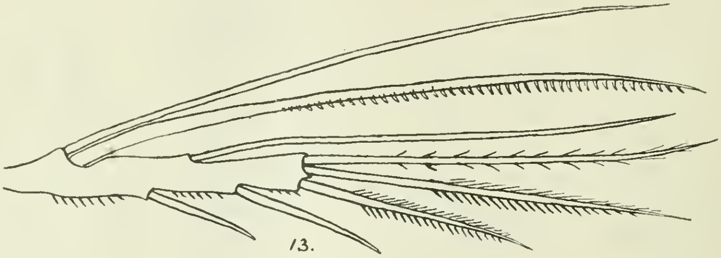


FIG. 13.—*Alteutha purpurocincta* (male). Third joint of outer branch of fourth foot (*p 4 Re 3*).
Shad stomach, Scotsman Bay, N.S.

Out of thirty-eight shad stomachs containing Copepods, *Alteutha* was present in thirty. It is commonly associated in the stomach contents with Cypris-larvae of barnacles (*Balanus*). The numbers are indicative of a considerable consumption of this class of food.

Thalestris longimana Claus is another large, highly distinctive Harpacticoid and the type of its genus. The segments of the body are excessively hard and brittle, and the back of the female is strongly arched. It occurred sparingly in four of the stomach contents always accompanied by *Alteutha;* one female carried an ovisac (August 5). It was not previously known from the Western Atlantic, the only species of *Thalestris* named from Woods Hole being *Thalestris gibba*.

A single female of another species occurred in one of the vials (No. 355, August 5), and is tentatively referred to *Thalestris brunnea*, with which it agrees in its short caudal furca. The structure of the fifth feet agrees with the type, except that the inner border of the inner expansion of the basal joint is coarsely spinulose, being rendered smooth by Sars.

An interesting record for the shad is that of *Halithalestris croni,* a pelagic Harpacticoid first obtained in the Western Atlantic at two stations of the U.S.

Fisheries Schooner *Grampus* in 1894 and recorded by R. W. Sharpe (1910). Since then it has been observed in plankton from Passamaquoddy Bay (J. P. McMurrich) and from several stations in the Gulf of St. Lawrence (A. Willey). A single example was present in shad stomach contents (No. 353, August 5). It bears a superficial resemblance, in shape of body and diverging caudal rami, to *Canuella*, but is double the size.

As mere stragglers into the diet of the shad must be mentioned the male of *Tachidius littoralis* Poppe and the male of *Nannopus littoralis* n. sp. According to Sars, the female of *Nannopus palustris* has no power of swimming. Each of these males was observed once only, in one sample, the bulk of which consisted of *Eurytemora thompsoni*. There is a certain amount of vagueness in the characterization of *Nannopus palustris* Brady. Sars states that Brady's figures of the first and fourth feet do not differ essentially from the Norwegian form. In Brady's figure of *p 1*, Re 3 has six full-sized setae instead of the four setae in the Norwegian and Nova Scotian representatives. On the other hand the three setae on *p 1 Ri 2* in Brady's figure, namely, 1 se 1 as 1 si, are more like the variety which I have called *littoralis*. In the latter the formula for *p 4 Re 3* is 3 se 1 st 3 si, a total of seven setae, while according to Sars, the formula for his type is 3 se 1 st 2 si, six in all. This is a clear difference. In *N. littoralis*, *p 3 Re 3* also carries seven setae (3 se 1 st 3 si) and the inner setae are not reduced; *p 2 Re 3* has six setae (3 se 1 st 2 si); the caudal setae are plain, the middle one not spurred, and there is an extra dorsal one; in *p 5* the distal lobe is not articulated, very slightly elevated, with four setae, the inner expansion is obsolete, but there is a row of four widely spaced setae in its place; lastly, in the second maxilliped the middle joint is much longer than the basal joint, at least as long as the claw. Although these are features of the male (length of 0.60 mm.), hitherto undescribed, they seem to warrant the creation of a new species. The inner branches of the first three pairs of feet are biarticulate, those of the fourth pair are vestigial, uniarticulate, bisetose, the inner of the two setae being much the smaller. In the first two feet the distal segment of *Ri* carries three setae, namely, an outer apical spine, an inner apical bristle and an inner distal bristle. In the third foot, the apical spine of *Ri 2* is transformed into a powerful claw (Figs. 14 and 15).

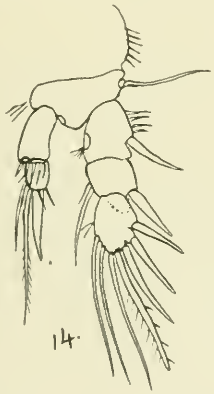


FIG. 14.—*Nannopus littoralis n. sp.* (male). Third foot (*p 3*). Shad stomach, Scotsman Bay, N.S.

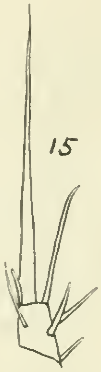


FIG. 15.—*Nannopus littoralis* n. sp. (male). Left furcal ramus from above.

The century count of the shad stomach contents in which the single examples of *Nannopus* and *Tachidius* were found gave the following result:

Eurytemora thompsoni	86 per cent.
Eurytemora herdmani	3 " "
Acartia clausi	10 " "
Leimia vaga	1 " "

The length of the shad was 19 cm. and its age two years (No. 320, July 31, 1920).

In the distribution of *Nannopus* a zonal arrangement can be made out somewhat analogous to that of *Cannella*. *N. palustris* was taken by Sars in a single locality near Christiania, in a shallow creek of the Fjord, on a muddy bottom close to the shore. *N. perplexa* G. O. Sars, is from Lake Tanganyika in Central Africa. The former, as indicated by the specific name, belongs to the paludine zone; the latter to the lacustrine zone. There was thus room for a littoral species, now occupied by *N. littoralis*.

IV. MIRAMICHI PLANKTON, 1918.

An expedition to investigate the fishery problems of the Miramichi river, estuary and bay was undertaken by the Atlantic Biological Station, N.B., in the *Prince* during the summer of 1918. A portion of the plankton material was entrusted to me by Dr. A. G. Huntsman, the director of the station, together with information regarding the localities visited. The numbers of the river "stations" are those established by the *Prince*. Station 82 lies in the centre of the brackish portion of the estuary. It is in the middle of a long, narrow channel between the confluence of the two main tributaries (the North West and the South West Miramichi rivers) and the inner bay formed by the broad mouth of the river. At this station on June 7, 1918, the maximum catch of smelt larvae was registered. The surface tow with the large pelagic metre net (mesh No. 0) consisted of 200 cc. of smelt larvae almost pure; in the deep tow at eight metres with the same net there was a solid phalanx of smelt larvae to the quantity of 400 cc. It was also the date of the minimum bottom salinity for this station and of the maximum uniformity of salinity and temperature from the surface to the bottom (depth 10 metres): the salinity standing between 7 and 8 pro mille, and the temperature between 14° and 15°C. The rise of the tide here has a maximum range of 8 feet.

On this date (June 7, sta. 82, 10.25 a.m.) the deep tow at 7 metres with the plankton net (mesh No. 5) amounted to 40 cc. and included very numerous smelt larvae and the following percentage Copepod content:

Acartia tonsa	52 per cent.
Eurytemora hirundoides	43 " "
Eurytemora herdmani	3 " "
Tortanus discaudatus	2 " "

In addition there was one example of a species, *Pseudodiaptomus coronatus*, to which further reference will be made later.

On July 4 (1 p.m.), the deep tow at station 82 contained several young fish larvae, together with 88 per cent. of *Acartia tonsa* and 12 per cent. of *Eurytemora hirundoides*. In addition there were present in individual numbers 98 *Ergasilus chautauquaënsis*, 8 *Laophonte huntsmani* n. sp., 109 *Bosmina longirostris* var. *cornuta*, one *Argulus* and five "Cypris" larvae of *Balanus*.

Ergasilus chautauquaënsis was originally found swimming freely, adults of both sexes, at Lake Chautauqua, N.Y., in 1886. The fresh-water fish upon whose gills the female would be a facultative parasite has not been discovered. In the Miramichi material I have seen only males which are distinguished from the females by the possession of a very large pair of blunt, claw-like posterior maxillipedes. Like *Bosmina*, they probably drifted down with the current into the lower reaches of the river-system without reproducing there. When seen from the ventral aspect, after preservation, they exhibit flecks of blue pigmentation (Fig. 16).

On August 9 (10 a.m.) the surface tow at station 82 with the finest plankton net (No. 20) amounted to 26 cc., comprising abundant phytoplankton and nearly 100 per cent. of *Acartia tonsa*, all females. In addition there were very few *Eurytemora hirundoides*, numerous Calanoid and Balanid nauplii, 28 crab larvae, 46 *Laophonte huntsmani*, 160 *Ergasilus*, two *Evadne* and no *Polydora* larvae. At the same time in the deep tow at 7 metres with the medium net (No. 5) the total quantity of plankton was 30 cc. This consisted largely of Copepods with some Mysids. The percentage count gave the following results:

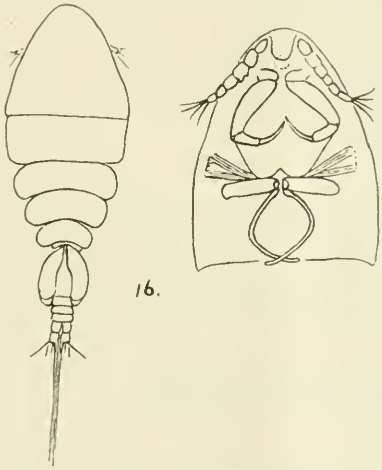


Fig. 16.—*Ergasilus chautauquaënsis* Fellows. Male from above and forebody from below. Miramichi river.

Acartia tonsa (female)	58 per cent.
Acartia tonsa (male)	22 " "
Eurytemora hirundoides	8 " "
Temora longicornis	5 " "
Pseudodiaptomus coronatus	4 " "
Tortanus discaudatus	3 " "

Two or three *Oithona similis* were found; *Centropages hamatus* was very rare and *Labidocera aestiva* still rarer.

No diatoms of the genus *Coscinodiscus* were seen.

On September 7, the deep tow at station 82 yielded 20 cc. of a nearly pure *Acartia tonsa* plankton, with scanty intermixture of *Eurytemora hirundoides*, *Pseudodiaptomus coronatus*, an Ergasilid copepod (*E. chautauquaënsis*) and a couple of *Laophonte huntsmani*.

Station 75 is the typical station for the centre of the inner bay, which is separated by islands from the outer bay. At this station on August 8 (11.10 a.m.), in the five-minute deep tow at five metres (net No. 5), the quantity was 12 cc., with the following approximate percentage:

Acartia clausi	16	per	cent.
Acartia tonsa	38	"	"
Centropages hamatus	4	"	"
Eurytemora herdmani	3	"	"
Labidocera aestiva	1	"	"
Pseudocalanus elongatus	5	"	"
Pseudodiaptomus coronatus	2	"	"
Temora longicornis	20	"	"
Tortanus discaudatus	8	"	"
Oithona similis	3	"	"

The Cladoceran *Evadne* was present, and some *Sagitta*.

On August 14, the surface tow at station 75 (0-2 m. with finest net No. 20, 11.45 a.m.) yielded a preponderance of juvenile stages in a total quantity of 9 cc. The following is an attempted synopsis of the entire Entomostracan content:

Balanus nauplii and metanauplii	25	per	cent.
Calanoid nauplii and metanauplii	25	"	"
Acartia (juniores)	30	"	"
Acartia tonsa (female)	4	"	"
Acartia clausi (female)	4	"	"
Acartia spp. (males)	4	"	"
Temora longicornis (female juv.)	1	"	"
Labidocera aestiva (juv.)	1	"	"
Tortanus discaudatus (juv.)	1	"	"
Centropages hamatus	1	"	"
Cladocera (*Evadne* and *Podon*)	4	"	"

The diatom *Coscinodiscus* was superabundant; *Oithona similis* was very rare in the sample, and but one male *Eurytemora herdmani* was found. In addition there were numbers of the larvae of the Annelid *Polydora;* molluscan veligers and crab larvae.

Laophonte huntsmani n. sp., is fairly close to *L. nana* G. O. Sars, having like it a six-jointed antennule in the female. The rostrum is so meagre and depressed that the animal looks in side view as if it were decapitated. The outer branch of the first foot is 3-jointed in both sexes, instead of being 2-jointed as it is in *L. nana*. The exopodite of the posterior antennae (*Ap Re*) is not so reduced as in the latter species; it bears four setae and is practically indistinguishable from that in *L. parvula* and *L. nordgaardi* for example. The uniarticulate mandibular palp bears five setae, namely, one at the end and four on the outer margin. The fourth foot is the same as in *L. nana;* so is the fifth foot of the female, though the formula 5:4, is apt to differ on the two sides of the body, *e.g.*, 5:3 on the right to 4:4 on the left. When the setae on the distal lobe are normal, the second (counted from the inside) is the longest, the third the thinnest, as in *L. nana*, but their insertion is distinctive, the second, third and fourth lying side by side at the apex, a gap separating the fourth from the fifth (*i.e.*, the two outermost setae of the distal lobe), while in *L. nana* the fourth and fifth setae are contiguous. Thus the interrelative lengths of these setae are essentially the same in *L. huntsmani* and in *L. nana*, but their insertions are slightly different.

The caudal setae are nearly alike in the two species under comparison, all the marginal setae with terminal insertion, but the cylindrical caudal rami of *L. huntsmani* are sharply marked off from the anal segment and nearly twice the length of it, and each ramus is nearly three times as long as wide. The abdominal segments are fringed behind with fine combs below and at the sides, less conspicuously so in dorsal view.

In the fifth feet of the male, the inner expansion of the basal joint is suppressed, and the distal lobe carries 4 marginal setae, as against 3 in *L. nana*. The genital segment bears a rudimentary sixth pair of feet, each armed with a strong spine (broken in the one figured). The *anterior antennae* of the male are armed with a powerful, blunt, refringent spur projecting distad from the swelling, followed by a short, slender, tapering, terminal portion bearing setae. The modified inner branch of the third foot in the male resembles *L. nordgaardi* in the aspect of the sigmoid, spiniform process of the middle joint, and *L. nana* in the number of setae in the terminal joint. The length of the female is 0.59 mm., and of the male 0.48 mm. (Figs. 17 and 18).

Although *Pseudodiaptomus coronatus* Williams 1906 is reported to be very common in surface net tows among algae in Eel Pond and other suitable spots at Woods Hole, Mass. (R. W. Sharpe, 1910), yet its capture in considerable numbers (up to four per cent. of the copepod gathering) at the Miramichi Station 82 seems to be worth noticing. The genus *Pseudodiaptomus* was created by C. L. Herrick in 1884 for *P. pelagicus* from the estuary of the Mississippi, and was regarded by him as a "missing link" between the fresh-water genus *Diaptomus* and its "fellows of the sea." Other species have been described from the estuaries of the Amazon and the Congo. It is clearly bound up with a certain limited range of density, and illustrates the principle that intermediate form-complexes occupy intermediate locality-complexes.

Next to the rotundity of the head, a striking superficial feature, mentioned by L. W. Williams, is due to the fact that the long natatory setae of feet and furca are jointed at some distance from their bases. A unique characteristic is the disparity of the ovisacs, one of which is only large enough to accommodate a couple of eggs. Many females, but only one male, came under my observation, although I searched very carefully for more males. The single male occurred in the deep tow at Station 82 on September 7th. In the same gathering there were some six females, none of which carried ovisacs. Females with ovisacs were taken from June to August inclusive.

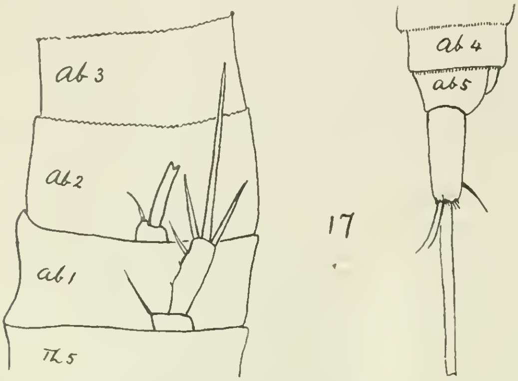


FIG. 17. *Laophonte huntsmani* n. sp. (male). Portion of urosome with fifth foot from the left side, and end of urosome with furcal ramus from the left side.
Miramichi river.

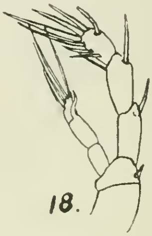


FIG. 18. *Laophonte huntsmani* n. sp. Third foot of male.

This species is the most remarkable Calanoid in the Miramichi plankton, and when I saw it for the first time I was unable to place it in any genus known to me.

In Giesbrecht's and Schmeil's system (1898), *Pseudodiaptomus* is the seventh genus of Centropagidae; *Diaptomus* is the eighth and *Temora* the fourteenth genus in the same family. Sars (1902), in a footnote, created the family Pseudodiaptomidae to include the two genera *Pseudodiaptomus* Herrick and *Poppella* Richard, which he thinks form a natural group between the Diaptomidae and the Temoridae.

V. HUDSON BAY EXPEDITION, 1920.

In the course of a biological excursion to the Hudson Bay region in 1920, Mr. Frits Johansen succeeded in bringing back with him a valuable collection of plankton from James Bay. As the locality is a new one, the results were likely to be of special interest, and this expectation has been fully realized. The gathering that I have examined was obtained in an all-night setting of the plankton net below the surface off the east coast of James Bay, about latitude 53½° N., September 9th, 1920. It consisted of a great quantity of one of the commonest and most widely distributed of all marine Calanoid copepods, *Acartia clausi*, together with other and rarer forms scattered throughout the mass.

Acartia clausi is equally abundant in Passamaquoddy Bay and is not a high Arctic species, James Bay lying far to the south of the Arctic circle, while for comparison it may be mentioned that Christiania lies on the 60th parallel of north latitude. Sars describes and figures the last segment of the cephalothorax (Th 5) as having the edge armed with from four to six extremely small and closely set denticles. These cannot be found in the North American individuals, in which the fifth thoracic segment is edentulous. Some of the James Bay examples show a refringent spirally twisted *receptaculum seminis* which I have not observed elsewhere.

Other leading species common to Passamaquoddy and James Bays are *Pseudocalanus elongatus*, *Eurytemora herdmani* and *Tortanus discaudatus*. All of these species have discovered the northwest passage, and are found on the north Pacific coast, as well as on the north Atlantic coast of America. Of *Pseudocalanus* very few adult females were found; of *Tortanus* and *Eurytemora* some of both sexes. To these representative northwest species is to be added the name of one of the most abundant of northern Harpacticoids, from James Bay to Woods Hole, *Idyaea furcata*. An interesting confirmation of the identity of this form with the original type from the Mediterranean and coasts of northern Europe is afforded by its commensal Acinetarian, *Ophryodendron trinacrium* Grube, which I have observed on several occasions in Passamaquoddy Bay at the Biological Station. According to Bernard Collin it attaches itself exclusively to this host.

The *Centropages* of James Bay is not the common North Atlantic species, *C. hamatus*, which occurs in the Gulf of St. Lawrence and in the Bay of Fundy, but it is the representative North Pacific species, *C. mcmurrichi*. A female of this species from James Bay measured 1.30 mm. in length, a male 1.40 mm. The female has the ental spur with the specific marks and proportions on the second joint of the outer branch of the fifth foot (*p 5 Re 2*), right and left. This spur is denticulated on its outer side with two rows of small teeth; and its length somewhat exceeds two-thirds of the length of the end-joint (*p 5 Re 3*). In the male the spur occurs only on the right foot, where it is called the "thumb," while the right *p 5 Re 3* is prolonged into a slender curved "dactylus" which is opposed to the thumb, the two processes together constituting a "chela." In the male *C. mcmurrichi*, the thumb or ental spur of the right *p 5 Re 2* is strongly curved towards the dactylus (Re 3) and, measured from its distal angle of origin to the tip, is exactly two-thirds the length of the dactylus, measured from base to apex. The latter (Re 3) carries a vestigial spine (*se*) about the middle of its outer curvature, and a small *si* set upon an oblique process (as in *C. hamatus*) on the inner curvature; a short way distad of the *si* there is a strong recurved hamulus, duly figured by McMurrich, but not present in *C. hamatus*. It is clear therefore that *C. mcmurrichi* fulfils the conditions of an elementary species, deviating from the standard at all points.

Stephos sinuatus n. sp. An undescribed species of the Calanoid genus *Stephos* T. Scott 1892 appears in the James Bay plankton. The species of this genus are characterized by an extraordinary complication of the fifth legs in the male. They are bottom-forms (benthonic) and cannot as a rule be captured in the ordinary tow-net. Their presence in the plankton is therefore exceptional and to be attributed to nocturnal excursions. The anterior antennae of *Stephos* are 24-jointed, about as long as the cephalothorax, and the same in both sexes.

In the female of *Stephos sinuatus* n. sp. the last segment of the thorax (*Th 5*) is symmetrical and evenly rounded behind; in the male it is rounded on the left side, bluntly produced on the right. The genital segment of the female is symmetrical, convexly protuberant below; in the male the second abdominal segment is produced below into a blunt process. The fifth legs of the female are three-jointed, counting the basal pieces which are confluent across the middle line; the terminal joint, less than twice the length of the middle joint, consists of a tumid proximal portion, with convex inner border, separated on the outside by a distinct shoulder from the curved, sharp-pointed distal portion with concave inner border; the points of the feet meet like finger-tips in the middle line *in situ;* on the outer side of the distal portion, about the end of the first third of it, there is a delicate spinule beyond which the nearly even outer border appears to be obscurely and minutely ciliate.

In the description of the fifth feet of the male in this genus, writers are compelled to rely largely upon faithful representations in order to spare their text. The right and left feet are nearly equally long but the left foot is more evenly hinged, its segments consisting of two basal pieces and a three-jointed ramus, the inner branch being suppressed. The end-joint of the left foot commonly terminates in a cluster of spines (e.g., *S. gyrans*, *S. fultoni*, *S. lamellatus* and *S. sinuatus*); but in *S. scotti* the terminal joint carries a row of four small, leaf-like appendages outside and two short claw-like lamellae at the tip; in *S. minor* the end-joint has a group of delicate setae (about two in number) outside, a doubly toothed border inside and two blunt digitiform processes at the tip; while in *S. longipes* the end-joint is rectangular terminating at its distal angles in two short processes, one acuminate and straight, the other curved and blunt.

The right fifth foot of the male has one of its proximal segments (the third, corresponding to Re 1) greatly elongated, while the end-joint is variously modified: in *S. gyrans* it appears as a complex clutch; in *S. fultoni*, *S. minor* and *S. scotti* it is a strong, curved claw, shaped like a reaping hook, i.e., falcate; in *S. longipes* it is an acutely geniculate claw; in *S. lamellatus* it is shaped like an irregular hand with several obtuse, digitiform processes; finally in *S. sinuatus* it has a deep, bay-like emargination which possibly serves for threading the spermatophore as it is being sewn on to the body of the female. (Fig. 19.)

CYCLOPOIDA: Of the marine Cyclopoida two species are represented in Mr. Johansen's collection. One of these is a very striking form, *Euryte longicauda* Philippi (=*Thorellia brunnea* Boeck), first described from the Mediterranean. Sars has found it along the whole Norwegian coast from Christiania in the south to Vadso in the north. Its extreme range is from the Polar Islands north of Grinnel Land to the Black Sea. It has not been recorded from the western Atlantic before. In the female, the anterior antenna, although shorter than the cephalic segment, is 21-jointed; the furcal ramus is about nine times as long as its minimum breadth in the middle. In the male the anterior antenna is about 17-jointed, from the fifth to the tenth inclusive the joints are very short and crowded: I have noted the caudal furca as being only four times as long as broad;

as there is no mention of a sexual difference in the length of the caudal rami it seems not impossible that the short-tailed male may belong to another species. A female measured 1.32 mm. in length; a male 0.99 mm. and another male 0.82 mm. The maxillae and the posterior maxillipeds showed the generic characteristics of *Euryte*, the former having a lamelliform palp terminating in a broad serrated edge, and the latter being prehensile and geniculate, the distal portion bent at an acute angle upon the proximal portion.

The other cyclopoid Copepod was identified as belonging to a species having the same range of distribution (from the Polar Islands to the Black Sea) as *Euryte longicauda*, namely *Cyclopina gracilis*. The anterior antenna of the male is the same as in the type figured by Sars; in the 4-jointed posterior antenna the last joint is as long as the antepenultimate; the caudal furca of the male is as long as the anal segment, each ramus $1\frac{1}{3}$ times as long as the greatest breadth. It seems likely that it is a brevifurcate form of *Cyclopina gracilis*. The length of the male is 0.50 mm.; a mature female was not found. But an adult female was found, in which the furcal ramus is no longer than it is broad and in other respects it agrees closely with *C. brevifurca* Sars, but unfortunately the distal portion of the anterior antennae was broken off on both sides so that this piece of confirmation is lacking. It is not uncommon to find the male of one species and the female of another species of the same genus in one small plankton gathering.

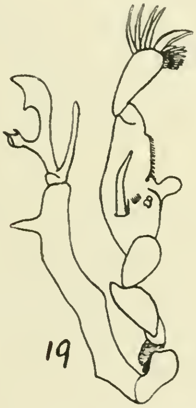


FIG. 19. *Stephos sinuatus* n. sp. Fifth pair of feet of male. James Bay.

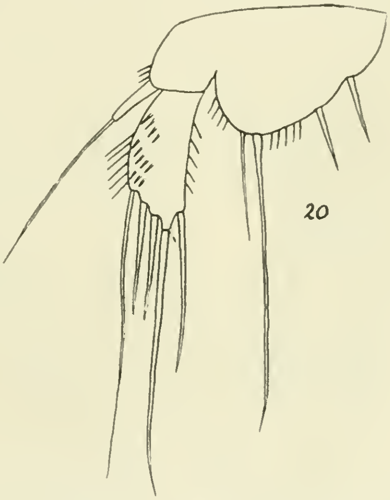


FIG. 20.—*Zaus aurelii* Poppe. Fifth foot of female. James Bay.

HARPACTICOIDA: In addition to *Idyaea furcata*, already mentioned, there were present a number of other interesting Harpacticoids. The Family Ectinosomidae is represented by *Ectinosoma melaniceps* Boeck; the length of the female measured about 0.55 mm., which is the size of a closely related species, *E. normani*, both having 7-jointed antennules (anterior antennae), but the particular mark of *E. melaniceps*, apart from colour, is the unusual breadth and lanceolate form of the short outer apical spine on the inner expansion of the proximal joint of the fifth foot, and this feature is exactly reproduced in the specimen which I dissected. Other minor characters confirm the identification.

The family Harpacticidae is represented by *Harpacticus uniremis*, which is frequently associated ecologically with *Idyaea furcata*, and by *Zaus aurelii* Poppe. The latter was first obtained in the North Pacific on floating kelp in Lat. 55° 56′ N., Long. 154° 7′ W. It occurs also in Passamaquoddy Bay. Its critical mark is to be found in the fifth feet of the female. These are constructed on the same plan as in *Zaus spinatus* and the following differences are based on a comparison between my preparation of *Z. aurelii* from James Bay, and Sars's figure of *Z. spinatus*. The inner expansion of the proximal joint joins the main stem at an acute angle (obtuse in *Z. spinatus*) and the summit nearly reaches the end of the first quarter of the distal joint. The setae of the inner expansion are four in number, *St 1* to *St 4*, counted from within outwards; of these, *St 3* is the apical seta and the longest of all; *St 4* is the slenderest, less than half the length of St 3; *St 1* and *2* are short equal spines; the interspace between *St 1* and *St 2* is narrower than the interspace between *St 2* and *St 3*. The distal lobe carries five marginal setae, *St 1* to *St 5*, counted from within outwards; *St 2* is the apical seta and is markedly exserted; *St 5* is slender, with a very fine capillary distal portion. The distal lobe itself is longer than broad in the proportion 12:5 and its inner border is slightly concave, while in *Z. spinatus* it is convex (Fig. 20).

Hardly any free-living Copepods have such an extraordinary shape as the Tegastidae, looking like miniature amphipods, with highly compressed, ventrally flexed body and very hard yellow to brown-coloured integument. The genus *Tegastes* is not previously recorded from America. In Mr. Johansen's collection from James Bay there are many examples of *Tegastes nanus* and fewer *T. falcatus*. After treatment with caustic soda a reticulate sculpturing of the integument is brought into view, together with the dark brown intersegmental junctions. Five species of *Tegastes* have been observed by Sars off the western Norwegian coast, and four of these were taken at one locality, Eggesbonaes, at a depth of three fathoms on muddy sand. *Tegastes falcatus* has been recorded by A. Scott from Ceylon; hence its range is from James Bay to the Gulf of Mannar.

In the family Thalestridae there is a form which I take to be the hitherto unknown male of *Thalestris brunnea* Sars. The intersegmental junctions appeared dark red under the microscope and the integument was so hard that the needle glanced off it; this in itself is given as a characteristic of *Th. brunnea*. The rostrum appears as a short cone, not defined behind; and the furcal rami are shorter than the anal segment. The characters of the second maxilliped and of the mandibular palp confirm the identification. In the first foot the inner spine of the second basal joint is a straight rod abruptly hooked at the tip; the distal joint of the two-jointed inner branch of the second foot carries two sigmoidally curved outer spines, a similar but smaller spine at the apex, three plumose setae and one capillary seta. The length is 0.50 mm. (Figs. 21 and 22).

Another leading member of the family new to the western Atlantic, is *Rhynchothalestris helgolandica*, of which male and female individuals were secured. This is a crimson-banded harpacticoid with long mobile rostrum and very short caudal furca, the rami broader than long. Its specific marks are very distinct and there is no possibility of mistaking it. The length of the female, measured from the base of the elongated rostrum to the end of the abbreviated furca, is 0.75 mm.; that of the male 0.51 mm. The crimson coloration extends to the bases of the thoracic legs and to the basal joint of the 9-jointed anterior antenna.

A third Thalestrid of the same size (0.75 mm.) having a rostrum of medium length defined behind and furca again shorter than the anal segment which in its turn is much shorter than the penultimate segment, and 9-jointed anterior antennae, proved to be *Dactylopusia vulgaris* Sars.

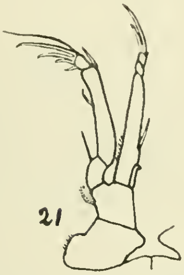


Fig. 21. —*Thalestris brunnea* G. O. Sars. First foot of male. James Bay.

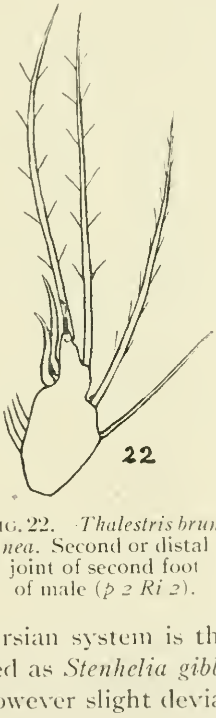


Fig. 22. —*Thalestris brunnea*. Second or distal joint of second foot of male (*p 2 Ri 2*).

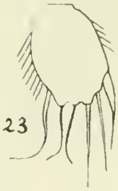


Fig. 23. —*Stenhelia gibba*. Distal joint of fifth foot of female. James Bay.

The next family in the Sarsian system is the Diosaccidae, represented by a species which I have identified as *Stenhelia gibba* with which it agrees in size, 0.63 mm. long. There are however slight deviations which approximate it to *S. proxima*. In the first foot the third joint of the outer branch (p 1 Re 3) is shorter than the second joint (Re 2) as in *S. gibba*, but the whole outer branch (Re) is almost as long as the first joint of the inner branch (Ri 1) and this joint is very slightly more than twice as long as the two distal joints (Ri 2 and Ri 3) combined. In the fifth foot it may be said in general that the shape is like that of *S. proxima*, but the disposition of the setae is more like that of *S. gibba*, without being identical with the latter. On the inner expansion, the two outermost setae (*St 4* and *St 5*) are inserted upon a common eminence, *St 5* being very short as in *S. gibba*. Near the inner side of the line of insertion of the distal lobe, the basal lobe presents a slight acuminate spur. The distal lobe is evenly rounded at the margin; of its six setae, *St 2* and *St 3* (counted from the inside) are extremely slender and equal. In *S. gibba*, as figured by Sars, there is no excessively slender seta, *St 1* being the most exiguous. Ovisacs were not observed (Fig. 23).

In the Canthocamptidae, *Ameira longipes*, characterized by its slender and pellucid body, and a single somewhat aberrant example of *Parameira parva* were picked out.

The last family with which we have to deal is that of the Laophontidae, represented by one of the most extraordinary of all the species which have been mentioned here, namely, the phasma-like *Laophonte horrida*, 1.15 mm. in length. Norwegian examples reach the length of 1.30 mm. It is distinguished by the strong spinous armature of the body. Sars found it rather abundantly in the upper part of the Christiania Fjord at 10-20 fathoms on a muddy bottom; also occasionally off the west coast of Norway up to the Trondhjem Fjord; and T. Scott records it from the Finmark coast. Other extra-Norwegian polar records are mentioned by Sars, and it is stated by A. Brian (1921) to be not uncommon in the Gulf of Genoa, where it is much smaller, not exceeding 0.75 mm. The body is apt to be densely coated with mud when captured fresh, unless by chance it is taken pelagically by night as at James Bay.

In conclusion, the finds recorded from James Bay up to the present may be summarized in the subjoined tables, in which the standard of accuracy aimed at ranges between one and two per cent. Only one *Laophonte horrida* was found, but other Laophonte instars were present, and I have named it in the table as the representative of a number of harpacticoid species, rarely taken in the plankton net, which occurred in the material as solitary individuals.

PERCENTAGE COUNT EXCLUSIVE OF ACARTIA.

Pseudocalanus elongatus	2 per cent.
Stephos sinuatus	2 " "
Centropages mcmurrichi	5 " "
Eurytemora herdmani	52 " "
Tortanus discaudatus	8 " "
Cyclopina gracilis	2 " "
Tegastes nanus	8 " "
Idyaea furcata	20 " "
Rhynchothalestris helgolandica	1 " "

PERCENTAGE COUNT EXCLUSIVE OF CALANOIDS.

Idyaea furcata	68 per cent.
Tegastes nanus	16 " "
Tegastes falcatus	4 " "
Rhynchothalestris helgolandica	1 " "
Ameira longipes	2 " "
Dactylopusia vulgaris	1 " "
Laophonte horrida, etc.	1 " "
Cyclopina gracilis	3 " "
Cyclopina brevifurca	1 " "
Euryte longicauda	3 " "

It cannot be without some significance that the plankton of James Bay, so far as observed, has yielded such a high proportion of well-known species not hitherto recorded from the American coast. Free-living Copepods are not only active in themselves, but they are carried long distances by currents. Every species that we know has doubtless had several thousand years to spread over the seven seas, and some of them have almost achieved an ocean-wide distribution. It is too soon to attempt any far-reaching generalization on the available data, but it seems certain that the Arctic Ocean has been a great centre of dispersal, a fact which may be connected with the extremes of climate of which that region has been the seat during geological time.

Montreal, July 1, 1922.

APPENDIX.

Since the above was written I have ascertained the occurrence of *Laophonte calamorum* in Lake St. John, which lies 120 miles north of Quebec, and am now able to add the description of the male of that species. The length is barely 0.4 mm.; the antepenultimate segment of the anterior antennae is expanded and the terminal segment is bluntly pointed. By these appendages the male holds on to the young female, the two moving about in linear procession as in *Canthocamptus* and some other genera. The second feet are unmodified; the third, fourth and fifth feet are transformed in the male, and there is a pair of setae on each side of the first abdominal segment representing a sixth pair of appendages. Of the six setae of p 3 Re 3, all, except the proximal *si*, are spines, and the same five spines recur on p 4 Re 3, where they are closer together, radiating out somewhat like the spokes of a wheel. The inner branch of the third foot is 3-jointed, and the middle joint has a straight mucroniform process not exceeding the length of the last joint which carries two apical setae and two inner setae. The basal joint of the fifth foot has no trace of an inner expansion; the short distal joint bears two long terminal setae only.

Associated with the *Laophonte* in the littoral zone of a swampy shore on the south side of Roberval, amongst dwarf reeds, was *Eurytemora affinis* Poppe. The history of this Copepod in Canadian waters is as follows: In Sir William Herdman's traverses of the North Atlantic in 1897 it was taken in two gatherings, on the outward and homeward journey, in company with *Eurytemora herdmani*, within a few miles of the mouth of the Saguenay river on both occasions. It is listed, without comment, by the authors of the report, Messrs. I. C. Thompson and A. Scott (Trans. Liverpool Biol. Soc., vol. XII, 1898). Giesbrecht and Schmeil admit the record of *E. affinis* in the Gulf of St. Lawrence with reserve. There is no reason to doubt the identification of so well-marked a species, and in this paper I have established the presence of *E. herdmani* in the Hudson Bay region (Johansen collection) and that of *E. affinis* in the Lake St. John region.

Montreal, September 16, 1922.

BIBLIOGRAPHY.

The text references to G. O. Sars are to the different parts of his *Crustacea of Norway*, published by the Bergen Museum, volumes IV-VI: Copepoda-Calanoida, Harpacticoida, and Cyclopoida, 1901-1919.

I. Quill Lakes.

1. Bailey, L. W. Diatoms from the Quill Lakes, Saskatchewan, and from Airdrie, Alberta. Contrib. Canad. Biol., 1921. Biol. Board of Canada, Toronto, 1922, pp. 157-165, 2 pls.
2. Byrnes, Esther F. The Fresh-water Cyclops of Long Island. Cold Spring Harbour Monographs, VII, with 15 pls. Brooklyn, N.Y., 1909.
3. Chapman, Frank M. Camps and cruises of an ornithologist. New York (Appleton), 1908.
4. Dawson, Sir J. William. The Canadian Ice Age. Montreal, 1893.
5. Forbes, Ernest B. North American Fresh-water Cyclopidae. Bull. Illinois Lab., vol. 5 (1897-1901), Urbana, Ill., 1902. Article II, pp. 27-82, 13 pls.
6. Huntsman, A. G. The Quill Lakes of Saskatchewan and their fishery possibilities. Contr. Can. Biol. (n.s.) vol. I, No. 9, 1922.
7. Marsh, C. D. A Revision of the North American species of Diaptomus. Trans. Wis. Acad., 15, pp. 381-516, 15 pls. 1907.
8. Marsh, C. D. A Revision of the North American species of Cyclops. Trans. Wis. Acad., 16, pp. 1067-1135, 10 pls. 1910.

II. Shubenacadie River.

9. Birge, E. A. The Water Fleas (Cladocera). "Fresh-water Biology," by H. B. Ward and G. C. Whipple. 1st edit. New York (Wiley), 1918, pp. 676-740.
10. Marsh, C. D. Copepoda. *Ibid.*, pp. 741-789.
11. Sharpe, R. W. The Ostracoda. *Ibid.*, pp. 790-827.
12. De Guerne, Jules et Richard, Jules. Révision des Calanides d'eau douce. Mém. Soc. Zool. France, t. II, pp. 53-181, pls. I-IV, Paris, 1889.

III. Shad Stomach Contents.

13. Claus, C. Copepodenstudien. 1 Heft. Peltidien. 37 pp., 9 pls., 4to. Vienna, 1889.
14. Sharpe, R. W. Marine Copepoda and Cladocera of Woods Hole and adjacent regions. Proc. U.S. Nat. Mus., Vol. 38, pp. 405-436 (1910), Washington, 1911.
15. Farran, G. P. Marine Entomostraca. Clare Island Survey, Part 45. Proc. Roy. Irish Acad., XXXI, 1913.
16. McMurrich, J. P. The Winter Plankton in the neighbourhood of St. Andrews, 1914-15, pp. 1-8, with Table. Contributions to Canadian Biol., 1915-1916, Ottawa (Dept. Naval Service), 1917.

17. Willey, A. Report on the Copepoda obtained in the Gulf of St. Lawrence and adjacent waters, 1915. Canadian Fisheries Expedition, 1914-15, pp. 173-220 (1918), Ottawa, 1919. [*Halithalestris Croni,* Tables III, VIII and XII.]

IV. Miramichi Plankton, 1918.

18. Giesbrecht, W., and Schmeil, O. Copepoda. I. Gymnoplea. Das Tierreich, 6. Lieferung, Berlin, 1898.

19. Herrick, C. L., and Turner, C. H. Copepoda, etc., of Minnesota. St. Paul Minn., 1895.

20. Williams, L. W. Marine Copepods of Rhode Island. Amer. Nat., vol. 40, pp. 639-660. Boston, 1906.

21. Wilson, C. B. North American Parasitic Copepods belonging to the Family Ergasilidae. Proc. U.S. Nat. Mus., vol. 39, pp. 263-400, pls. 41-60, Washington, 1911.

22. Willey, A. Economic History of Copepods. Trans. Amer. Fish. Soc., vol. 50, pp. 320-325, Washington, 1920.

V. Hudson Bay Expedition, 1920.

23. Brian, Alessandro. I Copepodi Harpacticoidi del Golfo di Genova. 112 pp., 12 pls., 38 text figures, 4to. Genoa (Laboratorio Marino di Quarto dei Mille) 1921.

The following species are common to the Gulf of Genoa and James Bay: *Ectinosoma melaniceps, Harpacticus uniremis, Idyaea furcata, Dactylopusia vulgaris, Laophonte horrida.*

24. Collin, B. Étude monographique sur les Acinétiens. Arch. zool. exp., t. 51, Paris, 1912. [*Ophryodendron trinacrium* on *Idyaea furcata*, p. 389.]

25. Giesbrecht, W. Pelagische Copepoden. Naples Monograph, 1892. [*Stephos (Moebianus) gyrans.*]

26. Giesbrecht, W. Copepoden. Expédition Antarctique Belge, 49 pp., 13 pls., 4to, Antwerp, 1902. [*Stephos longipes.*]

27. McMurrich, J. P. Notes on the Plankton of the British Columbia coast. Trans. Roy. Soc. Canada, Series III, vol. X, pp. 75-89, 14 text figures, Ottawa, 1916.

28. Poppe, S. A. Ueber die von den Herren Dr. Arthur und Aurel Krause im nördlichen Stillen Ocean und Behringsmeer gesammelten freilebenden Copepoden. Arch. f. Naturg., 50 Jahrg., pp. 281-304, Taf. 20-24, 1884. [*Zaus aurelii.*]

29. Scott, T. Additions to the Fauna of the Firth of Forth, Part IV. Tenth Ann. Rep. Fishery Board Scotland for 1891, 4to, Edinburgh, 1892. [*Stephos minor,* p. 245.]

30. Scott, T., and Scott, A. Descriptions of three apparently new Copepods from the Clyde. Ann. Nat. Hist., (7) I, pp. 185-190, 1898. [*Stephos fultoni.*]

31. Scott, T., and Scott, A. On some Entomostraca collected in the Arctic Seas in 1898 by William S. Bruce. Ann. Nat. Hist., (7) VIII, pp. 337-356, pls. III-VI, 1901. [*Zaus aurelii,* together with *Zaus spinatus* Goodsir and *Zaus goodsiri* Brady, off Kolguev Island.]

32. Willey, A. Marine Copepoda. Canadian Arctic Expedition 1913-18. Vol. VII, Part K. Ottawa, 1920.

No. 17

THE LARVAL STAGES AND MEGALOPS OF CANCER AMŒNUS (HERBST)

BY

C. J. CONNOLLY, PH.D.
St. Francis Xavier's College, Antigonish, N.S.

The Larval Stages and Megalops of Cancer Amœnus (Herbst)

By C. J. Connolly, Ph.D.
St. Francis Xavier's College, Antigonish, N.S.

While considerable attention has been paid to decapod larvæ by Europeans, comparatively little has been done on this side of the Atlantic in recent years, and the development of many species of decapods has yet to be investigated. Much is yet to be learned concerning the season at which the decapod larvæ appear in Canadian waters and the characters by which the larvæ of various species may be distinguished as also the various larval stages of the same species.

During the summer of 1921, the writer undertook the study of several decapod larvæ, both living and preserved, which were separated from plankton hauls made at different points along the Atlantic coast of Canada.

The most common crab occurring along the coast of the Maritime Provinces is the common rock crab, *Cancer amœnus*, Herbst, (*C. irroratus*, Say.), but little is known of its life history. Of its larval stages, Smith (1873, Pl. VIII) gives a drawing of a zoëa stage and also a post-larval stage, but in both of these the characters are not diagnostic. Faxen (1882, Fig. 12, Pl. XIV) gives a drawing of a megalops which he believed to belong to this species or to *Cancer borealis*. It is evidently the megalops of *Cancer amœnus*.

As the material examined was very abundant, it was possible to arrive at a fairly complete knowledge of the different stages passed through in the development of this species, and the results are given in the following paper.

The results of investigations of other decapod larvæ will be given in later papers.

During the first week of August, 1921, a specimen with eggs about to hatch was taken at the wharf of the Biological Station at St. Andrews, N.B. The eggs measured 0.37 to 0.40 mm. in diameter. The colour of the mass of eggs carried on the pleopods of the parent crab was dark brownish, owing largely to the presence of pigment and soiling of the egg membrane. Another specimen taken during the same week carried eggs in an earlier stage of development which were of an orange colour.

On examining the eggs of *Cancer amœnus*, movements of the embryo within the egg, as well as the heart beats with the corpuscles entering laterally and leaving the heart anteriorly and posteriorly, could be observed in the great majority, and on the second day after capture several larvæ had hatched out. These were transferred to a small beaker containing sea water and the beaker then placed in the Station tank in order to keep the temperature more constant. The water in the beaker was renewed with fresh sea water several times a day, but the larvæ, though continuing to hatch out, died before reaching the next stage. The process of hatching was observed when some ripe eggs were placed in a watch glass and examined under the microscope. The vigorous movements of the antennæ and telson play the most important rôle in breaking the egg membrane, these first emerging from the egg, the membrane being finally pushed off by the telson.

THE PROTOZOËA

The larva emerges from the egg in the stage represented in Text-fig. I. It is completely surrounded by an embryonic cuticle. This stage has been referred to as the Protozoëa. It is, properly speaking, an embryonic phase, and the larva is unable to swim until this cuticle is thrown off and the appendages developing within it become segmented and functional.

The first and second antennæ of this stage are highly developed, and, together with the telson, play an important rôle in the hatching process. The first antenna consists of a long tapering setose branch and a very short slender branch near the base. The second antenna has a long basal segment which divides distally into four setose branches. From the base arises a shorter branch, the tip of which extends as far as the point of division of the basal segment into four branches. In the basal portion of these transparent branches, the antennæ of the zoëa stage are developing. The telson on each side of the furca has seven setose branches. Within the cuticle are to be seen the developing spines of the future zoëa stage.


FIG I

There is present in the median frontal region the bud of the rostrum, and the dorsal spine is bent forward and closely appressed to the carapace by the embryonic cuticle. The buds of the mandible, first and second maxillæ are clearly indicated, and following these are the biramous first and second maxillipeds with a small bud of the third maxilliped. The maxillipeds are unsegmented, but a short time after hatching the endopodites were fully segmented. The abdomen is indistinctly segmented, while the cuticle covering it is unsegmented, though constricted at some of the abdominal joints.

The larva at the time of hatching is richly pigmented. There are two patches of pigment on the lower portion of the carapace. These are black, shading off to brown towards the periphery, where two or three spherical spots of a brilliant crimson colour are present. The mandible bears a black pigment spot and there is a definite configuration of pigment enclosing a shield-shaped area over the labrum. Pairs of pigment patches are present on the lower portion of the abdominal segments and telson, and these are connected by strands of pigment with those of adjacent segments. There are also black pigment areas in the region of the heart, and above these, as well as above the dark patches on the carapace, a bright green pigment is revealed by reflected light. The yellow yolk projects forward as two lobes on either side of the saggital axis.

Professor Alexander Meek (1918, p. 19) draws attention to the confusion existing in the use of the terms protozoëa and zoëa, both names being applied to very different stages with appendages varying from 7 to 13. He suggests that "We can best define the stage at hatching and subsequent stages by reference to the appendages which have been fully developed" and accordingly, he proposes that the term applied to the stages following the nauplius with its three pairs of appendages be defined as follows: Protozoëa, more than three pairs but not more than eight pairs of appendages; and zoëa, more than eight but not more than thirteen pairs of appendages.

In Brachyura, the larvæ are hatched in the stage corresponding to the protozoëa of the Penæidae. In the case of *Cancer amœnus* and other Brachyura, all the thoracic appendages are present as rudiments in the various larval stages, but do not become functional until the megalops stage is reached. According to Meek's nomenclature then, there are no zoëa stages in the Brachyura. The various stages would be all protozoëæ followed by the megalops.

In view of the fact that the term zoëa was first applied to the crab larva, then regarded as a distinct genus, and that in all stages the thoracic appendages are present as buds, it would seem better to retain the name zoëa now so universally applied to these stages. On the other hand, the so called protozoëa stage is really not a distinct larval stage in the Brachyura as Williamson (1915, p. 317) rightly suggested, but a post-embryonic stage of short duration, and indeed in some species ecdysis is said to occur simultaneously with hatching so that this phase is not a distinct stage. However, as Meek points out "the name [zoëa] should not be applied to such obviously different stages as the newly hatched larvæ of the crab and the lobster."

THE LARVAL STAGES

The further larval stages were obtained from plankton material collected at various stations in the waters of Eastern Canada and preserved in formalin. The plankton proved to be very rich in larvæ of many decapods, and, as was to be expected from the distribution of *Cancer amœnus,* the larva of this species appeared most frequently. No protozoëæ were found in the plankton, and apparently the duration of this post-embryonic phase is very short, as is the case with some other species.

Four zoëa stages and a post-larval or megalops stage are passed through before the young stage is reached. The following characters are found in all stages: The carapace has smooth rostral, dorsal, and lateral spines. The telson fork bears two smooth spines, the upper larger spine being lateral and the other situated on the dorsal surface near the outer margin. On the inner or mesial side of the furca on each side there are three spines with characteristic arrangement of teeth. The second abdominal segment bears laterally about the middle of the segment on each side, a stout tooth-like process directed outward and upward. The appendages are functional as far back as the second maxillipeds inclusive, in all the larval stages, but the rudiments of the succeeding appendages of the thorax are already present in the first zoëa stage, and gradually increase in size during the later stages.

The four stages can be easily recognized by the number of plumose setæ borne on the exopodites of the maxillipeds. The first zoëa has four, the second six, the third eight, and the fourth has eleven on the first maxilliped and twelve on the second maxilliped, the smallest of the latter being situated at a distance from the distal end about equal to the width of the exopodite.

That there are four and only four larval stages followed by a megalops or post-larval stage in *Cancer amœnus* is practically certain. Hundreds of larvæ were separated from plankton hauls taken weekly in most cases by the Station boat throughout the summer season in different years. At all the stations where the adult abounds four larval stages, and only four, constantly appeared in regular succession between June and September. The larvæ, taken at stations where only *Cancer amœnus* occurs among the Brachyura, were compared with identical forms occurring together with the larval stages of various other species, and always the same four stages appeared.

While the stages vary somewhat in size, they do so within well defined limits, and it is possible to separate the four stages by the unaided eye.

STAGE I

Plate I, Fig. 1, shows the first zoëa stage. The perpendicular distance from the end of the rostral to the end of the dorsal spine is 1.46 mm. The length of the rostral spine measured from the anterior border of the eye is 0.47 mm. The length of the dorsal spine measured from the posterior angle where it joins the carapace is 0.61 mm. The lateral spine measures 0.12 mm., the carapace 0.61. The length of the abdomen from the lower border of the carapace to the end of the telson fork is 0.78 mm. Characteristic of this stage is the number (viz., four) of plumose setæ on the exopodites of the first and second maxillipeds.

First Antenna. Fig. 2, a^1, shows the first antenna of the first larval stage. It consists of a short triangular basal segment and a long segment bearing five sensory tubes or aesthetascs. Two of these are as long or longer than the segment, the third about one-half the length of the large tubes, the fourth about one-quarter, and the fifth quite small.

Second Antenna. The second antenna (Fig. 2, a^2) consists of a single segment which has an extension bearing on its dorsal surface two rows of teeth pointing upwards. Where the segment narrows off to form this spinous extension, the exopodite arises. It consists of a slender segment bearing at its extremity a long spine and two short spines. The endopodite or permanent flagellum arises as an outgrowth from the base of the spinous extension in later stages.

Mandible. (Fig. 3.) The mandible consists of a single segment. It possesses an outer cutting plate slightly curved with the concavity on its inner surface, and an inner grinding surface. The face of this grinding surface is oval in outline, and below on the outer side and on the same level as the edge of the cutting plate there is a tooth-like process. The lower corner of the cutting plate forms an angular projection. A very interesting feature of the mandible in this and the following stages is the presence on the blade of the cutting plate of small canals, running out perpendicularly to the edge of the blade, reminding one of plasmodesmen in some plants.

Labrum and Labium. The lower median lip of the labrum bears about half a dozen short spines on its inner surface. Both lobes of the labium bear a row of hairs on the upper margin.

First Maxilla. (Fig. 4.) The first maxilla has a protopodite with two lobes and a palp of two segments. A segmentation of the protopodite was not observed, but the two lobes probably represent two protopodite segments. The upper lobe closely approximates to the mandible. It has stout serrate spines. The lower lobe has more delicate spines, some of which are finely setose. The palp bears six terminal hairs and also one on the proximal segment.

Second Maxilla. (Fig. 5.) The second maxilla consists of three notched lobes together forming the endognath and the scaphognathite. The lobes bear terminal spines, some of which are serrate while others have delicate setæ. The scaphognathite has five plumose setæ.

First Maxilliped. (Fig. 6.) The first maxilliped has a protopodite consisting of a short basal segment and a long segment, with the distal end of which an endopodite of five segments and an exopodite of two segments are articulated. The segmentation of the exopodite is not complete, no line of separation being visible on the outer surface. The exopodite bears four plumose setæ.

Second Maxilliped. (Fig. 6.) This has likewise a two-jointed exopodite, but the endopodite has only three segments. The exopodite bears four plumose setæ.

The Third Maxilliped and Pereiopods. The appendages following the second maxillipeds are, as already noted, not functional during the zoëa stages, but are represented by buds which gradually increase in size until the post-larval stage is reached, when they become functional.

In the first zoëa stage, the third maxillipeds and the pereiopods are very small buds crowded together in the concavity between the second maxillipeds and the first abdominal segment. (Fig. 7.) The third maxilliped is very slender at its lower portion and closely approximates the base of the second maxillipeds, giving frequently the appearance of arising from it. The first pereiopod is easily distinguished by its large size and expanded lower portion. The remaining pereiopods are alike in size and shape. They are hollow sacs.

The Abdomen. This consists of five segments and a telson. The posterior lateral border of the segment overlaps the succeeding segment. There is a very small spine on this projection of the fourth segment, and in the fifth it is minutely serrate. A pair of small hairs is present on the posterior dorsal border of the second to the fifth segments.

The Telson. (Fig. 8.) As previously noted, each telson fork bears on its outer margin two smooth spines, and three long spines along the inner margin of the furca. The upper mesial spine is the shortest and is minutely serrate. Towards its base it bears on either side long needle-like teeth. The middle spine is minutely serrate along its entire length and is the longest of the spines. The third and lowest of the three spines is serrated along its mesial side. The proximal portion is minutely serrate, but the teeth gradually enlarge distally, becoming stout and curved like the teeth of a band saw just beyond the middle of its length, and then become gradually smaller again, disappearing altogether a short distance from the tip. The outer side of the spine is generally smooth but may have a few small teeth towards the base.

These spines are present in all zoëa stages. In later stages additional spines are present as will be noted later.

STAGE II, (Fig. 9)

In this stage there is a considerable increase in size. The distance from the tip of the rostral spine to the tip of the dorsal spine is 2.06 mm. The distance of the tip of rostral spine from the anterior border of the eye is 0.72 mm. The length of the dorsal spine is 0.79 mm. The length of the carapace is 0.59 mm. The length of the abdomen measured from the lower border of the carapace to the extremity of the telson fork is 1.35 mm.

The carapace is provided with five plumose setæ on each side of the posterior lateral border. They arise on the inner surface near the margin. The eye stalks are lengthened and the corneal facets more clearly defined than in Zoëa I.

First Antenna. The first antenna is similar to that in the first stage, but four of the sensory tubes are now long, two of them being stouter than the others. There are usually six in all.

Second Antenna. (Fig. 10.) The spinous extension bears a bud of the future flagellum at its base near the origin of the exopodite. There is a constriction near the middle of the long segment. The exopodite is similar to that in Stage I.

Mandible. The mandible does not show any very marked changes from the preceding stage.

First Maxilla. (Fig. 11.) There is little change in this stage. The two-jointed palp bears a series of smooth hairs on the distal joint and a single hair on the proximal joint. There is an increase in the number of spines on the large lobe, and a plumose hair is present on the outer margin of the protopodite.

Second Maxilla. (Fig. 12.) The scaphognathite has now nine plumose hairs. The subdivisions of the endognath bear setæ spines, more delicate than those on the first maxilla. There is a slight increase in the number of spines present in this stage.

First Maxilliped. The exopodite has six plumose setæ. The exopodite has, as in Stage I, two segments, and the endopodite three.

Second Maxilliped. Similar to Stage I, but the exopodite, like the first maxilliped, has six plumose setæ.

Third Maxilliped, and Pereiopods. (Fig. 13.) These appendages, while still rudimentary, have undergone considerable growth. The hollow, sac-like character is very apparent in this stage. They are tucked closely together in the depression between the second maxillipeds and the abdomen. The third maxilliped is biramous, the exopodite being the more slender of the two branches. The first pereiopod is easily recognized by its relatively large size. On the proximal portion a double gill is just beginning to form as a hollow outgrowth of the pereiopod. The second and third pereiopods show buds of single gills at their base.

Abdomen. The most noticeable change in the abdomen is the lateral extension of the tergum of each segment to form a spinous process over the succeeding segment. The protoplasm is collecting at the lower ventral border of the segment to form the pleopods, but there is yet no outpushing of the wall.

There is no change in the structure of the telson at this stage.

STAGE III. (Fig. 14)

The distance from the tip of rostral spine to the tip of dorsal spine is now 3.2 mm. The length of the rostral spine measured from the anterior border of the eye is 1.1 mm. The length of the dorsal spine is 1.3 mm. The length of the carapace is 0.7 mm. and that of the abdomen measured to end of telson fork is 1.7 mm.

As in the previous stage, the carapace is provided with plumose hairs along the posterior lateral border. The Zoëa III can be recognized by the presence of eight plumose setæ on the exopodites of the first and second maxillipeds.

First Antenna. There is no change except increase in size.

Second Antenna. In some specimens of this stage only one short spine together with the long spine was observed on the exopodite. The bud of the flagellum has increased in size.

Mandibles, Labrum and Labium. The labrum is provided with many short spines on its median ventral surface. In Fig. 15 the cutting plate on the mandible to the right of the figure is bent back, showing the crushing portion of mandible.

First Maxilla. Plate II, Fig. 16. There are additional spines as indicated in the drawing.

Second Maxilla. Fig. 17. The scaphognathite now bears eight plumose setæ on its outer and lower edge. The drawing shows the number of spines on the sub-divisions of the lobes of the endognath.

First and Second Maxillipeds. These possess the same number of segments as in previous stages, but the exopodites each bear eight plumose setæ. There are additional hairs scattered over the segments. Fig. 18 shows the plumose setæ on the exopodite of second maxilliped.

Third Maxilliped. The rudiments of a gill are seen on the exopodite, and below it another bud which is that of the epipodite and gill (Fig. 19).

Pereiopods. (Fig. 19.) The first pereiopod is now chelate; at its proximal end it bears the rudiments of two gills. The second and third pereiopods bear each a single gill as a hollow outgrowth from the proximal end.

The Abdomen. There are six segments in the abdomen of this stage. The additional segment which has been cut off from the telson is much smaller than the others. The lateral spines of the projecting terga have increased in size.

The Telson. The telson has two additional spines, small in size, situated on either side of the furcal angle.

STAGE IV, (Fig. 20)

This is the last zoëa stage and is sometimes referred to as the metazoëa. A considerable increase in size has taken place and the appendages have undergone a marked development. The eye stalk has lengthened and approaches that of the megalops in appearance.

The tip of the rostral spine projects 1.9 mm. in front of the anterior border of the eye. The length of the dorsal spine is 2.06 mm. Both dorsal and rostral spines have a few scattered hairs. There is an increase in the number of plumose hairs along the posterior lateral margin of the carapace. The length of the abdomen measured from the lower border of the carapace to the end of the telson fork is 3.2 mm. The pleopods are present as club-shaped extensions from the ventral wall of the abdominal segments.

First Antenna. (Plate III, Fig. 24, a.) This appendage exhibits a marked advance as compared with previous stages, and an approximation to the post-larval condition. It has, in fact, the same plan of structure as in the megalops, and this similarity, together with some other features to be noted, confirms the view of Spence Bate (1859, p. 589) that in the development of the crab we have not a metamorphosis strictly speaking, but a gradual change. The approach to the post-larval condition is to be seen in the beginning of a segmentation, the arrangement and increase in the number of aesthetascs, and the origin of a branch just above the ganglion in the large segment.

There are four large aesthetascs, two of which arise just a little within the margin, and a fifth, smaller and situated on the outer edge of the tip. At a short distance from the distal end, two groups of aesthetascs arise at the same level, one of four and the other of three. There is a beginning of a segmentation here separating this part from the segment below which bears two aesthetascs.

The large segment containing a ganglion has on its distal portion the bud of a branch, and immediately above it an incomplete segmentation was noted. This is the third segment of the megalops, but at this stage it is not completely segmentated off from the lower portion, which also contains a ganglion.

The first or proximal segment is globular in shape and bent upon itself as in the megalops. This segment contains the auditory organ in the adult. From the location of the rudimentary joints the position of the ganglia, the small branch and the groups of aesthetases, it is possible to recognize the future seven segments of the first antenna of the megalops.

Second Antenna. (Plate III, Fig. 24, a^2.) The flagellum is now almost as long as the spinous extension. A segmentation was observed at its base.

Mandible. (Plate II, Fig. 21.) In this stage the mandibular palp is seen arising on the dorsal side of the mandible at the base of the cutting plate. It has but one segment.

First Maxilla. (Fig. 22.) This is similar to that in previous stage, but shows an increase in the number of spines on the lobes.

Second Maxilla. (Fig. 23.) The scaphognathite has now thirty-one plumose hairs and there is an increase in the number of spines on the lobes of the endognath. The upper lobe was segmented off at this stage. In all probability this lobe is the homologue of the endopodite. It is replaced by a very much modified structure in the megalops which is an endopodite.

First Maxillipeds. The exopodite now bears eleven plumose setæ. Otherwise it is similar to previous stage with increase in the number of scattered hairs.

Second Maxilliped. The exopodite now bears twelve plumose setæ, the smaller being situated at a distance from the others equal to about the width of the exopodite. An epipodite is beginning to develop.

Third Maxilliped. (Plate III, Fig. 25.) This has undergone a rapid development since the last stage. The epipodite has greatly lengthened. It bears a small gill which in the megalops is seen to become the podobranch, and just above it is seen a pair of gills which are the future arthrobranchs. One of these gills is about the same size as the pereiopod gills; the other is quite small. The exopodite is segmented.

The Pereiopods. These have also increased in size and have become segmented. The chelæ are large and the dactylopodite segmented off. The pereiopods, as in other Brachyura, do not bear exopodites.

The gills (Fig. 25) have increased considerably in size, but are not yet lobed. A pair is seen close to the basal segment of the first pereiopods and one gill each over the second and third pereiopod.

The Abdomen. The second to sixth segment inclusive now bear pleopods, which decrease in size posteriorly, those of the sixth segment being quite small. They are single jointed, but a small process projects from the middle of the mesial side. This process is the endopodite. The lateral extensions of the terga, especially those on the second and third segments, are long and pointed.

The Telson. This has, in addition to the spines present in Zoëa III, a small spine situated on each side of the furcal angle on the mesial side of the spine which appeared in the third stage. This latter spine is minutely serrate. The three large serrated spines are alike in all the zoëa stages.

The table below shows the comparative measurements in millimetres of the four zoëa stages.

	Zoëa Stages I	II	III	IV
Distance between tips of Rostral and Dorsal spines.	1.4 to 1.7	2.06	3.2	4.2
Distance of Rostral tip from anterior border of eye.	0.52	0.60	1.1	1.9
Length of Dorsal Spine.	0.65	0.79	1.3	2.06
Length of Abdomen from posterior border of Carapace to end of Telson fork.	0.81	1.2	1.7	3.2
Length of Lateral Spine.	0.14	0.19	0.28	0.33
Length of Abdominal Segments	0.14	0.18	0.27	0.40
Number of plumose setæ on exopodites of First and Second Maxillipeds.	4	6	8	11 on mxp. 1 12 on mxp. 2

THE MEGALOPS

The megalops (Text-fig. II) or post-larval stage presents an appearance quite different from the zoëa stages described, but, as we have seen, there is a gradual approach in the structure of some of the appendages in the zoëa stages to that of the megalops, and no new appendages appear in the megalops that are not present, at least in a rudimentary form, in the zoëa stages. The chief changes in structure are correlated with the changed habit of the creature, which now becomes to some extent demersal. Some parts become functional for the first time, while other parts undergo a change of function. The pereiopods for example, which appeared as buds in Zoëa I, showed a slow growth in

FIG. II

later stages and became segmented in Zoëa IV, are now functional and similar to those of the adult, enabling the megalops to creep on the bottom.

The first and second maxillipeds which were the swimming organs in the zoëa stages and, with the third maxilliped, hitherto rudimentary in structure, assume the fundamental structure and consequently the same function as those of the adult.

The rostral and dorsal spines are relatively smaller than in the zoëa stages, and there are no lateral spines. The forked telson of the zoëa stages becomes in the megalops a plate similar to that of the adult. The pleopods become now the functional swimming organs. When at rest the abdomen is held slightly bent toward the ventral surface of the thorax. The megalops, however, is quite unlike the adult in many points of structure. The greatest length of the megalops measured from the tip of the rostrum to the middle of the posterior border of the carapace is 1.8 mm. The greatest breadth is 1.2 mm. The appendages will now be described in more detail.

First Antenna. (Fig. 26, a^1.) The segmentation already indicated in Zoëa IV is now complete. There are seven segments. The basal segment is bent upon itself as in the adult. The second segment is large and contains a ganglion. The bud which appeared in the third segment in the last zoëa is now a single jointed endopodite. It bears three long smooth terminal hairs and two that arise farther back. A ganglion is located in the segment bearing the endopodite. The next three segments are small and the distal segment elongate and constricted near its middle. The first of these small segments does not bear aesthetascs. The latter arise on the three distal segments. Nine were observed arising at the same level on the fifth segment from the basal one, four on the sixth, and three on the seventh arising below the constriction. There are also two terminal plumose setæ on the last segment, and a long smooth spine arises farther back.

Second Antenna. (Fig. 26, a^2.) The second antenna is now much modified and has essentially the same structure as in the adult. It has eight segments, the first three of which are wider than the others. The fourth is short and the four distal segments long. The sixth segment bears distally three long smooth hairs. The segments above and below also bear hairs, but somewhat shorter than those on the sixth segment.

Mandible. (Fig. 27.) The mandible undergoes a great change in structure. The cutting plate is large and rounded and the transparent blade is wide with prominent canals running vertically through it, as was noted for the zoëa stages. The lower portion of the mandible is greatly thickened. Its inner surface has scattered spines. On the dorsal surface arises the palp. It is now three jointed and its distal segment bears six or seven spines. Its distal part hangs down in the groove formed by the cutting plate above the base of the mandible.

Fig. 28 shows mandible, labrum, labium and first maxilla *in situ*.

First Maxilla. (Fig. 29.) This appendage is somewhat similar to that in the zoëa stages; the lobes show an increase in the number of spines. The principal modification is to be found in the palp, which is a flattened single jointed process, bearing two small terminal spines, and a large one on the upper margin near the base.

Second Maxilla. (Fig. 30.) The scaphognathite is now very large and bears many (58 were observed) plumose hairs. The endognath is much changed in appearance. The large upper notched lobe of the zoëa stages is replaced by a conical lobe. It bears no terminal spines but on the outer side towards the base are two (sometimes three) plumose hairs. The other lobes of the endognath are now provided with smooth hairs some of which have delicate setæ.

First Maxillipeds. (Fig. 31.) The maxillipeds undergo a profound change in structure and function. In the zoëa stages they function as swimming organs, while in the megalops they become mouth parts and approach the adult condition. The first segment of the protopodite bears a long epipodite, the upper portion of which is triangular in shape and the lower portion projected into a long ribbon-like process provided with eight long filaments. The upper angle of the epipodite bears two long filaments. The inner side of the first protopodite joint ends in a lobe provided with spines, a few of which are serrate. The upper protopodite joint has a much larger lobe and its inner margin has smooth hairs, but a few may possess delicate setæ. The segmentation of the protopodite is frequently obliterated.

The endopodite is a single-jointed flattened process, truncate at its distal end. It bears on its upper edge three smooth hairs and one on its inner side towards the base. The exopodite has a long basal joint followed by a second narrower joint bent at right angles to the first, and is provided with five plumose setæ. The second joint is incompletely segmented near the middle. The distal part of the first joint bears on its outer margin three plumose hairs.

Second Maxilliped. (Fig. 32.) This appendage is provided with a short epipodite bearing a terminal filament, one on each side. On the dorsal side of the epipodite there is a small undeveloped gill. The exopodite is similar to that of the first maxilliped, and likewise shows the rudimentary segmentation in the second joint. The endopodite has five segments, the two distal ones being provided with strong spines. On the fifth or last joint three of the spines are heavily armed with teeth.

Third Maxilliped. (Plate IV, Fig. 33.) The growth of the third maxilliped, which was retarded during the zoëa stages, has suddenly undergone a rapid development and appears in the megalops as a functional organ similar to that of the adult. The protopodite is large and projected a little distance on either side as folds, between which arises the long epipodite bearing many filaments, two being terminal, the others scattered along the epipodite mainly on its outer margin. The upper inner margin bears three plumose hairs. Along the side of the large protopodite joint is a row of nine plumose hairs and there are three situated above these. The segmentation of the protopodite is largely obliterated. A short thick gill arises from a stout cylindrical process on the outer side of the base of the epipodite. It is a podobranch. A pair of gills arise anterior to the epipodite and very close to the origin of the epipodite. One of these gills is quite large, and lobed except towards its distal end, and *in situ* lies parallel to the epipodite along its outer margin. The second gill is much smaller and undeveloped. These two gills are arthrobranchs.

The exopodite is similar to that in the other maxillipeds. The endopodite consists of five segments. The first segment is very large and tapers to a thin edge on its mesial side, along which are many spines. The distal end of the segment is wider than the proximal. The second joint is somewhat rounded. This and the following two segments are provided each with five or six spines, some of which are serrated, and the fifth or distal segment is provided with twelve spines, the terminal ones being heavily armed with teeth.

It may be well to recall here the arrangement of the gills and epipodites in the adult stage. In the adult the first maxilliped bears no gill but has a long epipodite curving over the outside of all the gills of the succeeding appendages. The second maxilliped bears two gills. One is a podobranch arising on the dorsal portion of the epipodite and extended horizontally above the epipodite of the third maxilliped. The other gill is an arthrobranch extending upward and adhering closely to the anterior part of the pleuron. The third maxilliped has a long epipodite running under the gills of the pereiopods. It bears a small gill arising on the dorsal margin near the base. The gill is asymmetrical in appearance, owing to the fact that the outer gill plates at the base are much broader than the inner plates. This gives the gill a bifid appearance. This podobranch is closely appressed to the base of two large arthrobranchs belonging to the third maxilliped. The first pereiopod bears two arthrobranchs. Above each of the second and third pereiopods there is a pleurobranch. This is essentially the condition to be found in the megalops, but here only the gills of the pereiopods are fully lobed and functional. Fig. 34 shows a side view of the thorax of the megalops after removal of the carapace showing the gills *in situ.* The first pereiopod bears two arthrobranchs which are lobed. Along its anterior side lies the larger of the two arthrobranchs of the third maxilliped. On the pleuron a short distance from the basal segments of each second and third pereiopods a gill arises. These are pleurobranchs.

The Pereiopods. These possess the full number of segments present in the adult. Fig. 35 shows a ventral view of the thorax with the basal segments of the pereiopods. The appendages have been broken off at the fracture plane of the basi-ischiopodite. The coxopodite of the second pereiopod bears at its base on the anterior side a stout conical spur which is directed anteriorly and mesially.

The first pereiopod (Fig. 36) bears on the inner distal part of the basi-ischiopodite a hooked spur directed proximally. The basal segment of the fifth pereiopod is directed upwards. The dactylopodite of this appendage bears three long curved setæ, which arise a little distance below the tip. The stoutest of these, median in position, is provided with a double row of teeth (Fig. 37). A more highly magnified view of the inner curved portion is shown in Fig. 38.

The Abdomen. The lateral extensions of the terga are now rounded as in the adult. The sixth abdominal segment is much smaller than the others.

The Pleopods. The second to sixth abdominal segments inclusive bear pleopods the first four of which are biramous (Fig. 39, 4th pleopod); the fifth pair arising from the small sixth segment is uniramous (Fig. 40).

The endopodite is a club-shaped structure and bears near its tip on the inner margin three or four small hooks. The exopodites and the single branch of the fifth pair of the pleopods all bear long plumose setæ. The number varies, but to give a typical example the third pleopod had seventeen, two being terminal, six on the outer margin and nine on the inner margin, while the last pair had nine setæ, two being terminal, five on the outer margin and two on the inner margin near the distal end.

The Telson. (Fig. 40.) This is now a flat plate with a rounded posterior margin.

Though distinct species, there is considerable similarity in the larval stages of *Carcinus maenas* (Leach) as described by Williamson (1903) and *Cancer amœnus.* I have therefore given relatively few figures, though sufficient, I hope, to give a fairly complete idea of the larval stages of our common crab.

The figures have all been drawn with the camera lucida. The drawings of the entire zoëæ have been drawn to the same scale. The drawings of the appendages were made at a higher magnification but to the same scale.

In conclusion I wish to thank the Director of the Atlantic Biological Station, Professor A. G. Huntsman, for placing at my disposal for examination the many plankton hauls preserved at the Station, for literature, and for many other kindnesses extended while making this investigation.

LITERATURE

Bate, C. Spence.	On the Development of Decapod Crustacea. Phil. Trans. Roy. Soc. London, 1859, p. 589, pls. XL-XLVI.
Faxon, Walter.	Selections from Embryological Monographs compiled by A. Agassiz, Walter Faxon and E. L. Mark. I. Crustacea, in Memoirs Museum Comp. Zool. Harvard College, Vol. IX, No. 1, Cambridge, U.S., 1882, pl. XIV.
Meek, A.	On the Crustacea. I. Larval Nomenclature. Report of Dove Marine Laboratory, Cullercoats, New Series VII, 1918. Newcastle-on-Tyne.
Smith, S. I.	The metamorphosis of the Lobster and other Crustacea. Invertebrate Animals of Vineyard Sound (Verrill and Smith). Rep. U. S. Fish Commission for 1871-72, Washington, 1873, pp. 522-537, pl. VIII, figs. 37 and 37a.
Williamson, H. C.	On the larval and early young stage and rate of growth of the shore crab (*Carcinus maenas*, Leach), in 21st Ann. Report Fishery Board of Scotland for 1902, Part 3, pls. VII-XIII, 1903. Decapoden, I Teil (Larven) in Nordisches Plankton. Achtzehnte Lieferung VI. Kiel und Leipzig, 1915.

EXPLANATION OF PLATES

Abbreviations used.

a^1.	First Antenna	lb.	Labium
a^2.	Second Antenna	lr.	Labrum
abd.	Abdomen	1m.	First maxilla
br.	Gills	mn.	Mandible
ce.	Cutting plate of mandible	mp.	(1-3). First, second and third maxillipeds
ep.	Epipodite		
ex.	Exopodite	per.	(1-5). Pereiopods

Plate I

Fig.	1.	First zoëa stage.	
“	2.	First and second antennæ	Zoëa I
“	3.	Mandible	“
“	4.	First maxilla	“
“	5.	Second maxilla	“
“	6.	First and second maxilliped	“
“	7.	Third maxilliped and pereiopods	“
“	8.	Telson	“
“	9.	Second zoëa stage.	
“	10.	Second antenna	Zoëa II
“	11.	First maxilla	“
“	12.	Second maxilla	“
“	13.	Third maxilliped and pereiopods	“
“	14.	Third zoëa stage.	
“	15.	Mandible	Zoëa III

Plate II

Fig.	16.	First maxilla	“
“	17.	Second maxilla	“
“	18.	Setæ of first maxilliped	“
“	19.	Third maxilliped and pereiopods	“
“	20.	Fourth zoëa stage.	
“	21.	Mandible	Zoëa IV
“	22.	First maxilla	“
“	23.	Second maxilla	“

Plate III

Fig.	24.	First and second antennæ	“
“	25.	Basal segments of second and third maxillipeds, and of first three pereiopods	“
“	26.	First and second antennæ	Megalops
“	27.	Mandible	“
“	28.	Labrum, mandible, labium and first maxilla *in situ*	“
“	29.	First maxilla	“
“	30.	Second maxilla	“
“	31.	First maxilliped	“
“	32.	Second maxilliped	“

PLATE IV

Fig. 33.	Third maxilliped	Megalops
“ 34.	Side view of thorax showing the gills on the pleuron above the exopodites of the pereiopods	“
“ 35.	Ventral view of thorax	“
“ 36.	First pereiopod	“
“ 37.	Curved serrate seta on last segment of fifth pereiopod	“
“ 38.	Curved portion of seta more highly magnified	“
“ 39.	Fourth pleopod	“
“ 40.	Telson and fifth pleopod	“

LEGENDS FOR THE TEXT-FIGURES

Fig. I. The protozoëa stage of *Cancer amœnus*.
Fig. II. The megalops stage of *Cancer amœnus*.

PLATE I

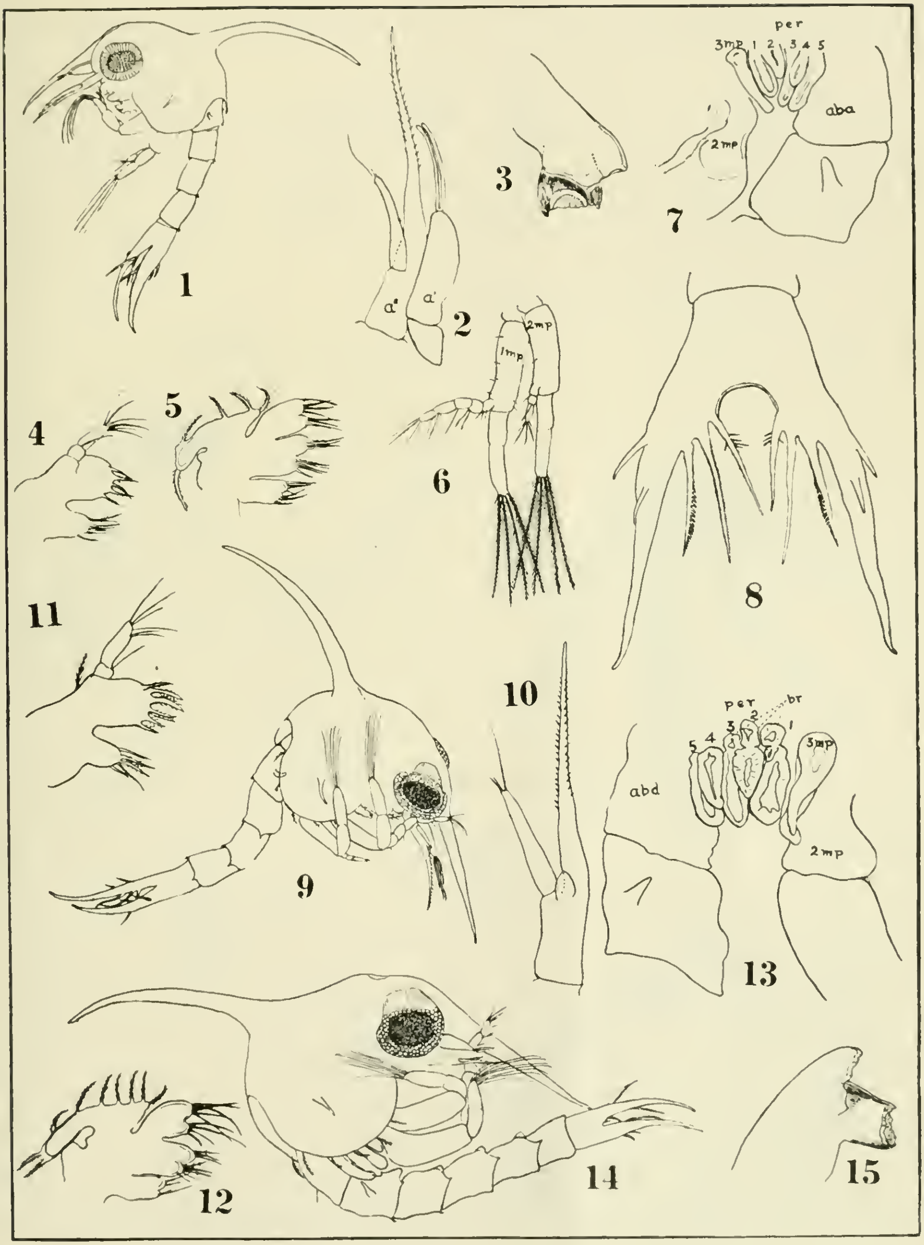

1
a'
a'
2
3
per
3mp 1 2 3 4 5
aba
2mp
7
4
5
1mp
2mp
6
8
11
10
per
br
5 4 3 2 1
3mp
abd
2mp
9
13
12
14
15

PLATE II

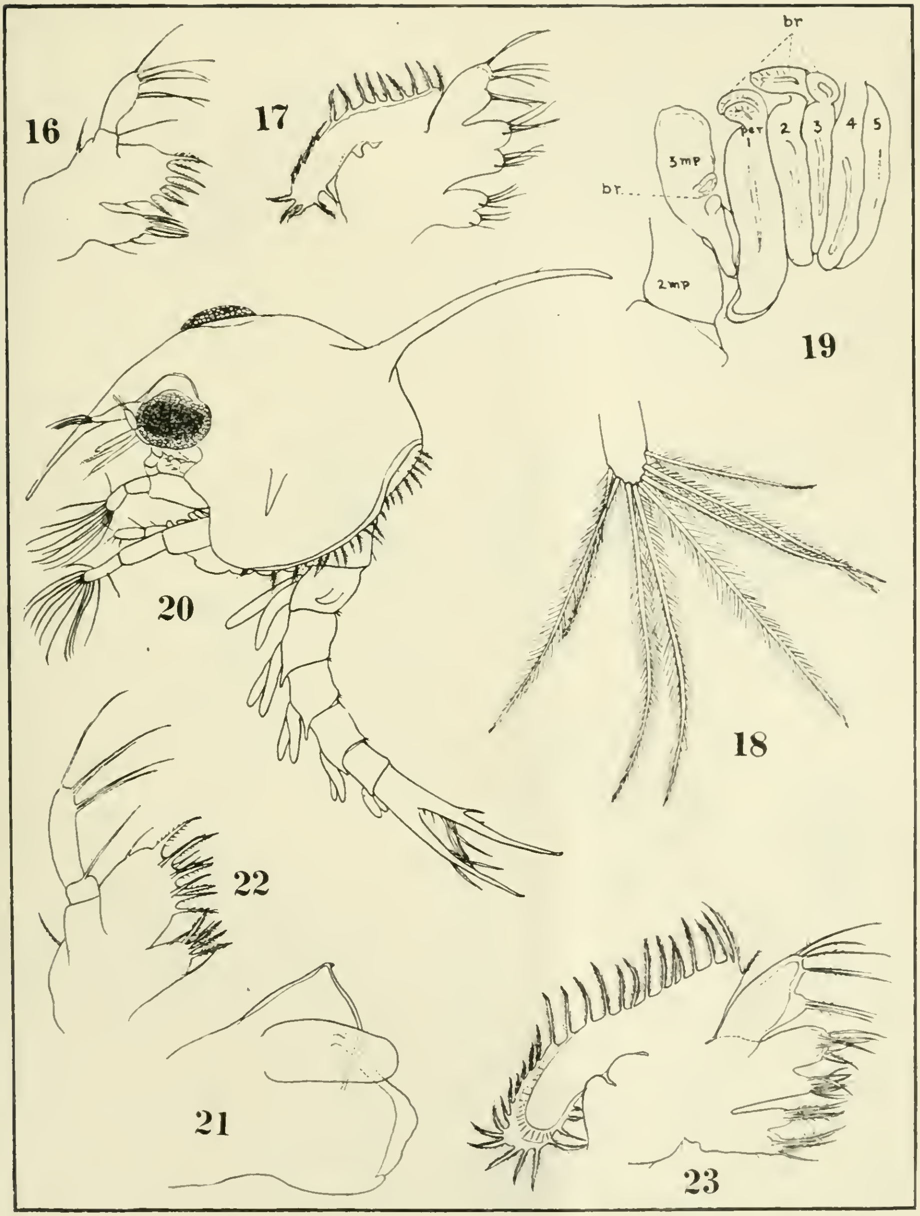


Plate III

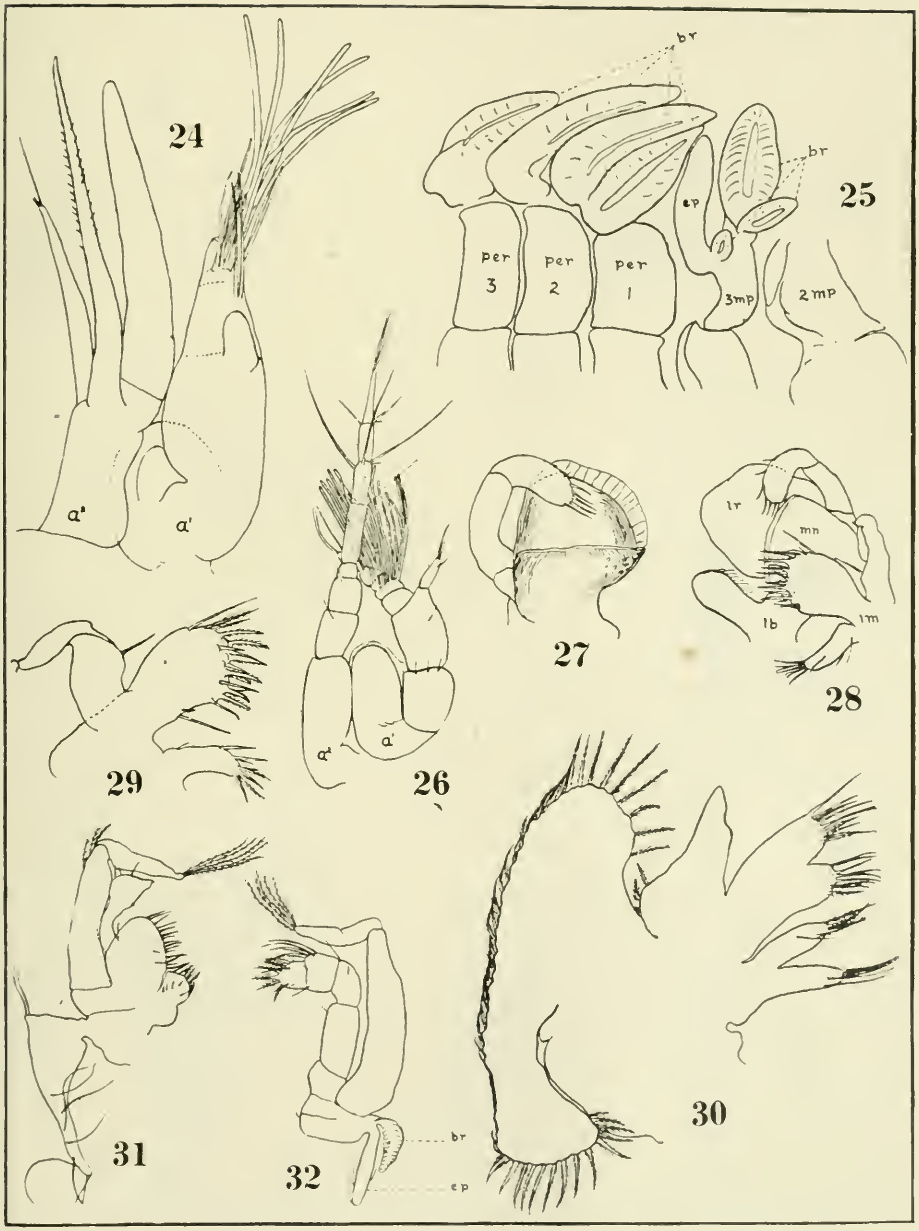
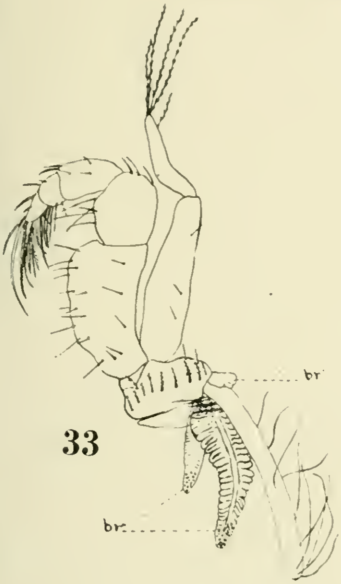
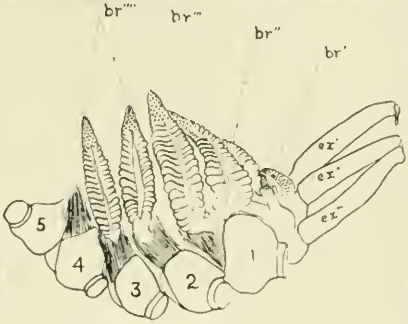

24
a'
a'
br
25
br
ep
per 3
per 2
per 1
3mp
2mp
26
a'
a'
27
lr
mn
lb
im
28
29
30
31
br
ep
32

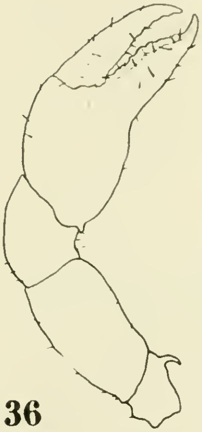
PLATE IV



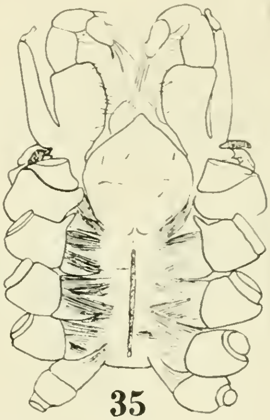
33



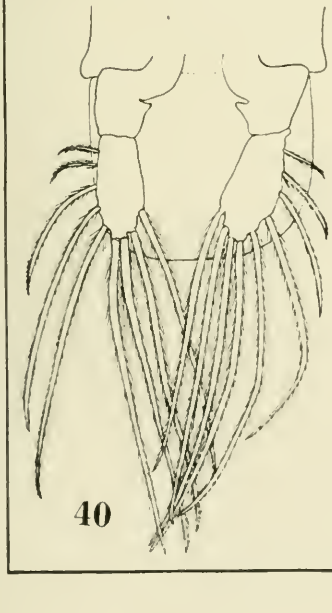
34



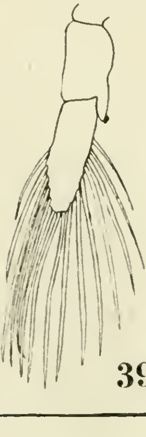
36



35

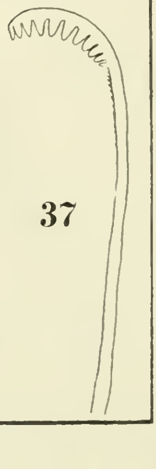


40



39

38



37

No. 18

THE CIRCULATION OF THE WATER IN THE BAY OF FUNDY

PART II

THE DISTRIBUTION OF TEMPERATURE, SALINITY AND DENSITY IN 1919 AND THE MOVEMENTS OF THE WATER WHICH THEY INDICATE IN THE BAY OF FUNDY

BY

JAMES W. MAVOR

The Circulation of the Water in the Bay of Fundy.

Part II

The Distribution of Temperature, Salinity and Density in 1919 and the movements of the water which they indicate in the Bay of Fundy.

By James W. Mavor.

CONTENTS.

1. GENERAL CONSIDERATIONS.

We are compelled to compare the phenomena of the ocean or any large geographical body of water to what we see in the small quantities of water commensurate with our senses contained in models or in regular vessels. There are, however, certain important differences. If, for example, we place a bowl of warm or cold water in a room, in the course of a few hours all the water in the bowl will have the same temperature as that of the room. The warming or cooling of the water in the bowl has been due to conduction and convection. While conduction or the actual passing of heat from molecule to molecule leads to fairly appreciable changes in the temperature of the water in the bowl, its effect on the temperature of a large body is insignificant. The convection currents are caused by the unequal heating of the water in different parts of the bowl, warmer water rising to displace colder water; their rate is determined by the temperature gradient. In the bowl this gradient may be considerable, some degrees per centimetre and distances in the water small. Convection currents in a bowl may therefore quickly lead to a complete mixing of the water and an equalizing of its temperature.

In the Bay of Fundy conditions are quite different. Except for a brief period in the early spring, which will be referred to later, the temperature decreases from the surface to the bottom. The temperature gradient is very gradual; even at the surface a difference of 1° C. in 10 metres is unusual, while at a depth of 50 metres the rate of change of temperature is usually less than 1° C. in 25 metres. It will therefore be seen that any mixing of the water comparable to that which occurs in the bowl is out of the question. Mixing of the water in the sea occurs near the atmospheric surface, due to the waves and tides, and where volumes of water moving at different velocities pass each other.

Let us carry our comparison further and place without stirring a quantity of salt water in the bottom of the bowl (the same kind of result can be obtained by placing salt in the bowl and adding fresh water, when the salt will gradually pass into solution). If the water is not stirred it will be weeks before the salt has diffused into the fresh water so as to make the salinity even approximately the same throughout the water in the bowl. Diffusion, then, which, like conduction, is a molecular phenomenon, is negligible so far as changes in salinity in the sea are concerned. We can thus understand why any large body of sea water will remain at the same temperature and salinity provided it is not mixed with water of a different temperature or salinity. When such a body of water moves, it may be recognized by its temperature and salinity.

We know that water above 4° C. expands on heating and that warmer water being lighter tends to rise if surrounded by colder water. Salinity adds to the weight of the water, so that increased salinity means increased density, provided the temperature remains the same. An increase of temperature leads to a decrease in density when the salinity remains the same.

In any large body of water which is at rest, or where there is no vertical motion, equal densities occur at equal depths, and surfaces of equal density will be horizontal and parallel to the surface of the sea. Where, as in the Bay of Fundy during the whole of the year with the exception of the short period referred to above, the temperature and salinity decrease gradually from the surface to the bottom, the surfaces of equal temperature, isothermal surfaces, and of equal salinity, isohaline surfaces, will also tend to be horizontal. It is easily seen that any relative movement of a part of the body of water will move these isothermal and isohaline surfaces and surfaces of equal density out of the horizontal. Where moving water encounters resistance it becomes heaped up and the intervals between the isothermal and isohaline surfaces become greater. Where water moves away from a given region, water from another stratum is sucked in to fill its place, and the isothermal and isohaline surfaces move correspondingly. It follows therefore that the form of the isothermal and isohaline surfaces and surfaces of equal density gives a means of determining the movement of the water. It has previously been shown how the source of a given body of water may be recognized by its temperature and salinity.

Since the density of sea water increases from the surface to the bottom and in water in a state of rest the surfaces of equal density are horizontal, it is easy to see that any displacement of the water which involves an alteration in the position of the surfaces of equal density must be accompanied by greater forces when the density gradient is rapid and the surfaces of equal density near together and by smaller forces when the gradient is slow and the surfaces of equal density farther apart.

HYDROGRAPHIC TERMS USED.

Temperature.—The temperature *in situ* in degrees C. This is determined with a Richter reversing thermometer reading to tenths of a degree, the second place of decimals being estimated by eye.

Salinity.—The total salt content in grams per 1000 grams of water calculated from the chlorine content by Knutzen's tables, the chlorine being determined by titration with silver nitrate. Symbol $S\,^0/_{00}$.

Density.—The weight in kilograms of 1000 cc. of the water. This is calculated from the salinity $S\,^0/_{00}$ by correcting for temperature. In the present investigations the correction for pressure has been omitted, being small for the depths considered. Symbol e.

Specific Volume.—$\frac{1}{\text{Density}}$. Symbol v. It is the volume in cc. of one gram of the water.

Isothermal surface.—A surface passing through the points of equal temperature in any given area. In sections isothermal curves or "isotherms" pass through points of equal temperature in the section.

Isohaline surface.—A surface passing through the points of equal salinity in any given area. In sections isohaline curves or "isohalines" pass through points with the same salinity in the section.

Surface of equal density.—A surface passing through points having the same density in any given area.

Isoteric surface.—A surface passing through the points of equal specific volume in any given area. In sections isoteric curves or "isosteres" pass through points with equal specific volume.

Stability.—The resistance of the water to displacement. It is measured by the difference in specific volume per 10 metres of depth.

2. THE HYDROGRAPHIC DATA.

Observations were made in six sections, including 28 stations in the Bay of Fundy, between August 21st and 27th. The lines of the sections are stated in Table V., and their positions given on the chart (Figure 16). A bathymetric chart of the lower half of the Bay of Fundy is shown in Figure 17. The sections were chosen so as to cover the part of the Bay where the water was over 100 metres (55 fathoms) in depth; the upper part of the Bay was not included. The directions in which the sections were made were chosen with a view to cutting at right angles the direction of the general movement indicated in the calculations from Dawson's tables. The distance between the Stations averaged about 12 kilometres (7.5 nautical miles). At each station the temperature was determined and a water sample taken at the surface and, as far as the depth permitted, at 10, 25, 50, 100, 150, 200 metres. The temperature *in situ* was determined to one-hundredth of a degree centigrade by a Richter reversing thermometer reading to one-tenth of a degree. Water samples were taken in the new Nansen stopcock water bottle (see Bjerkan :19), to which the reversing thermometer was attached. The hydrographic data are given in Table VII.

The salinities were determined and the densities *in situ* calculated by Dr. Alexander Vachon of Laval University. (For the method used by him in determining the salinities see Vachon :17 and Bjerkan :19.)

The temperatures and water samples at all of the twenty-eight stations in the Bay were taken within a period of seven days. The stations in any one section were all completed in a single day. How nearly the determinations from the observations approach the values to be expected in actual simultaneous observations can best be judged from a consideration of the data given in the tables and shown graphically in the contours and sections.

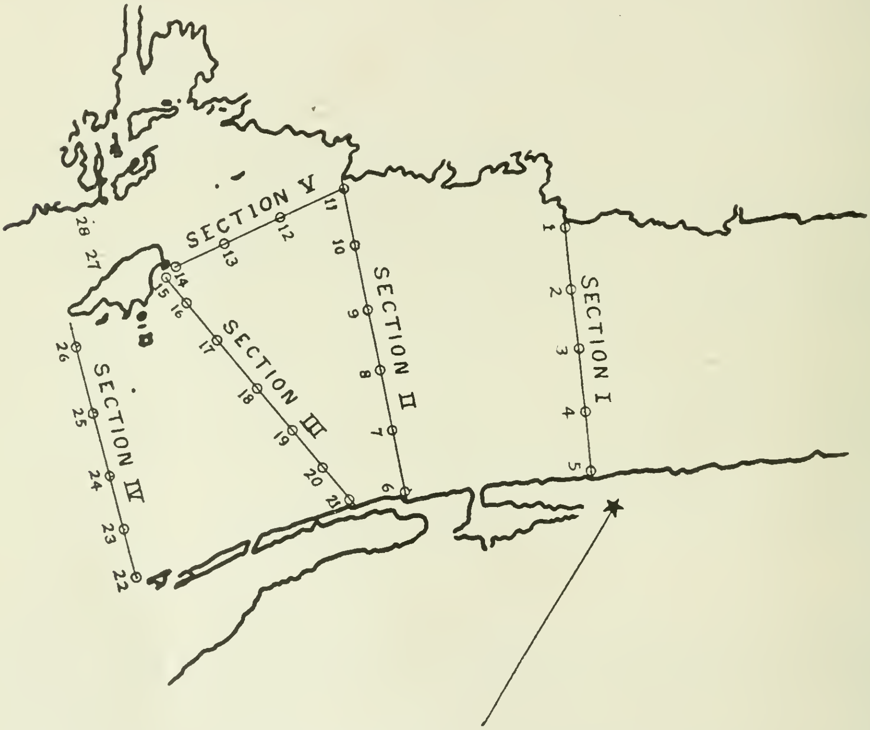


Figure 16. Location of sections and stations in the Bay of Fundy.

The strength of the tides in the Bay of Fundy makes it necessary to give them careful consideration in any attempt to determine the hydrographic conditions in the Bay. The sections will therefore first be considered in their relation to the tides.

Certain general considerations may first be mentioned. The main movement of the tide in the Bay of Fundy is in and out parallel to the long axis of the Bay. This is clearly shown by the velocity diagrams for Dawson's stations A, B, C, D, E, F given in Plates II. and III. of Part I. of this report.[1] Five of the

---

[1] In the legend of Plate III. "true north" should read "magnetic north."

hydrographic sections, numbers 1-4 and 6, extend across the Bay approximately at right angles to this movement. The other section, number 5, lies more nearly parallel to the movement of the tide. A further consideration of the velocity diagrams of Plates II. and III. of Part I. of this report shows that between high water and low water a sample of water might move, for example, a distance of some fourteen miles at Dawson's station E. This is nearly twice as great as the average distance between stations in the same section, although it is not as great as the average distance between the sections.

The state of the tide at each station when the temperature and the water sample were taken is given in Table VI. It will be noticed that usually one side of a section was made during the ebb and the other side during the flood tide. In the case of Section I. the first station to be occupied was on the northern side of the bay and the tide had been on the ebb for approximately two hours. The next three stations were occupied later on the ebb tide. While the temperature and water samples were taken at the northern stations of Section I. the movement of the water in the bay was outward. The southern station of Section I. was occupied 1 hr. and 29 min. after the beginning of the flood. In the case of Section II. exactly the reverse was the case, the first stations to be occupied were those on the southern side of the bay. Station 6 was occupied at the beginning of the ebb and the next three stations progressively later in the ebb. Station 10,

Figure 17. Depths in the lower half of the Bay of Fundy.

on the northern side of the bay, was occupied at the beginning of the flood and Station 11 somewhat later. Hence while the temperature and water samples were taken at the northern stations of Section II. the movement of the water was into the bay, and while they were taken at the southern stations the movement was out of the bay. Turning to Section III. it will be noticed that the stations of that section, which correspond in position to the stations of Section II., were occupied at about the same state of the tide as those stations were occupied. In the case of Section IV. the conditions, so far as the tide is concerned, are again reversed, so that Station 26, which is on the northern side of the bay, was occupied at the beginning of the ebb and the four stations to the southeast of it during the flood.

Figure 18. Location of stations corrected to correspond with position at high tide of water sample examined.

Using the velocity diagrams in Plates II. and III. of Part I. for Dawson's stations A, B, C, E it is possible to determine approximately where the water at different stations in the sections was at the time of high water previous to the time the station was occupied.[1] When these positions are connected the sections have

---

[1] In the legend of Plate III. "true north" should read "magnetic north."

the form shown in Figure 18. When thus charted the hydrographic data obtained at the different stations is strictly comparable since it refers in each case to the same period of the tide. The lines indicating the sections in Figure 18 are, of course, only very approximate. They are, however, sufficiently accurate to show that the sections do not in any case intersect and that the difference in the hydrographic conditions on opposite sides of the bay cannot be due to the state of the tide when the different stations were occupied.

If the reader will now turn to Plates VIII. to X., which show the hydrographic conditions found in the four sections just considered, he will at once notice the great similarity in the distribution of temperature, salinity and density in the several sections. The southeastern side of the bay shows, on the whole, a greater salinity than the northeastern side both on the ebb and flood tides,— further the shapes of the isotherms and isohalines in the sections are similar even when the temperatures and water samples at the corresponding stations were taken at different phases of the tide.

These facts justify the discussion of the general movement of the water in the bay which follows in the next section of this report. The hydrographic data may be exhibited graphically in a number of ways. Two of these have been chosen, one by drawing contour charts which represent the intersections of isothermal, isohaline or surfaces of equal density with horizontal surfaces at the depths of observation (0, 10, 50, etc., metres), Plates V. to VII.; and the other, by drawing vertical sections where the intersection of the isothermal, isohaline or surfaces of equal density are represented by the curves where they intersect the vertical planes of the sections, Plates VIII. to X.

3. THE HORIZONTAL DISTRIBUTION OF TEMPERATURE, SALINITY AND DENSITY.

In attempting to determine the circulation of the water in the Bay of Fundy it is advisable to consider together the distribution of temperature, salinity and density in the bay. An inspection of Plates V., VI. and VII. will show the similarity in the distribution of these quantities.

The greater part of the lower half of the surface of the Bay of Fundy consists of warm (temperature 11° C.), fresh (salinity 32. ‰) and light (density 1.02450) water. This water is on the northern side of the bay and would be included by a curve drawn from a point above St. John Harbour to the Island of Grand Manan and bulging out towards the Nova Scotia shore so as to extend about two-thirds of the way across the bay. It was shown in Part I. of this report and may be easily seen by reference to Figure 2, Part I., that more than half of all the fresh water which enters the Bay of Fundy enters by the St. John River at St. John Harbour. In the summer this water is relatively warm. The contour lines, therefore, show that in summer the fresh water entering the Bay of Fundy at St. John Harbour flows south and west over the bay.

The distribution of the fresh water at the surface is found to be duplicated at 10 metres, where the shape and positions of the contour lines for temperature

(10°C.), salinity (32. $^0/_{00}$) and density (1.02500) correspond closely with the shape and position of the corresponding contour lines at the surface (11° C., 32 $^0/_{00}$ and 1.0250).

At a depth of 25 metres a somewhat different distribution of these quantities is to be observed. The coldest water is in the centre of the bay and extends in a bulge toward Point Lepreaux, on the New Brunswick side. This is shown in the shape and position of the 9° contour lines. The shape and position of the 32.25 $^0/_{00}$ contour line shows that the salinity has approximately the same distribution as temperature at a depth of 25 metres.

The shape and position of the contour lines for temperature, salinity and density in the Bay of Fundy may be interpreted as indicating a movement of the colder, salter and denser water which enters the Bay of Fundy on the southern side of the bay. This movement is into the bay on the Nova Scotia side and across the bay towards the New Brunswick shore between St. John Harbour and Point Lepreaux. This is shown most clearly by the density contour line for 1.02500 at 25 metres.

At 50 metres the coldest water, under 8°C., is confined to a somewhat oval-shaped area in the centre of the bay. The salter and denser water is still found on the Nova Scotia side and extending toward the New Brunswick coast as at 25 metres.

At 100 metres the coldest (below 7°), saltest (over 32.75$^0/_{00}$) and therefore densest water (over 1.02575) is confined to the centre of the bay. The contour lines for a temperature of 7°C., salinity of 32.75 $^0/_{00}$ and density of 1.02575 are approximately circular.

Only a small portion of the Bay of Fundy attains a depth of 150 metres. Here also we find the coldest (below 7°C.) and the saltest (above 33$^0/_{00}$) water confined to circular areas at the centre of the lower portion of the bay.

It is clearly to be seen from the contour lines at 50, 100 and 150 metres for temperature, salinity and density that the colder, salter and denser water of the bottom of the bay has been caused to move upward in the centre. The upward movement of the water in the deeper and central part of the bay can be understood if one considers that water at a temperature between 8° and 9°C., and with a salinity between 32.25$^0/_{00}$ and 37.75$^0/_{00}$ enters the Bay of Fundy from the Gulf of Maine on the southern or Nova Scotia side. This tends to continue its direction of movement and to move up the Nova Scotia side of the bay.

On account of the contour of the bottom of the bay this water encounters resistance. The contour of the bottom of the Bay of Fundy is shown in Figure 17. It will be seen that the 100 metre contour line comes to lie further from the Nova Scotia coast as one moves up the bay until finally opposite Digby it crosses over to the New Brunswick side towards St. John. This conformation of the bay causes the deeper layers of this water to be deflected from its movement along the Nova Scotia coast and to move across the bay. As the water from the Gulf of Maine moves round in the Bay of Fundy and away from the centre of the bay, the surface water is sucked downward and the bottom water is sucked upward. The upward movement of the bottom water is shown in the contour lines for temperature, salinity and density for the 50, 100, 150 metre levels. The movement of the deeper water in the bay will be considered again after the vertical sections have been considered.

The distribution of temperature in the Bay of Fundy found by Craigie in 1915, and the hydrographic section made by him in 1914, may be compared to the temperature distribution shown in Plate V. The distributions are very similar. The distribution of temperature found by Craigie suggested to him (:18) that there was "a current of warm surface water from the Atlantic flowing in along the south shore and then turning north about half way up the bay." The water entering the Bay of Fundy in 1919 had a temperature between 8° and 9° and seems not to have been appreciably different in temperature from that already in the bay at the same depth.

4. THE VERTICAL DISTRIBUTION OF TEMPERATURE, SALINITY AND DENSITY.

The interpretation of the distribution seen in the sections is much helped if one bears in mind, firstly, the tendency which any body of moving water has to continue to move in the same straight line and at the same rate, and, secondly, the effect of the rotation of the earth on the moving water. The rotation of the earth gives to all water at the same parallel of latitude a certain velocity from west to east, which is greatest at the equator and falls off toward the poles. In the northern hemisphere water moving northward moves into water which is moving less rapidly from west to east than it is, and therefore acquires a relative motion toward the east. In the case of water moving southward in the northern hemisphere the reverse is the case, and the water acquires a relative movement to the west. These facts may be expressed by saying that, in the northern hemisphere, a current moving northward is deflected to the east, while a current moving southward is deflected to the west.

The best picture of the distribution of temperature and salinity in the Bay is obtained when the vertical sections are placed in their proper relations. This can be done in the simple model devised by the writer, where the isotherms or isohalines are drawn on transparent sheets of paper or on plates of glass and arranged in their proper relations over a chart. In this discussion each section must be considered separately.

We begin with Section I. across the middle of the Bay from Cape Spencer to Parker Cove. As has been seen already from the contour charts, the water generally is warmer and fresher on the New Brunswick side. The obliquity of the isotherms and isohalines on either side of the Bay, on the New Brunswick side from Stations 3 to 1, and on the Nova Scotia side from Stations 4 to 5, is conspicuous. To explain this distribution of temperature and salinity let us consider what would happen to a mass of fresh water moving along the New Brunswick shore. If it moved in a southwesterly direction the rotation of the earth, as already explained, would cause it to diverge to the west and press up against the shore; if it moved in a northeasterly direction it would diverge to the east and leave the shore. The slope of the isotherms and isohalines from Station 3 westward to the New Brunswick shore indicates that fresh water is being pressed against the shore and, therefore, moving in a southwesterly direction.

Such fresh water must obviously come from the upper part of the Bay. In the same way it is seen that the inclination of the 9° isotherm and 32.50 isohaline on the Nova Scotia side may be explained if there is a movement of salt water into the Bay on that side. The explanation of the heaping up of cold salt water at Station 4 will be apparent after Section IV. has been considered.

If Section II., taken from Gulliver Hole, N.S., to Point Lepreaux, N.B., be compared with Section I., certain differences are noticeable. On the New Brunswick side of Section II. the obliquity of the isotherms starts at Station 10, while in the previous section the obliquity of the isotherms starts at Station 4. The isotherms and isohalines in this region of Section II. are relatively much higher. These conditions indicate a slower and more superficial movement of fresh water along the New Brunswick coast at right angles to the section. The 10° isotherm and the 32.00‰ isohaline show the spreading of the fresh water over the surface of the Bay seen also in the contour charts. On the Nova Scotia side of the sections the spreading of the isotherms from Station 8 to the coast is very marked. The isohalines spread in the same way, but this is not well shown graphically because the isohalines are relatively further apart than the isotherms. This is also the reason why the heaping up of salt water in the centre of the Bay is not well shown. The explanation of this distribution is the same as that given for the distribution in Section I.

The next two sections, numbers III. and IV., provide, in the opinion of the writer, the key to the distribution and movement of the water in the Bay of Fundy. Section III. is taken from Fish Head, Grand Manan, N.B., to Centreville, N.S. The 10° isotherm and the 32.00‰ isohaline show the spreading of the fresh water over the Bay already seen in the contour charts. The fresh water in this section extends to a greater depth and the main body of it has moved slightly off shore; a possible cause of this is discussed in a later paragraph. Very conspicuous is the rising of the cold (below 7°) and salt (above 33.00‰) water in the middle of the section. This is accompanied by a spreading of the isothermal and isohaline lines from the centre, Station 18, to either side of the Bay. This striking distribution of the water is undoubtedly due to a rotation of the deeper water about Station 18 as a centre. Any salt water entering the Bay of Fundy must enter from the Gulf of Maine. If this salt water enters on the southeast side of the bay off the Nova Scotia coast, it should be deflected in an easterly direction on to the coast. Water at a depth of 50 to 150 m. moving in this direction should soon encounter the bottom at the 100 metre (55 fathom) contour line or the resistance of the shallow water and be deflected westward across the bay. This should give rise to a left-handed or counter clockwise rotation of the water in the lower half of the bay. In this case the moving water would be continually pressing against the sides of the Basin and the more slowly moving water of the deepest part of the bay would rise up to fill its place. This is the condition seen in the sections. If, on the other hand, the salt water entered the northwest side off the coast of Grand Manan, it would be deflected by the rotation of the earth in an easterly direction, would cross the bay and rotate spirally in a right-handed or clockwise direction toward the center of the basin. This would force the water of the current down to deeper layers, producing the sinking center of an anticyclonic current; the reverse of what occurs in the Bay of Fundy. The cold (9° to 7°) and salt (32.25 ‰ to 33.00 ‰) water after circling the basin of the bay leaves it on the northwestern side, off the coast of Grand Manan.

The two sections left, numbers V. and VI., will help us to decide whether this deep salt water leaving the Bay goes to the northwest as well as the south of Grand Manan. The cyclonic movement of the deeper water produces on account of the rising center superficial currents from the center of the bay toward its shores. These currents may be the reason of the greater depth to which the fresh water layer extends on the New Brunswick side of Section IV.

Section V., taken from Point Lepreaux to Fish Head, Grand Manan, shows a slanting of the isotherms and isohalines from Grand Manan downward to Point Lepreaux. Such a condition could result from a movement of the deeper water from the New Brunswick side of the bay southward to the east of Grand Manan.

It is difficult to determine the horizontal movement of the water in Section VI., in which there are only two stations. The temperatures, salinities, and densities show very little differences either between the stations or between the surface and the bottom. There is undoubtedly a great deal of mixing of water at the different depths in this shallow channel. This mixing makes it difficult to draw isotherms and isohalines. However, Station 27 on the Grand Manan side is on the whole less cold and salt than Station 28 taken on the New Brunswick side. Station 27 was occupied at 3 hrs. 12 min. ebb and Station 28 at 4 hrs. 1 min. ebb. It seems unlikely that any great general movement of the water could occur where the resistance to the tide is such as to cause great mixing.

The question arises as to whether the circulation which has been shown to take place during the summer months goes on during the rest of the year, and if so, to what conditions it gives rise. Considerable light is thrown on this by the series of observations made at "Prince Station 3", which is identical with our Station 17 of Section IV. This station was taken monthly for a period of twenty-two months. I am kindly permitted by Dr. Alexander Vachon to use in advance of publication his figures for salinity and density at this station, and certain of his figures for temperature and salinity are reproduced in Table VIII. There is clearly a very rapid mixing of the surface water with the deeper water down to the bottom of the Bay when the stability is low, in the spring, in April in 1917 and 1918. During the summer from July to October warm fresh water flows out over the surface of the Bay and gives rise to the marked stratification of the water seen in the hydrographic sections. The stability of the water is then high, and it is unlikely that any great interchange occurs between the surface and the deeper water. In the winter this supply of fresh water is cut off owing to the freezing up of the rivers and the land. The water of the Bay then becomes salter and more uniform, owing to the constant inflow of salt water from the Gulf of Maine. The cooling of the water at the surface increases its density until it becomes almost as dense as the warmer but salter water below. The stability then decreases in places to zero or becomes negative. This gives rise to the rapid mixing which occurs in April.

It is clear that the cyclonic circulation demonstrated in the sections and contours, combined with the mixing occurring in the spring, brings about a complete changing of the water in the Bay at least once a year.

In August, 1914, under the direction of the writer, E. Horne Craigie ('14) made a hydrographic section across the Bay of Fundy from E. Quoddy Head, Campobello Island, N.B., to Boar's Head, Petite Passage, N.S. In this section there is a spreading of the isotherms on either side of the Bay as was found in 1919. Unfortunately, at that time it was only possible to determine the density with a hydrometer. Even there approximate figures show the spreading of the isohalines corresponding to the isotherms. In July, 1915, Craigie ('18) made a more extensive exploration of the Bay of Fundy, making three transverse and one longitudinal section, one of the transverse sections being a repetition of the 1914 section. Unfortunately salinities were not determined, temperatures alone being available for comparison with the figures for 1919. However, there is evident in Craigie's sections the same spreading of the isotherms on either side of the Bay and towards the upper part of the Bay in the longitudinal section. This may be taken to indicate the presence of the cyclonic circulation evident in our 1919 sections.

5. THE RELATION OF THE CIRCULATION OF THE WATER IN THE BAY OF FUNDY TO THAT IN THE GULF OF MAINE.

For a complete understanding of the hydrography of the Bay of Fundy a knowledge of the conditions and movements of the adjacent waters is necessary. The Hydrography of the Gulf of Maine has been investigated by Bigelow (:14, :15, :17) during a series of years. The following is quoted from one of his reports (:17, pp. 234-235): "The northern water on our coast (Gulf of Maine) is chiefly of St. Lawrence, not of Labrador Current origin." "Salinities, temperatures and current records combined, reveal an unmistakable current, flowing from northeast to southwest, along the southeast coast of Nova Scotia in August, 1914, with a velocity of 1 knot per hour, only 30 miles from the entrance of the Gulf of Maine . . . There is an important and well-known outflow from the Gulf of St. Lawrence along the west side of Cabot Straits, the Cabot Current, (Dawson, 1896, 1913), the natural presumption would be that our Nova Scotia current is the direct continuation of the latter."

"Actual hydrography further supports this contention, for both in salinity, in minimum temperature, in the degree to which solar warming progresses in summer in the surface layers, in the level at which the temperature is at its minimum, and in the superficiality of the cold water, our Nova Scotia Current agrees very closely with the outflow in Cabot Straits, as well as with the neighbouring parts of the Gulf of St. Lawrence (Dawson, 1913), with which it is actually continuous both in temperature (Townsend, 1901), and in salinity (Dickson, 1901)." The presence of the Cabot Current east of the Nova Scotia coast was demonstrated by the Canadian Fisheries Expedition (see Hjort :19).

Concerning the influence of the Cabot Current in the Gulf of Maine, Bigelow (:17) remarks: "The influence of the Cabot Current, in the Gulf, is most evident at about 40 metres, its effect on temperature and salinity being limited to the upper 100 metres, even when at its maximum; and it is certain that though it flows southward along the eastern slope of Brown's Bank in summer, it neither crosses the latter nor follows it around to the west at that season, but exhibits a greater and greater tendency to recurve upon itself off Shelburne as the depth increases, the Eastern Channel being much warmer and salter."

It is of importance to determine whether any part of the Cabot Current enters the Bay of Fundy. Conclusive evidence from a hydrographic point of view could be obtained only by simultaneous observations off the south-eastern and southern coasts of Nova Scotia and in the Bay of Fundy. Unfortunately such observations are not at present available. That northern water does enter the Bay of Fundy is indicated by the plankton, especially that from the Nova Scotia side of the Bay (see Huntsman :19).

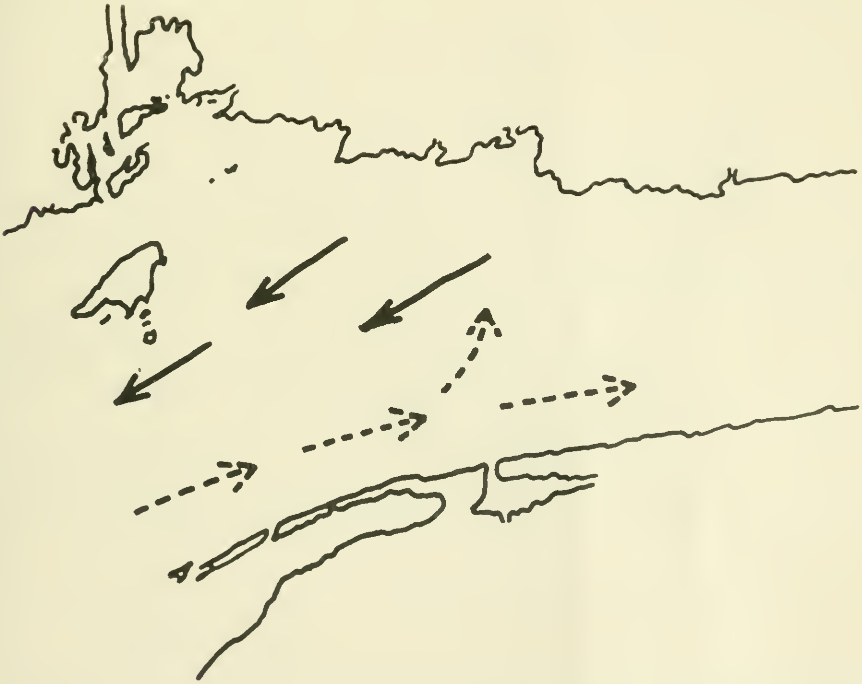


Figure 19. Diagrammatic representation of the movement of the water in the Bay of Fundy deduced from the hydrographic data.

The movement of the fresh water at the surface of the Bay of Fundy on the New Brunswick side out of the bay on that side and down the northwestern coast of the Gulf of Maine has already been discussed in Part I. of this report.

6. SUMMARY.

The consideration of the hydrographic data obtained in the present investigation shows conclusively that there is a movement of water into the Bay of Fundy from the Gulf of Maine around the southern end of the Nova Scotia coast and along the eastern side of the Bay of Fundy. This movement is most marked at a depth of 50 metres but can be recognized from the surface to a depth of 100 metres. It extends into the Bay of Fundy on the Nova Scotia side at least 12 miles below the Gut of Digby. A portion of this water probably moves across the bay towards St. John Harbour. A diagram of the movement of the water in the Bay of Fundy, deduced from the hydrographic data, is shown in Figure 19.

NOTE. A bibliography will appear at the end of Part III. of this report.

TABLE V.

HYDROGRAPHIC SECTIONS IN THE BAY OF FUNDY.

Section I.	Cape Spencer, N.B., to Parker Cove, N.S.	Stations 1- 5.
Section II.	Gulliver Hole, N.S., to Point Lepreaux, N.B.	Stations 6-11.
Section III.	Fish Head, Grand Manan, N.B., to Centreville, N.S.	Stations 15-21.
Section IV.	Southern end of Brier Island, N.S., to S. W. Head, Grand Manan, N.B.	Stations 22-26.
Section V.	Point Lepreaux, N.B., to Fish Head, Grand Manan, N.B.	Stations 11-14.
Section VI.	Grand Manan, N.B., to Coast of Maine	Stations 27-28.

TABLE VI.

STATE OF THE TIDE WHEN THE HYDROGRAPHIC STATIONS WERE OCCUPIED.

Section I, August 21, 1919.

	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5
Mean time at station.	9:30 a.m.	10:41 a.m.	11:59 a.m.	1:17 p.m.	2:50 p.m.
Tide.	1hr. 53min. ebb	3hrs. 4min. ebb	4hrs. 22min. ebb	5hrs. 40min. ebb	1hr. 29min. flood

Section II, August 22, 1919.

	Sta. 11	Sta. 10	Sta. 9	Sta. 8	Sta. 7	Sta. 6
Mean time at station.	3:46 p.m.	2:35 p.m.	1:09 p.m.	11:43 a.m.	10:16 a.m.	8.51 a.m.
Tide.	1hr. 15min. flood	0hrs. 5min. flood	4hrs. 27min. ebb	3hrs. 1min. ebb	1hr. 34min. ebb	0hrs. 9min. ebb

Section III, August 26, 1919.

	Sta. 15	Sta. 16	Sta. 17	Sta. 18	Sta. 19	Sta. 20	Sta. 21
Mean time at station.	7:31 a.m.	8:20 a.m.	9:45 a.m.	11:19 a.m.	12:41 a.m.	1:59 p.m.	3:17 p.m.
Tide.	1hr. 28min. flood	2hrs. 17min. flood	3hrs. 42min. flood	5hrs. 15min. flood	0hrs. 37min. ebb	1hr. 55min. ebb	3hrs. 13min. ebb

Section IV, August 27, 1919.

	Sta. 26	Sta. 25	Sta. 24	Sta. 23	Sta. 22
Mean time at station.	1:22 p.m.	12:17 p.m.	10:43 a.m.	8:54 a.m.	7:37 a.m.
Tide.	0hrs. 36min. ebb	5hrs. 33min. flood	3hrs. 59min. flood	2hrs. 10min. flood	0hrs. 13min. flood

Section V, August 23, 1919.

	Sta. 11	Sta. 12	Sta. 13	Sta. 14
Mean time at station.	7:56 a.m.	9:13 a.m.	10:35 a.m.	11:53 a.m.
Tide.	4hrs. 23min. flood	5hrs. 40min. flood	0hrs. 55min. ebb	2hrs. 13min. ebb

Section VI, August 27, 1919.

	Sta. 27	Sta. 28
Mean time at station.	3:58 p.m.	4:47 p.m.
Tide.	3hrs. 12min. ebb	4hrs. 1min. ebb

NOTE—"Mean time at station" is the mean of the time of beginning and ending observations at the station. The time consumed in making the observations was in no case more than 31 minutes. Opposite "tide" is given the time after low water in the case of the flood and after high water in the case of the ebb.

TABLE VII.

HYDROGRAPHIC RECORDS OF SECTIONS MADE ACROSS THE BAY OF FUNDY IN AUGUST, 1919.

Section I., Cape Spencer, N.B., to Parker's Cove, N.S., August 21.

Station Number	Hour	Temperature of air	Depth in metres	Temperature of water	Salinity S ⁰/₀₀	Density in situ, *P*	Specific volume, *v*
1	9.30 a.m.	13.69°	0	11.04°	31.29	1.02391	.97665
	9.30		12	10.74	31.53	2415	642
2	10.36	13.16°	0	11.57°	31.44	1.02394	.97662
	10.45		10	10.13	31.78	2444	614
	10.45		25	9.91	32.00	2467	592
	10.36		50	9.00	32.25	2500	561
	10.36		75	8.22	32.41	2524	538
3	11.54	12.52°	0	10.62°	32.14	1.02465	.97594
	12.04 p.m.		10	9.56	32.23	2490	570
	12.04		25	8.64	32.39	2516	546
	11.54 a.m.		50	8.47	32.45	2523	539
	11.54		75	8.35	32.45	2524	538
4	1.12 p.m.	14.23°	0	10.39°	32.09	1.02467	.97592
	1.22		10	8.71	32.39	2515	547
	1.22		25	8.54	32.43	2521	541
	1.12		50	8.49	32.57	2533	530
	1.12		75	8.52	32.59	2534	529
5	2.50	15.86°	0	10.67°	32.45	1.02488	.97572
	2.50		10	9.25	32.45	2511	551
	2.50		25	9.27	32.47	2513	548

Section II., Gulliver Hole, N.S. to Point Lepreaux, N.B., August 22.

Station Number	Time of Obser-vation	Temper-ature of air	Depth in metres	Temper-ature of water	Salinity S ‰	Density in situ	Specific Volume
6	8.51 a.m.	17.21°	0	9.44°	32.41	1.02505	.97556
	8.51		10	9.26	32.45	2511	550
	8.51		25	9.32	32.50	2514	548
7	10.08	14.23°	0	11.29°	32.14	1.02453	.97606
	10.24		10	9.65	32.38	2499	562
	10.08		25	9.31	32.43	2510	551
	10.24		50	8.40	32.63	2538	525
	10.08		100	8.08	32.68	2547	516
8	11.38	14.38°	0	11.17°	31.82	1.02430	.97628
	11.48		10	10.75	32.03	2454	605
	11.38		25	8.64	32.43	2519	543
	11.48		50	7.88	32.57	2540	523
	11.38		100	7.59	32.79	2562	502
9	1.03 p.m.	13.61°	0	11.57°	31.96	1.02434	.97624
	1.15		10	10.07	32.12	2473	587
	1.03		25	8.71	32.32	2508	553
	1.15		50	7.48	32.61	2549	514
	1.03		100	7.38	32.70	2557	507
10	2.30	12.90°	0	12.00°	31.78	1.02412	.97645
	2.40		10	11.75	31.85	2422	635
	2.30		25	8.34	32.32	2515	547
	2.40		50	7.51	32.39	2533	530
	2.30		100	7.40	32.66	2555	509
11	3.46	13.22°	0	10.59°	31.38	1.02406	.97651
	3.46		10	9.98	31.71	2440	618
	3.46		25	10.05	31.80	2448	610

Section III., August 26.

Station Number	Time of Observation	Temperature of air	Depth in metres	Temperature of water	Salinity S ⁰/₀₀	Density in situ	Specific volume
15	7.31 a.m.	13.41°	0	11.16°	31.58	1.02411	.97646
	7.31		10	9.78	31.78	2448	610
	7.31		25	9.40	31.98	2472	588
16	8.15	12.45°	0	10.86°	31.64	1.02422	.97635
	8.24		10	10.55	31.64	2427	630
	8.15		25	9.84	31.80	2451	608
	8.24		50	8.70	32.32	2510	551
	8.15		100	7.34	32.95	2580	485
17	9.29	12.53°	0	11.25°	31.55	1.02406	.97651
	10.00		10	11.14	31.65	2418	639
	10.00		25	9.08	32.14	2489	571
	9.46		50	7.85	32.59	2543	520
	9.29		100	7.07	32.88	2577	488
	9.46		150	7.02	32.97	2584	481
	9.29		175	6.69	33.10	2599	467
18	11.08	13.58°	0	11.46°	31.55	1.02404	.97652
	11.29		10	11.31	31.71	2419	638
	11.20		25	9.76	32.12	2477	583
	11.08		50	8.04			
	11.20		100	6.94	32.99	2588	477
	11.08		150	6.72	33.10	2599	467
19	12.29 p.m.	13.53°	0	10.66°	32.12	1.02464	.97595
	1.53		10	9.04	32.57	2524	538
	12.45		25	8.20	32.54	2533	530
	12.29		50	8.11	32.63	2542	521
	12.45		100	7.16	32.95	2582	483*
	12.29		125	7.33	32.95	2579	486*
20	1.54	13.00°	0	9.97°	32.36	1.02492	.97569
	2.04		10	9.06	32.38	2508	553
	1.54		25	8.93	32.57	2526	536
	2.04		50	8.06	32.68	2548	515
	1.54		100	7.98	32.77	2555	509
21	2.17	13.71°	0	10.05°			
	2.17		10	9.44	32.59	2520	542
	2.17		25	9.41	32.59	2521	541

* These records should probably be interchanged.

Section IV., August 27

Station Number	Time of Observation	Temperature of air	Depth in metres	Temperature of water	Salinity S ⁰/₀₀	Density in situ	Specific volume
22	7.33 a.m.	11.63°	0	9.35°	32.36	1.02503	.97558
	7.41		10	9.26	32.36	2505	556
	7.33		25	8.75	32.54	2526	536
	7.33		50	8.62	32.59	2532	531
23	8.39	12.10°	0	9.89°	32.16	1.02479	.97581
	9.09		10	9.69	32.18	2483	577
	9.09		25	8.96	32.48	2519	543
	8.58		50	8.56	32.63	2543	520
	8.39		100	8.10	32.63	2543	520
	8.58		150	7.50	32.77	2562	502
	8.39		185	7.56	32.83	2566	498
24	10.28	14.12°	0	9.91°	32.14	1.02477	.97583
	10.58		10	9.71	32.23	2487	573
	10.58		25	9.13	32.27	2499	562
	10.45		50	8.82	32.27	2505	556
	10.28		100	7.72	32.75	2557	507
	10.45		150	7.15	32.86	2574	491
	10.28		195	6.74	33.08	2598	468
25	12.12 p.m.	13.10°	0	9.54°	32.09	1.02478	.97582
	12.22		10	8.87	32.25	2502	559
	12.12		25	8.86	32.29	2505	556
	12.22		50	8.52	32.41	2521	541
	12.12		100	8.46	32.48	2527	535
26	1.22	13.91°	0	9.71°	32.01	1.02470	.97590
	1.22		10	9.37	32.01	2475	585
	1.22		25	9.81	32.09	2475	585

Section V., Point Lepreaux, N.B., to Fish Head, Grand Manan, N.B., August 23.

Station Number	Time of Observation	Temperature of air	Depth in metres	Temperature of water	Salinity S ⁰/₀₀	Density in situ	Specific Volume
11	7.56 a.m.	12.40°	0	11.13°	31.49	1.02407	.97650
	7.56		10	10.94	31.49	2409	648
	7.56		25	10.99	31.51	2410	647
12	9.09	12.49°	0	11.20°	31.35	1.02396	.97660
	9.17		10	11.01	31.44	2407	650
	9.09		25	10.44	31.53	2419	638
	9.09		50	9.34	31.91	2468	591
13	10.30	12.88°	0	11.40°	31.44	1.02396	.97660
	10.40		10	10.47	31.67	2430	628
	10.30		25	9.87	31.78	2448	610
	10.40		50	8.24	32.27	2512	550
	10.30		100	7.27	32.68	2559	505
14	11.53	16.28°	0	9.79°	31.96	1.02465	.97594
	11.53		10	9.35	31.94	2470	590
	11.53		25	9.20	32.05	2481	579

Section VI., August 27.

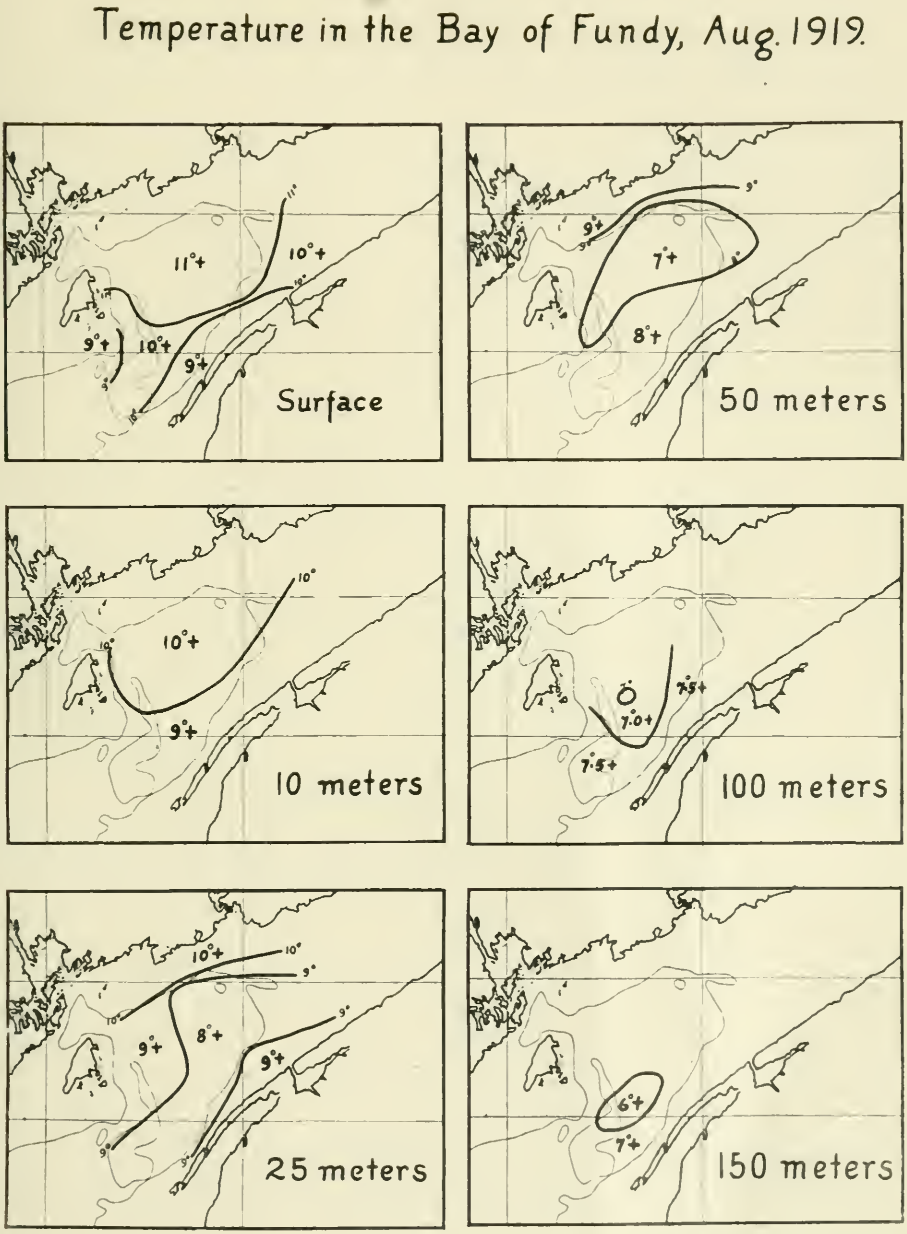
Station Number	Time of Observation	Temperature of air	Depth in metres	Temperature of water	Salinity S ⁰/₀₀	Density in situ	Specific volume
27	3.53 p.m.	13.91°	0	9.88°	32.01	2469	.97590
	4.02		10	9.45	32.01	2474	586
	4.02		25	9.80	32.05	2480	580
	3.53		50	9.25	32.05	2481	579
	3.53		85	9.40	32.09	2481	579
28	4.42	11.75°	0	9.83°			
	4.51		10	9.10	32.14	2489	571
	4.51		25	9.14	32.20	2493	568
	4.42		50	9.09	32.20	2494	567
	4.42		80	9.25	32.20	2492	569

TABLE VIII.

TEMPERATURE, SALINITY AND STABILITY AT PRINCE STATION 3 (STATION 17 OF SECTION IV. IN 1919) FROM AUGUST 25TH, 1916, TO MAY 10, 1918.

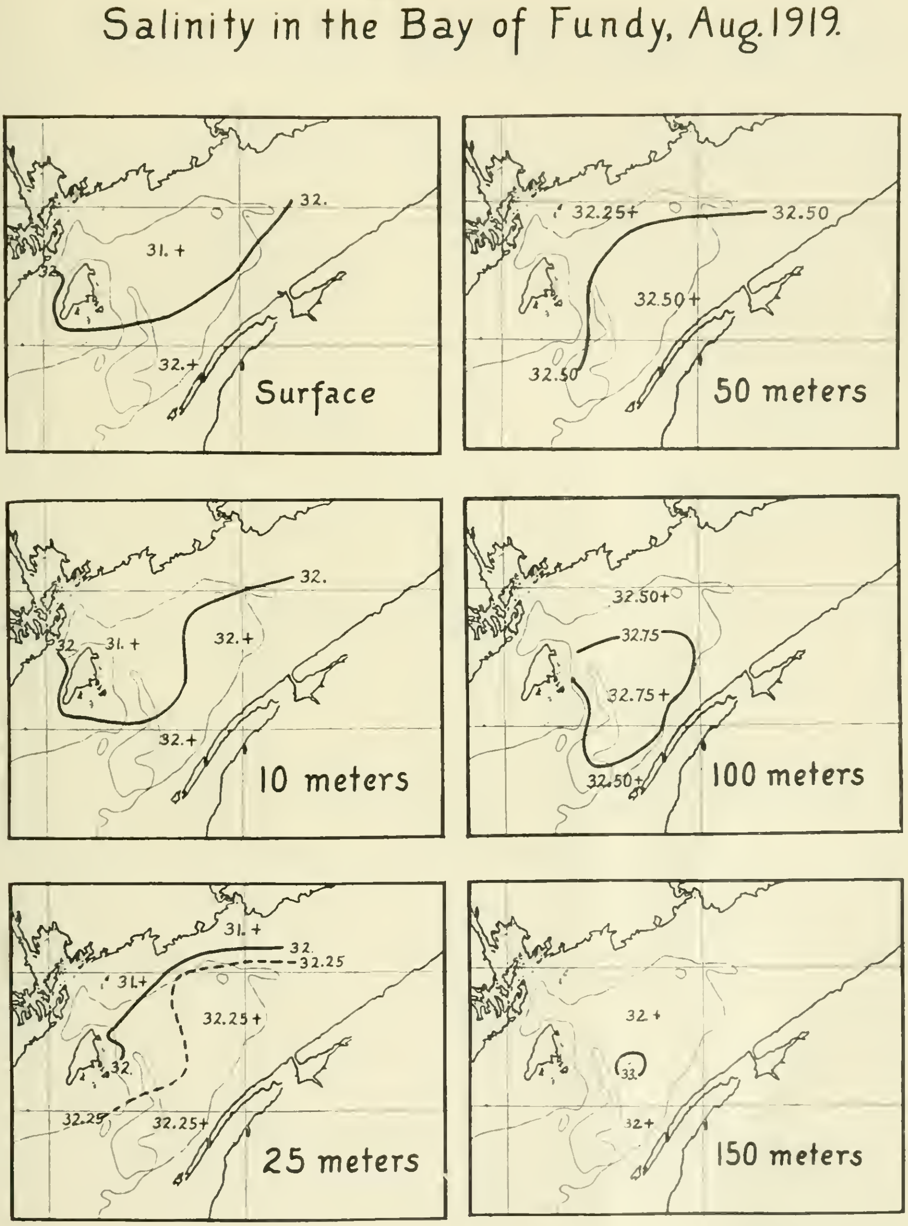
TEMPERATURES.

	1916				1917											1918		
	Aug. 25	Oct. 4	Nov. 6	Dec. 2	Jan. 3	Feb. 7	Feb. 28	Apr. 9	May 4	June 15	July 4	July 31	Sept. 4	Oct. 2	Dec. 5	Jan. 19	Apr. 9	May 10
0	10.98	11.07	7.55	6.18	3.69	1.46	1.47	2.27	2.96	8.18	8.68	12.18	12.19	9.77	5.62	2.39	1.98	4.19
10	9.87	10.05	7.62	6.33	4.04	1.20	1.59	2.27	2.18	6.23	7.74	9.18	11.18	9.69	5.81	3.23	2.02	4.17
30		8.59	.64	6.78	4.47	1.99	1.81	2.36	2.22	4.68	6.12	6.48	8.88	9.16	5.83	2.56	2.13	3.62
50	7.43	7.92	.62	6.42	4.56	2.44	1.99	2.05	2.01	4.13	5.06	6.01	7.65	8.76	5.72	2.58	1.98	2.35
75	6.47	6.70	.28	6.62	4.77	3.12	2.27	2.01	2.83	3.77	4.20	5.55	6.69	7.73	6.12	2.59	1.98	1.99
100	6.10	6.35	.08	6.60	5.30	3.20	2.95	1.87	2.23	3.92	4.50	5.08	6.13	7.37	6.16	2.60	2.17	2.01
125	6.02			6.64	5.12	3.36	2.53	1.73	1.93	3.91	4.28	4.96	5.94	7.30	6.15	2.60	2.18	1.99
150	5.83	6.12	6.30	6.69	5.33	3.22	2.49	1.75	2.08	3.87	4.21	4.88	6.15	7.08	6.14	2.63	2.35	1.99
175	5.82	6.13	6.33	6.60	4.59	3.35	2.56	1.71	2.11			4.78	6.06	6.74	6.18	2.64	2.41	2.02
SALINITIES.																		
0	31.77		32.72	32.77	32.61	32.72	32.66	32.56	27.90	31.49	30.61	31.22	31.92	32.27	32.01	31.91	32.23	28.48
10		31.92		.84	.66	.74	.68	.56	30.99	31.65	30.70	31.67	.94	.29	.05	.98	27	28.48
30				.86	.84	.77	.84	.57	32.12	32.05	31.85	32.14	.23	.34	.07	.96	.30	30.77
50	32.41	32.61	32.75	.86	.95	.95	.92	.57	32.32	32.39	32.27	.34	.75	.43	.03	31.96	.32	31.82
75	32.60	32.42	32.83	.90	33.03	33.03	.95	.61	32.39	32.65	32.41	.63	.97	.66	32.47	32.01	.34	32.16
100	32.85		32.88	.95	.24	33.06	.97	.66	32.50	32.70	32.43	.95	.99	.81	.72	32.03	.36	32.18
125	32.93			.97	.28	.00	.99	.66	32.54	32.88	32.59	33.26	.99	.88	.75	32.03	.36	32.27
150	32.93	32.51	32.97	.99	.30	.10	.99	.72	32.72	32.88	32.66	33.30	33.03	.90	.81	32.05	.61	32.29
175	32.95	32.98		.99	.33	.17	33.01	.72	32.72			33.30	.01	.90	.86	32.07	.61	32.30
STABILITIES.																		
15	134		6	16	38	22	8	0	1670	283	49	472	251	47	13	10	22	592
40	244	76		−5	34	33	24	10	86	152	219	145	271	57	0	0	5	585
63	99	8	46	4	15	4	4	10	0	87	76	78	121	130	61	15	0	12
87	102		26	20	40	4	0	20	46	15	4	117	30	65	110	8	0	−4
113	23	2		4	19	4	4	4	19	17	64	169	12	19	12	0	0	30
137	15		32	0	0	19	0	20	42	4	12	19	0	8	16	4	68	4
163	0	137	0	4	16	0	4	0	0	0	0	8	0	38	11	8	0	4



J.W. Mavor Del.

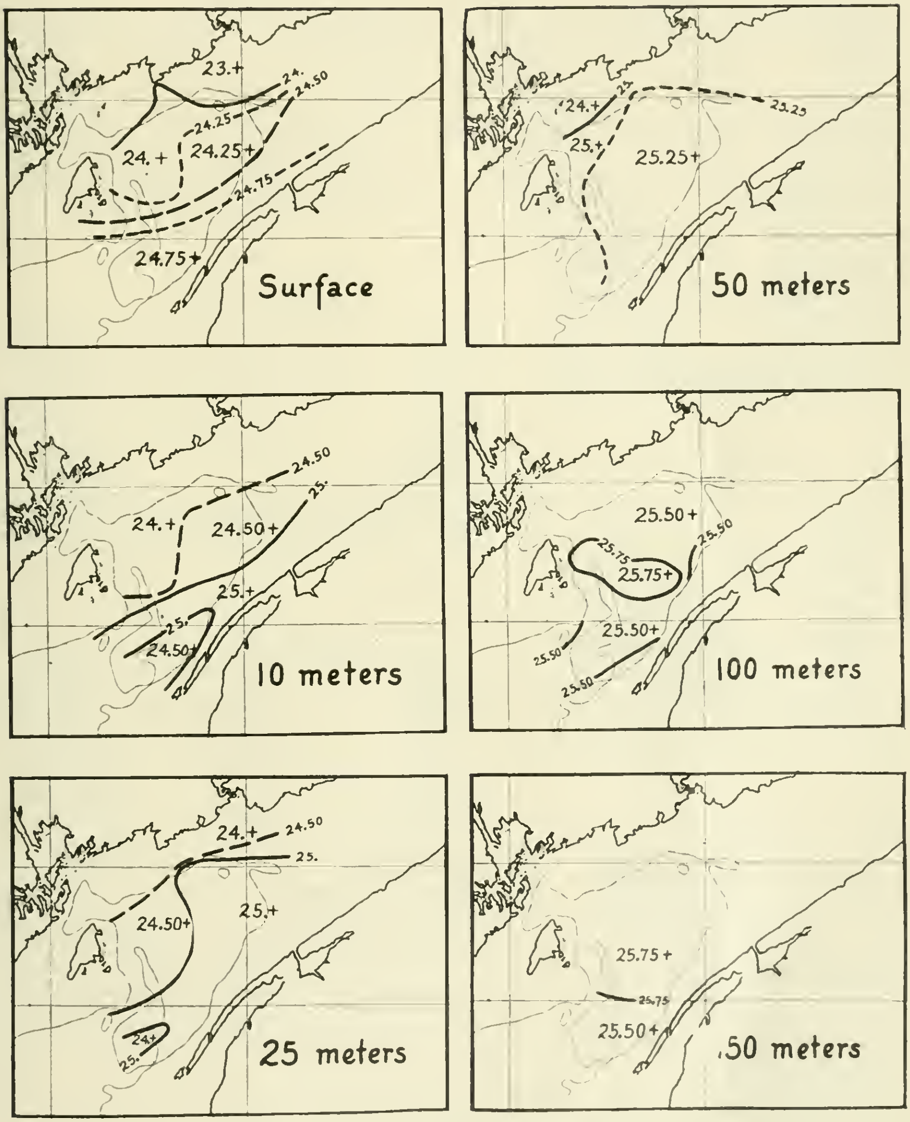
Plate V. Temperature contours in the Bay of Fundy in August, 1919.



J.W. Mavor Del.

Plate VI. Salinity contours in the Bay of Fundy in August, 1919.

Density in the Bay of Fundy, Aug. 1919.



J.W. Mavor Del.

Plate VII. Density contours in the Bay of Fundy in August, 1919.

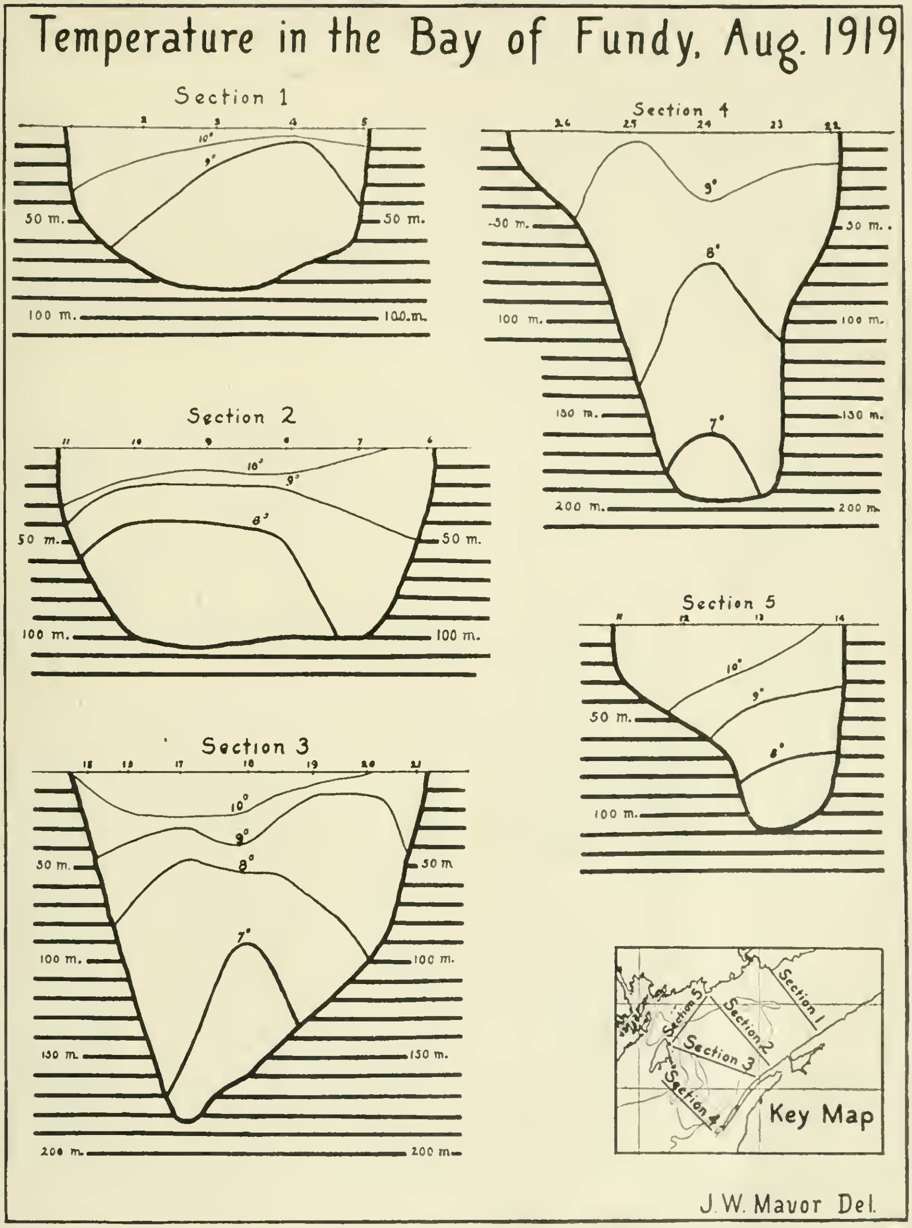


Plate VIII. Temperature sections in the Bay of Fundy in August, 1919.

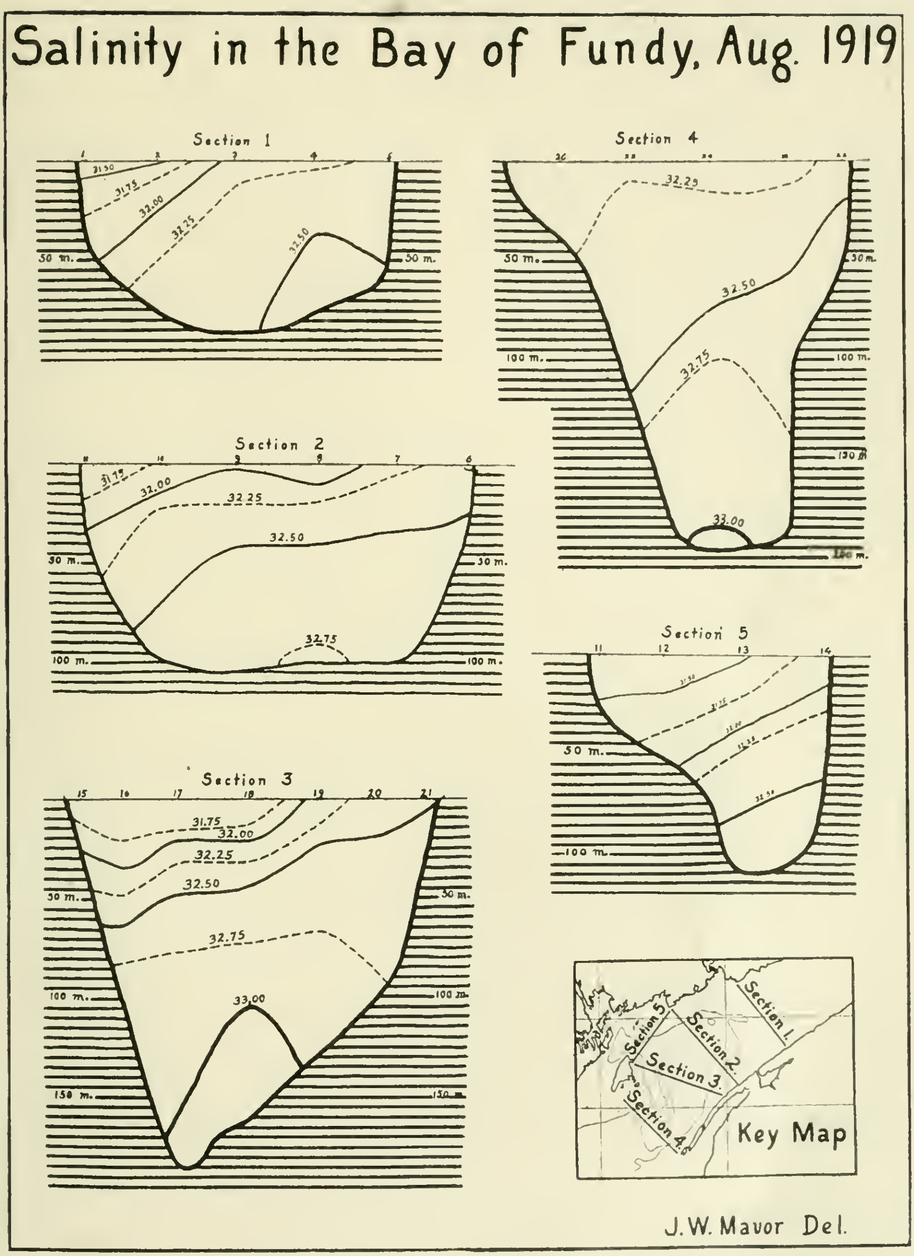


Plate IX. Salinity sections in the Bay of Fundy in August, 1919.

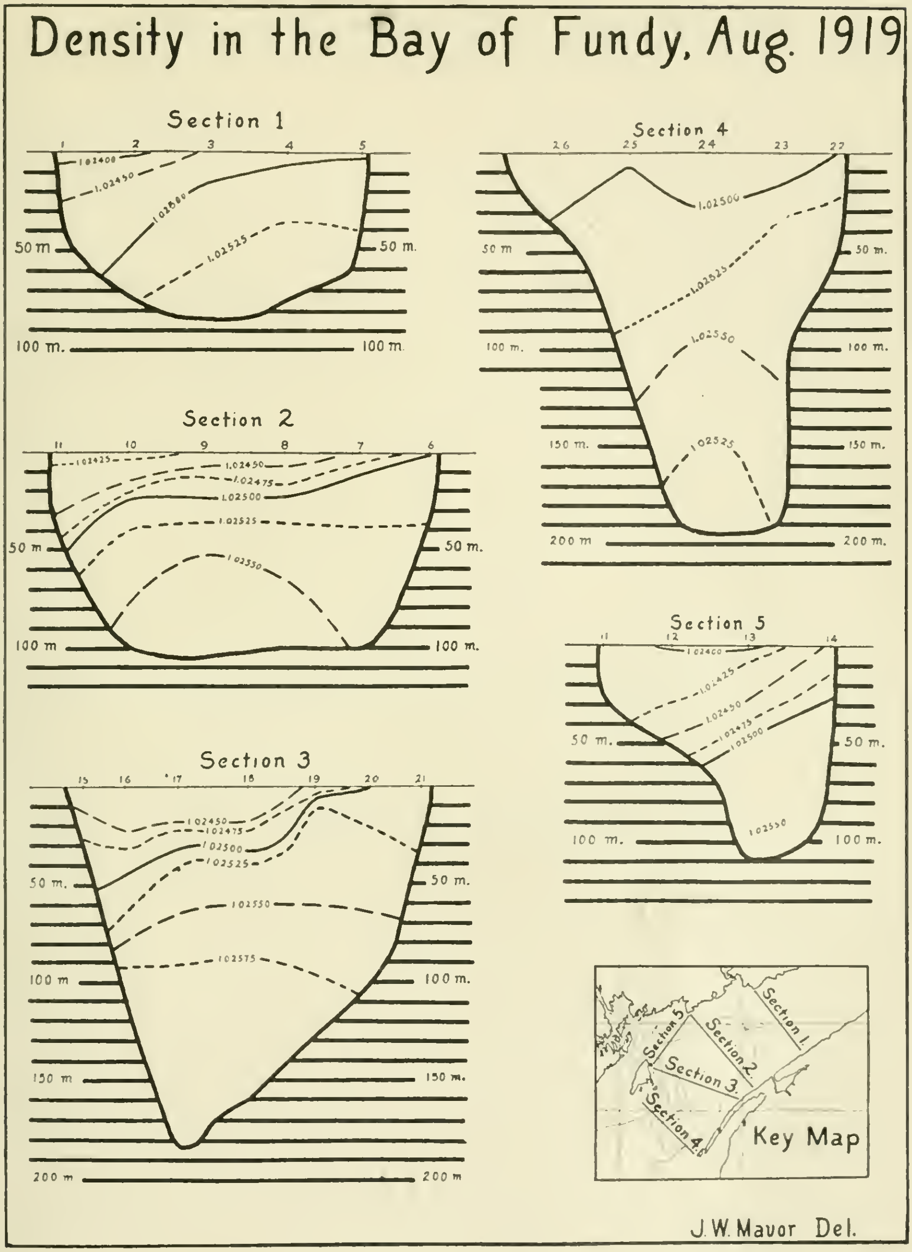


Plate X. Density sections in the Bay of Fundy in August, 1919.

No. 19

MARINE SPORE FORMING BACTERIA

BY

DOROTHY E. NEWTON, M.SC.

Marine Spore Forming Bacteria.

By Dorothy E. Newton, M.Sc.

This investigation was undertaken with the object of isolating and studying the spore forming bacteria found in the sea, in fish and shell-fish such as herring, clam, lobster, etc. The economic application of the investigation is based on the fact that certain of these organisms are able to resist the heating process to which canned fish are subjected, and, when these bring about undesirable changes by their growth, become a source of considerable loss to the fishing industry.

The plan of the work consists in: (1) the isolation of spore formers from the sources mentioned; (2) the selection of those which, because of their high thermal death points and the production of hydrogen sulphide, are likely to be responsible for the spoiling of canned fish; (3) the identification of these forms by a study of their morphological and physiological characters; and (4) an accurate determination of the thermal death points.

ISOLATION OF SPORE-FORMERS

The first part of the investigation, namely, the isolation from marine sources of spore-forming organisms, was carried out at the Atlantic Biological Station, St. Andrews, New Brunswick, in July and August, 1921. As organisms in any of the sea-water animals, and in the sea-water itself, are liable to occur in or upon fish commonly canned, isolations were not confined to the last class only. The author repeatedly isolated similar organisms from as widely different sources as herring, haddock, limpets, clams, and sea-water. Further proof was established when an organism isolated from canned lobster was found to be identical with that isolated from the slime of a haddock.

Plate cultures were made from the contents of the alimentary canal of lobsters, clams, mussels, limpets, flounders, herring, pollock, alewives, and deep water fish caught on the troll-line, such as cod, haddock, and hake. Cultures were also made from sea-water at different stages of the tide, samples of water being taken from the brackish water of the St. Croix below the town of St. Stephens to the more saline waters around the islands in Passamaquoddy Bay, and in the Bay of Fundy.

Technique

The medium used for all isolation work was standard nutrient agar, made up with sea-water instead of distilled water.

Cultures were always made from fish and shell-fish within a few hours after being caught. Clams and mussels were thoroughly scrubbed under the tap to remove the mud, before being opened. The animal was placed on a sterile surface, opened by instruments previously standing in a jar of 60 per cent.

alcohol, and several loopfuls of the intestinal contents transferred with a flamed platinum needle to sterile water blanks. The instruments were washed, replaced in alcohol, and flamed off, before a second specimen was dissected. Samples of sea-water were obtained in sterile test-tubes plugged with cotton-wool. These tubes of sterile water, with intestinal contents, and sea-water, were placed in a water bath, heated to 80° C., and held at that temperature for ten minutes, in order to destroy vegetative forms.

Agar plate cultures were then made, using 2 c.c. portions of the samples in each petri dish, and incubating at room temperature, or at 37° C. The plates were first incubated at room temperature, because it was thought sea-water organisms might not grow well at higher temperatures. However, it was later found that colonies were as numerous, and growth was more rapid at 37°, so all subsequent cultures were incubated at that temperature.

Stained preparations of all the colonies occurring on the plates were made with Loeffler's alkaline methylene blue, applied to the fixed smear for two or three minutes. This stain is taken up by vegetative cells, and not by spores. When a spore is encased within a vegetative cell, the clear spore and the blue cell are in sharp contrast. Free spores show a narrow rim of blue around the outside of the spore wall. By this method spore-formers occurring on the plates were quickly and efficiently demonstrated. These were transferred to agar slopes, and stored at room temperature.

Results

At the end of six weeks, a fairly representative collection of the spore-forming bacteria inhabiting the sea-water, fish, crustaceans, and mollusks, in the vicinity of Passamaquoddy Bay, had been made. About twenty obvious duplicates were discarded, and the remaining eighty pure cultures were taken to the laboratory at Macdonald College.

SELECTION OF FORMS MOST RESISTANT TO HEAT

The first method of sterilization of canned fish, adopted in this country in 1839, was three intermittent boilings for periods as long as one and a half hours, with tapping and sealing between each boiling to expel air and produce a vacuum. Now, the prevailing method at fish canneries is a straight three hours' boil after packing and sealing, which saves labour, but is not completely efficient, the proof being the large annual losses due to bacteriological spoilage of canned fish. Prominent among the types of spoilage in canned fish, is a blackening of the contents in contact with the cover or sides of the container, due to the action of hydrogen sulphide upon the iron of the can with the production of ferrous sulphide.

Long continued heating tends to disintegrate and darken canned goods, and adds to the expense of canning, so the aim of the canner is to reduce the time of processing as much as possible. Of first economic importance, then, was to find out what percentage of the common marine spore-forming organisms would survive three hours' boiling, what lengths of boiling they would survive, and whether they were capable of producing hydrogen sulphide.

Technique

The eighty organisms were inoculated into beef-broth, and placed in baths of boiling water. Exactly three hours after the water had resumed boiling, the test tubes were removed and placed in the incubator.

In order to test for the production of hydrogen sulphide, the organisms were inoculated into test tubes of Dunham's solution, over which was suspended strips of filter paper soaked in lead acetate solution. Such tubes were incubated for two weeks at 37° C.

Results

Twelve organisms survived the three hours' boiling, and twenty showed production of hydrogen sulphide. These results are concerned with the former group, to which was added five isolations from canned lobster. The canned lobster had been sent from Prince Edward Island, and had been subjected to the regular three hours' processing.

Six, out of the twelve heat resisting organisms, showed production of hydrogen sulphide. The twelve were re-tested, along with the five new isolations from canned lobster, on lead carbonate agar, a positive result (a blackening of the medium) being obtained in every case.

STUDY OF MORPHOLOGICAL AND PHYSIOLOGICAL CHARACTERS FOR THE PURPOSE OF CLASSIFICATION

Technique

For the study of the morphology of the seventeen organisms, Loeffler's methylene blue was used in all cases except for the determination of flagella. Slides were made from cultures at different periods of their growth in order to follow the development of the spore, and note any irregular forms present in young or old cultures. Drawings were made with the aid of the camera lucida, for the purpose of comparison, accuracy, and record.

Special attention was paid to the method of germination of the spores. For this purpose, an agar culture about three weeks or a month old was used. At this age the culture contained practically nothing but free spores. The spores were smeared with a platinum needle as a thin film over several square centimeters of an agar slant. The sloped tubes were placed in the incubator at 37°. After one and a half to two hours, the first examination was made. The platinum needle was rubbed gently over the surface of the smear, and the adhering material transferred to a drop of water on the slide. The smear was stained in the usual way, and examined. Successive examinations were made every hour until the desired stage was found.

Successful flagella stains were made of each organism using the following method: To 10 c.c. of a 20 per cent. solution of tannic acid were added 8 c.c. of a cold saturated solution of ferrous sulphate and 1 c.c. of a saturated solution of gentian violet in absolute or 95 per cent. alcohol. Smears were made on the slide and fixed in the usual way, special care being taken not to overheat. The above mordant was filtered on to the preparation and left for three minutes, the preparation being then washed with water and stained with anilin gentian violet applied for five minutes, during which time the slide was heated several times until the liquid began to vaporize. The mordant, after mixing, was never used for more than two days. This method proved very satisfactory, although some granular precipitate was always present on the slide.

In the study of the physiology of the organisms, the standard methods adopted by the American Society of Bacteriologists were followed. Agar and gelatine were adjusted to a P_H of 6.8 to 7.0. All cultures, except gelatine, were incubated at 37° C.

Results

Spore germination was found to proceed as follows. After one and a half to two and a half hours, depending on the organism, the spore walls, which, on staining, previously showed only a narrow rim of pale blue, showed now a wider rim of deep blue. The deepening of the blue colour of the spore wall sometimes started at one end, sometimes at the side, but usually simultaneously all around the spore. In the second stage, the whole spore began to swell appreciably, accompanied by a faint staining of the central part, either evenly or deeper towards the ends. The whole spore finally stained a deep blue, the spore-wall ruptured, and the tip of the new vegetative cell pushed its way out. In the case of polar germination, the spore and issuing vegetative cell together had a typical flask-shaped appearance. As the contents of the spore passed out into the vegetative cell, the spore case sloughed off in fragments or was left behind entire, retaining the original spore shape or becoming collapsed. The cast spore cases stained very faintly, except in the case of D. The first few cells formed after germination tended to be much larger than those formed later on.

In numbers 48, 62, and 136, the method of germination was not definitely established, for, although germination proceeded as above up to the point where the whole spore stained a deep blue, the next stage seemed to be that of an ordinary vegetative cell, differing only in the fact that it tapered slightly towards one end, and that the ends were more rounded. No sign of cast spore cases was found. Possibly the spore had grown directly into a new vegetative cell without rupturing the spore case.

In general morphological and physiological characteristics, the organisms isolated at St. Andrews corresponded to those described by Russell ('93) at Woods Hole. He mentions the granular appearance of the protoplasm as being very characteristic of marine bacteria. Three out of the twelve heat resisting organisms from St. Andrews exhibited this property conspicuously. He also says the majority of the organisms he isolated from the sea-water belonged to the liquefying group, producing a peptonizing enzyme that slowly liquefied gelatine, and producing ferments that digested the casein in milk, changing the insoluble proteins into soluble peptones. This was found to be true of all the organisms discussed in this paper.

The detailed results of the study of the morphology and physiology of the seventeen organisms are embodied in the key, and in the separate descriptions of each organism which follow. For purposes of identification the references consulted and compared were Russell's two articles, "Untersuchungen uber im Golf von Neapel lebende Bacterien," and "The bacterial flora of the Atlantic Ocean in the vicinity of Woods Hole, Massachusetts;" Migula's "System der Bakterien," Chester's "Manual of Determinative Bacteriology," Matzuschita's "Bacteriologische Diagnostik," and the key of the American Society of Bacteriologists.

KEY

Bacterium.—Produces endospores. Growth at room temperatures. Gram negative. Gelatine liquefied. Chromogenic. Aerobic and facultative aerobic. No gas production. Produces H_2S (Lead carbonate agar). **D**

Bacillus.—1. Produces endospores. Aerobic and facultative aerobic, liquify gelatine, non-chromogenic, no gas production, produce H_2S (Lead carbonate agar), non-lactose fermenting. Peritrichous flagella.

A. Rods not swollen at sporulation, germination polar.
B. Dextrose and saccharose+, Glycerin−.
C. Liquefaction of gelatine slow.
D. Gram-positive. Colonies on gelatine circular, zoned with opaqued rims.
E. On agar stroke, growth membranous. Spores formed profusely. **C**
EE. On agar stroke, growth viscid or butyrous. 72
DD. Gram-negative. Colonies on gelatine cream, homogeneous in density from centre to border, saucer-shaped liquefaction. 239
BB. Dextrose, saccharose and glycerin+. Gram-negative, germination doubtful.
C. Liquefaction of gelatine slow.
D. Colonies on gelatine with densely opaque centre, and crinkled ribbon-like, opaque border. 62
DD. Colonies on gelatine with centre filamentous, rim opaque. Subsurface colonies on agar rhizoid. 136
DDD. Colonies at first a homogeneous, cream-coloured hollow of liquefaction, spreading by long pointed fingers, or circular and zoned, with cream centre. 48
AA. Rods spindle shape at sporulation. Gram-positive, polar germination.
BB. Dextrose, saccharose, and glycerin+.
C. Liquefaction of gelatine rapid.
D. Gelatine colonies circular, zoned, with opaque border. Gelatine stabs, faint uniform growth along line of inoculation followed by crateriform liquefaction.
E. Non-chromogenic on potato. **K**, **K**$_2$.
EE. Producing red pigment on potato. 246

DD. Gelatine colonies circular, not zoned, but with opaque granular centre. Sub-surface colonies on agar rhizoid. 271

BB. Dextrose and saccharose+, glycerin−.

C. Liquefaction of gelatine rapid. Growth along line of inoculation in stab, slightly villous.

D. Sub-surface colonies on agar crystal-like to naked eye, under low-power composed of clusters of dense, ovate colonies. 201

CC. Liquefaction slow. Distinctly villous or arborescent growth on gelatine stab.

DD. Sub-surface colonies on agar, rhizoid. Sub-surface colonies on gelatine, stellate. Vegetative cells occur in very long chains. False branching observed. 288

BBB. Dextrose and glycerin+, saccharose−.

C. Liquefaction of gelatine rapid.

D. Colonies on gelatine white or cream-coloured centre, and indistinct border.

E. Sub-surface colonies on agar clouded, granular to naked eye, rhizoid under microscope. Surface colonies have rhizoid projections at the edge. B

EE. Surface colonies slightly umbonate, usually with curled edges. 145

AAA. Rods clavate at sporulation. Gram negative. No gas production. Dextrose, saccharose, lactose and glycerin−. Liquefaction of gelatine slow, non-chromogenic, hydrogen sulphide production with both lead carbonate agar, and Dunham's solution with lead acetate paper. Peritrichous flagelia. 162, 165

NOTE.—After eight months on an agar slope the spores of the above species isolated at St. Andrews were still viable.

DESCRIPTION OF SPECIES

D

Isolated at Macdonald College, P.Q., November, 1921. Source—Canned lobster.

Vegetative cells. Length 4-5 μ. Width 1-1.4 μ. The first rods formed after the germination of the spore tend to be much wider than those produced later on. In young agar cultures (six hours or less) long chains of vegetative cells connected by bridging strands of protoplasm, occur frequently. Older cultures usually contain many shadow forms consisting of enlarged, rounded or irregular, faintly staining vegetative cells. Gram-negative.

Motility. Non-motile.

Spore formation. The vegetative cells first assume a granular appearance, then swell slightly towards one end as the spore begins to develop. After 24 hours spore formation has begun, with occasional free spores present; in 48 hours free spores are fairly numerous.

In old cultures chains of vegetative cells often become beaded in appearance, producing groups of round refractile bodies resembling spores. Free spores measure 1.25-2 μ x 1-1.2 μ. Germination, equatorial.

Agar stroke. Thin soft spreading growth, glistening and moist. Colour, after 24 hours, light cream, after several days incubation deepening to Isabellinus[1] dotted with numerous small round yellowish transparent areas, resembling globules of fat. Medium, much browned.

Agar colonies. Colonies circular, smooth, flat, measuring two to eight mm. in diameter. Edges entire. Colour of colonies at first creamish, on further incubation becoming Isabellinus,[1] and then developing the translucent yellowish spots described in the stroke.

Gelatine stab. Faint growth along line of inoculation with slow crateriform liquefaction beginning at the surface in three days.

Gelatine colonies. Colonies small from 1-1.5 mm., in hollows of liquefaction. Distinctly yellowish in colour, the central portion being the darkest, followed by a somewhat hyaline zone and opaque border. Under the low power of the microscope the edges are filamentous.

Potato plugs. Thick yellow shiny growth. Medium much darkened.

Milk. After two days hard curd formed with extrusion of whey. In litmus milk the surface of the curd assumes a pinkish colour. After ten days, complete peptonization.

Fermentation.	Dextrose	Lactose	Saccharose	Glycerin
Gas	–	–	–	–
Acid	+	+	+	+

Production of H_2S. With lead carbonate agar+.

T.D.P. of spores. 1 minute boiling.

Classification. According to Chester, this organism is a *Bacterium* of the Anthrax group. It is not in Migula's group of bacteria which produce spores with equatorial germination, neither does it conform to his description of spore forming organisms which produce colour. In Matzuschita's ('02) classification, it agrees with *Bacillus multipediculus flavus*, Zimmermann, except in its ability to grow at blood heat, and upon potato.

162 and 165

Isolated at St. Andrews, N.B., July, 1921. Source—Mussel.

Vegetative cells. Length 1.5-3 μ. Width .6-.7 μ.

Slender rods, usually occurring singly, and as a rule containing deeply staining round granules at the ends or near the centre. Shadow forms larger than the ordinary vegetative cells, crescent, oval or rectangular shaped, and always possessing one or more of the deeply staining granules, are commonly present within 36 hours. Gram negative.

Motility. Very motile.

Flagella. Peritrichous, ten to twelve per vegetative cell.

Spore formation. After twenty-four hours only occasional cells forming spores. In 36 hours free spores abundant. Spores are always located at the

---

[1] Saccardo, P. A. Chromotaxia seu nomenclator colorum. Patavii, 1894.

ends of the rods from which they spring, forming a characteristic drum-stick. The free spores may be round, oval, or hemi-ovoid. Some of the spores retain small tags of protoplasm for a long time in culture, and in this state may have a somewhat triangular appearance. They measure .8-1.2 μ. The spore wall takes the stain deeply, even in very old cultures.

Agar stroke. Raised, glistening contoured growth, at first almost translucent, later growing opaque and deep cream coloured.

Agar colonies. Surface colonies circular or ameboid in form, slightly raised, smooth, glistening, edge entire, or irregular, sending out numerous pseudopodium like processes. Colour, brownish cream.

Sub-surface colonies, punctiform, under low power of microscope, ovate in shape.

Gelatine stab. Growth along line of inoculation echinate. After eight days a slow infundibuliform liquefaction starts. After thirty days, 10 mm. liquefaction in test tube of 15 mm. diameter. The long narrow funnel of liquefaction extending to the bottom of the tube contained a thick spirally-twisted membranous precipitate.

Gelatine colonies. Surface colonies 5-7 mm. in diameter with alternate hyaline and opaque zones. Edge entire. Sub-surface colonies about 4 mm. in diameter. Centre faintly cream-coloured with fuzzy edge.

Potato plugs. Thick, smooth, shiny growth, somewhat amber in colour. Medium grayed.

Milk. In three days unchanged except slightly more alkaline. In one week coagulated, peptonization commenced, and litmus completely reduced. After twelve days peptonization almost complete, and in litmus milk a greenish scum around the top.

Fermentation.	Dextrose	Lactose	Saccharose	Glycerin
Gas	—	—	—	—
Acid	—	—	—	—

Production of H_2S. With lead carbonate agar+.

With Dunham's solution and lead acetate paper+.

T.D.P. of spores. 2 minutes' boiling.

Classification. This organism agrees with *B. sublanatus*, Wright (Chester, '01), except in the coagulation of milk and the character of the growth on agar slant.

288

Isolated at St. Andrews, N.B., August, 1921. Source—Sea-water.

Vegetative cells. Length 1.5-2.25 μ. Width .6-.75 μ. Occur in long filaments. False branching observed. In chains of homogeneous rods, shadow-forms staining faintly in the centre and deeply at the ends, sometimes occur. Gram-positive.

Motility. Sluggishly motile in beef-broth.

Flagella. Peritrichous. Up to twelve per vegetative cell.

Spore formation. Spores formed abundantly in 24 hours at 37° on plain agar. They are slightly ex-central, and are wider than the vegetative cells from which they spring. Size of free spores .7 x 1 μ. Polar germination.

Agar stroke. Abundant, flat, somewhat glistening, opaque growth. Central portion of stroke punctate. Edge grown out into numerous filaments.

Agar colonies. Surface colonies show a tendency to spread in rhizoid manner from a small, round, central portion. Surface somewhat punctate, or in non-spreading colonies, slightly wrinkled, edges fuzzy and indefinite. Internal structure, coarsely granular. Sub-surface colonies irregularly round, with internal structure resembling a tangled mass of roots, and edges marked by numerous irregular rhizoid extensions.

Gelatine stab. Villous growth along the lines of inoculation, followed by a slow stratiform liquefaction. After 30 days at room temperature about one-quarter of the tube of gelatine was liquefied.

Gelatine colonies. Surface colonies have round dense creamish centres about 2 mm. in diameter, surrounded by a clear zone of liquefaction. Sub-surface colonies measure .75 to 1.5 mm. and are composed of oval creamish centres with delicate prickly radiations giving the whole colony a stellate appearance.

Potato plugs. Thick cream growth with granular appearance. Medium much darkened.

Milk. After three days milk unchanged. After 10 days there is some peptonization, a slight reduction of the litmus, and a granular curd.

Fermentation. (Sugar-free bouillon+1% sugar+1% Andrade's indicator.)

	Dextrose	Lactose	Saccharose	Glycerin
Gas	–	–	–	–
Acid	+	–	+	–

Production of H_2S. With lead carbonate agar+.

With Dunham's solution and lead acetate paper+.

T.D.P. of spores. 10 minutes' boiling.

Classification. This organism corresponds with the description of *Bacillus licheniformis* Weigmann, as given in Chester ('01), except that it is gram-positive, and that growth on potato is not slimy.

B, 145, 271

Isolated at Macdonald College, January, 1922. Source—Canned lobster, B.

Isolated at St. Andrews, N.B., July, 1921. Source—Pollock, 145; Sea-water, 271.

This type occurred very commonly in sea-water, deep-water fish, and shell-fish. Three strains from widely different sources were studied, and small differences recorded.

Vegetative cells. Length 2-3 μ. Width 1-1.2 μ. Large homogeneous rods with ends rounded or square, usually occurring in long chains, in young cultures often connected by bridging strands of protoplasm. Shadow forms may appear, much larger than the ordinary rods, and taking the stain irregularly or faintly. These often occur in pairs, each cell becoming hemiovoid in shape, or singly, becoming rounded, or retaining the rectangular shape. Gram-positive.

Motility. Sluggishly motile, in long chains. Lashing movement.

Flagella. Peritrichous.

Spore formation. In strains 145 and 271 the vegetative cells become conspicuously granular, and slightly wider, in the first stage of spore formation. In B the granulation is not as conspicuous, and is sometimes absent. In all cases spore formation begins within 24 hours, but free spores are not present in abundance until 48 hours. Spores are in central or sub-central position in the mother cell. When free, they measure 1.25-2.25 μ x 1-1.2 μ. Germination polar.

Agar stroke. Thick, moist, glistening, creamish growth, with irregular edge, along line of inoculation. Smooth or contoured. Consistency at first butyrous, gradually becoming softer. In old cultures the strokes often have a milky-looking appearance.

Agar colonies. Surface colonies B and 271 irregularly circular, smooth, glistening, raised or convex, with rhizoid projections giving the edge a fuzzy appearance. Sub-surface colonies have clouded or granular appearance to the naked eye. Under the low power of the microscope they resemble a tangled mass of fine roots. The surface colonies of 145 are more regularly round, with slightly umbonate elevation, and either curled or fuzzy edges. Sub-surface colonies, punctate, ovate, or small, round with fuzzy edges and finely granular internal structure.

Gelatine stab. Rapid infundibuliform liquefaction, complete in eight days with formation of a heavy membranous precipitate.

Gelatine colonies. The colonies rest in saucer-like excavations caused by liquefaction. They have a distinctly white or creamish centre, followed by a hyaline zone, and a faintly opaque rim. Internal structure finely granular, edge entire, but not sharply defined.

Potato plugs. Thick, dull, creamish growth. May be smooth or slightly rugose. Medium grayed.

Milk. In 24 hours at 37° C. a firm curd formed, peptonization began, and reduction of litmus started. After seven days complete peptonization.

Fermentation.	Dextrose	Lactose	Saccharose	Glycerin
Gas	–	–	–	–
Acid	+	–	–	+

The production of acid in glycerin was very weak. 271 produced acid in saccharose bouillon.

Production of H_2S. With lead carbonate agar+.

T.D.P. of spores. 145 and 271—2 minutes boiling.
B—3 minutes boiling.

Classification. This organism corresponds with the diagnosis of *Bacillus cereus*, Frankland, as given in Matzuschita ('02) but differs from Chester's ('01) description in the absence of outgrowths in gelatine colonies, the opaqueness on agar slant, and the cream colour of the potato growth.

K, K_2, 201

Isolated at Macdonald College, P.Q., November, 1921. Source—Strains K and K_2 canned lobster.

Isolated at St. Andrews, N.B., August, 1921. Source—Strain 201 Limpet.

Vegetative cells. Length 2-3.3 μ. Width .7-.8 μ.

Homogeneous rods with slightly rounded ends. Shadow forms present in old cultures. Gram-positive.

Motility. Motile.

Flagella. Peritrichous.

Spore-formation. Free spores are produced abundantly on agar in 24 hours at 37° C. They are formed centrally or ex-centrally with slight enlargement of the mother cell. Free spores are oval, and measure 1.2-1.6 μ x .75-.8 μ. Polar germination.

Agar stroke. Pale cream glistening growth, slightly raised and spreading, with irregular edges. The surface is thrown up into distinct ridges, which are usually more or less reticulate. Consistency, butyrous.

Agar colonies. Surface colonies are smooth and glistening or dull and finely punctate, spreading or circular. The circular colonies may be faintly zoned, with a less dense central area, and edges appearing entire to the naked eye, or they may be uniformly opaque from centre to border. Occasionally, some colonies have centres finely rugose and more opaque than the borders.

The sub-surface colonies are of two types, first punctiform and crystal-like, under the low power of the microscope composed of clusters of dense ovate colonies, or small, round and faintly opaque, with edges entire. Internal structure, finely granular.

Gelatine stab. Uniform growth along line of inoculation, followed by rapid saccate liquefaction, and formation of a surface pellicle.

Gelatine colonies. Colonies resting in saucer-like hollows of liquefaction, internal structure finely granular.

K. Opaque rim, with remainder of colony hyaline or with central opaque dot, edge entire.

K_2. Surface colonies may have a ring of opaque spots around rim, and faintly opaque, more coarsely granular centre. Sub-surface colonies are distinctly zoned. Edge entire.

201. Surface colonies have opaque edges, followed by a hyaline zone and opaque, more granular centre.

Potato plugs. Thick creamish growth, surface both verrucose and rugose. Medium darkened to a greyish-brown. In 201 the growth is more rugose and less verrucose than in the other two.

Milk. K and K_2. After 24 hours at 37° C. a hard curd formed, and peptonization began. Peptonization complete in one week.

201. After 48 hours at 37° C. a soft curd formed, and peptonization began. Peptonization complete in one week.

Fermentation.	Dextrose	Lactose	Saccharose	Glycerin
Gas	–	–	–	–
Acid	+	–	+	+

In strains K and K_2 the production of acid in glycerin is very weak. In strain 201 it is absent.

Production of H_2S. With lead carbonate agar+.

T.D.P. of spores. 7 minutes boiling.

Classification. This organism exactly corresponds with the short description of *B. granulosus*, Russell, given by Matzuschita. Russell ('93), in his original description, however, lays stress on the granular condition of the protoplasm, but this condition was not noticeable in the cultures under consideration.

246

Isolated at Bliss Island in the Bay of Fundy, N.B., August, 1921. Source—Sea-water.

Vegetative cells. Length 2-3.5 μ. Width .65-.75 μ. Homogeneous rods with slightly rounded ends, occurring singly or in short chains. Gram-positive.

Motility. Very motile, tumbling or boring.

Flagella. Peritrichous.

Spore-formation. Spores are formed freely within 24 hours. They are cylindrical, central or ex-central, produced with slight enlargement of mother cell. When spore is completely free from adhering tags of protoplasm the ends appear slightly rounded. Free spores measure 1.1-1.3 μ x .65-.8 μ. Germination polar.

Agar stroke. Flat, dull, rugose, deep cream or ecru growth spreading widely from line of inoculation at base of tube, where water of condensation present. Edges irregular, consistency, slightly viscous or butyrous.

Agar colonies. Surface colonies smooth and spreading, or small, rugose and irregularly round. Edge slightly undulate or ragged, with finely granular internal structure. Sub-surface colonies punctiform, appearing as dense irregular masses under the hand lens; or small, circular, homogeneous and faintly opaque.

Gelatine stab. Uniform growth along line of inoculation with liquefaction also along entire line. The liquefaction becomes saccate, and is complete in about 10 days.

Gelatine colonies. Circular colonies set in saucer-shaped hollows of liquefaction. They have an opaque dot in centre followed by a hyaline zone and a hazy, faintly opaque rim.

Potato plugs. Thick, deep cream or ecru, verrucose growth. After twenty-four hours the liquid in the bottom of the tube becomes the colour of dilute blood. After forty-eight hours the potato itself assumes a pale blood-red tinge along the margin of advancing growth. The part beneath the older growth becomes grey with a faint pinkish tinge.

Milk. After three days soft curd formed at bottom, with an amber-coloured peptonized zone at the surface. Litmus is reduced. Peptonization continues until in two weeks the entire milk tube is converted into an amber fluid.

Fermentation.	Dextrose	Lactose	Saccharose	Glycerin
Gas	–	–	–	–
Acid	+	–	+	+

Production of H_2S. With lead carbonate agar+.

T.D.P. of spores. 7 minutes boiling.

Classification. This organism agrees with *B. vitalis* (Chester '01) (=*B. mesentericus-ruber*, Globig, Matzuschita '02) except in the character of the growth in the gelatine stab and in the production of H_2S.

C

Isolated at Macdonald College, January, 1922. Source—Canned lobster.

Vegetative cells. Length 2-3 μ. Width .6-.65 μ.

Slender homogeneous rods with rounded ends usually occur singly, sometimes in short chains of three or four. In cultures several days old shadow forms appear, larger than the original cell, and made up of faintly staining protoplasm with sometimes deeply staining particles at the ends, towards the centre, or at the periphery.

Motility. Moderately motile, showing both tumbling and lashing motion.

Flagella. Peritrichous.

Spore formation.—Free spores formed abundantly in 24 hours on agar. Spores are formed either centrally or towards one end, without bulging of the rod. They measure 1-1.5 μ x .6-.75 μ. Germination polar.

Agar stroke. Flat, dull, cream-coloured growth, covered with irregular network of fine raised lines. In consistency membranous.

Agar colonies. Surface colonies may be round and smooth with edges entire, or they may be irregularly round, wrinkled, with undulate or lobate margins, showing in some cases a tendency to spread. Sub-surface colonies, small, round, faintly opaque, or irregular, clouded and crystalline in appearance.

Gelatine stab. Faint growth along line of inoculation, a rapid, saccate liquefaction beginning at the surface in two days, complete in three weeks.

Gelatine colonies. Gelatine colonies circular, crateriform, edge entire. They have a white central dot, surrounded by an opaque zone of granular appearance, then a hyaline zone, bordered by an opaque rim, consisting of more densely packed bacteria.

Potato plugs. Thick, dry, rugose, and verrucose growth, showing faint pink tinge. Medium browned.

Milk. Soft curd formed at the bottom with layer of peptonization at the surface. Complete peptonization in 10 days. Litmus reduced.

Fermentation.	Dextrose	Lactose	Saccharose	Glycerin
Gas	−	−	−	−
Acid	+	−	+	−

Production of H_2S. With lead carbonate agar+.

T.D.P. of spores. 2 hours 10 minutes boiling.

Classification. This organism does not conform to any spore-forming, motile, gelatine liquefying species described by Migula ('00), Chester ('01), Matzuschita ('02), or by Russell ('91). It is probably a new species.

72

Isolated at St. Andrews, N.S., July, 1921. Source—Herring.

Vegetative cells. Length 1.5-2.5 μ. Width .6 μ.

Homogeneous rods, either straight or slightly curved, with rounded ends. Shadow forms are abundant in a 24-hour culture, as well as in very old cultures. Gram-positive.

Motility. Very motile.

Flagella. Peritrichous.

Spore formation. Spore formation proceeds slowly, and spores are never produced abundantly. In 24 hours only very occasional rods are forming spores, and no free spores are present. In 48 hours a few free spores are present. In old cultures (three weeks or more) the majority of vegetative cells seem to have lost their protoplasm, and turned into shadow forms, leaving a small percentage of spores. Oval spores are produced centrally or ex-centrally without distortion of mother cell, and measure 1.1-1.2 μ x .6-.65 μ. Germination polar.

Agar stroke. Flat, or slightly raised, glistening, opaque growth, spreading somewhat from line of inoculation towards the bottom of tube, with irregular edges. Surface, either smooth, or delicately rugose, depending on moisture content of medium. Colour, cream. Consistency, butyrous, or in young cultures, slightly viscid.

Agar colonies. Surface colonies glistening, opaque, finely granular, with smooth margins and rugose centres, or sometimes spreading by stubby fingers. The edges are definite and entire. Under the low power there are distinct reticulations radiating from centre, and corresponding to the wrinkling on the surface. Sub-surface colonies, small, circular, opaque, finely granular, with edges entire, or punctiform and irregular.

Gelatine stab. Uniform growth along line of inoculation, followed by slow crateriform liquefaction, complete in three weeks.

Gelatine colonies. The colonies on gelatine have a dense central portion, to the naked eye, resembling ragged floating pieces of skin; under the microscope somewhat filamentous.

Potato plugs. Cream-coloured, spreading growth, smooth or rugose. Medium slightly greyed.

Milk. After three days at 37° C. unchanged. After 7 days, a soft curd produced, peptonization started, and litmus completely reduced. After two weeks, peptonization complete.

Fermentation.	Dextrose	Lactose	Saccharose	Glycerin
Gas	—	—	—	—
Acid	+	—	+	—

Production of H_2S. With lead carbonate agar+.

T.D.P. of spores. 4 minutes boiling.

Classification. This organism does not conform to any spore-forming, motile, gelatine-liquefying species described by Migula ('00), Chester ('01), Matzuschita ('02), or by Russell ('91). It is probably a new species.

239

Isolated at St. Andrews, N.B., August, 1921. Source—Lobster.

Vegetative cells. Length 1.5-2.2 μ. Width .5-.7 μ.

Slender homogeneous rods, with slightly rounded ends, usually occurring singly. Gram-negative.

Motility. Extremely motile.

Flagella. Peritrichous.

Spore formation. Spores may be formed centrally or ex-centrally, without distortion of mother cell. Spore formation starts within 24 hours, but at this time no free spores are present. Free spores are oval in shape and measure 1-1.2 μ x .6-.7 μ. Germination polar.

Agar stroke. Smooth, glistening, opaque growth, spreading little from line of inoculation. Cream colour, later assuming a pale ecru tinge. During the first four months of culturing, the consistency was always slightly viscid in young cultures. In later culturing it lost this property, and became butyrous.

Agar colonies. Surface colonies may be smooth, glistening and spreading from a central nucleus by stubby fingers; or circular with an inconspicuous depressed ring near the margin and a slightly umbonate centre. Sub-surface colonies are punctiform, irregular, or circular, opaque, 1-1.5 mm. in diameter. The edges in all cases are definite and entire.

Gelatine stab. Slight uniform growth along entire line of inoculation, followed by a slow crateriform liquefaction. At the end of three weeks liquefaction almost complete, with a flocculent precipitate.

Gelatine colonies. Surface colonies, circular, homogeneous, cream in colour, finely granular internal structure, edge entire; set in saucer-shaped hollows of liquefaction.

Sub-surface colonies irregularly circular, dotted in appearance, with filamentous edges.

Potato plugs. Thick creamy-grey growth, finely rugose, fairly flat. Medium, much darkened.

Milk. After 7 days unchanged. Litmus completely reduced.

Fermentation.	Dextrose	Lactose	Saccharose	Glycerin
Gas	–	–	–	–
Acid	+	–	+	–

Production of H_2S. With lead carbonate agar+.

With Dunham's solution and lead acetate paper+.

T.D.P. of spores. 2 minutes boiling.

Classification. This organism does not conform to any spore-forming, motile, gelatine-liquefying species described by Migula ('00), Chester ('01), Matzuschita ('02), or by Russell ('91). It is probably a new species.

62 and 136

Isolated at St. Andrews, N.B., July, 1921. Source—62, Haddock; 136, Cod.

Vegetative cells. Length 1.5-2.8 μ. Width .6-.7 μ.

Homogeneous rods with slightly rounded ends. Shadow forms present in old cultures. Gram-negative.

Motility. Motile.

Flagella. Peritrichous.

Spore formation. Spores are formed abundantly within 24 hours, either centrally or towards one end of the vegetative rod, with little or no distortion. They are oval in shape and measure 1-1.3 μ x .6-.7 μ. Germination doubtful.

Agar stroke. Moderate, smooth, glistening, opaque, cream-coloured, flat growth, spreading little from line of inoculation except at the base. Occasionally the surface is faintly punctate. Consistency, butyrous.

Agar colonies. Surface colonies are smooth, glistening, opaque, and usually spreading. The non-spreading colonies are circular, convex or slightly umbilicate, very occasionally showing a tendency to wrinkle in the centre. Edge entire.

Sub-surface colonies. 62.—They may be of two types, punctiform, dense, cream, and ovate, or circular and faintly opaque, with edges entire.

136.—The majority of the colonies are rhizoid, looking ragged and fuzzy to the naked eye. There occurs also the circular and faintly opaque colony, with entire edge.

Gelatine stab. Faint uniform growth along line of inoculation, followed by a crateriform liquefaction, beginning at the surface, and complete in 30 days at room temperature.

Gelatine colonies. 62.—Colony circular, set in saucer-shaped hollow of liquefaction. The centre is round, cream colour, finely granular, followed by a less dense area, and then a crinkled, ribbon-like, opaque border. In some colonies the central portion is irregular in shape, and followed by a faintly opaque zone, under the low power of the microscope shown to be composed of irregular floating clumps of bacteria.

136.—Surface colonies have a slightly opaque central zone, filamentous in character, followed by a hyaline zone, and opaque rim.

Sub-surface colonies are 2 to 5 mm. in diameter, and are distinctly zoned, with a creamish centre.

Potato plugs. Thick, spreading, rugose, creamy-grey growth. Medium darkened.

Milk. After four days, a soft curd formed, peptonization begun, and litmus reduced. After ten days, completely peptonized.

Fermentation.	Dextrose	Lactose	Saccharose	Glycerin
Gas	—	—	—	—
Acid	+	—	+	+

Production of H_2S. With lead carbonate agar, 62 and 136+. With Dunham's solution and lead acetate paper, 62+.

T.D.P. of spores. 4 minutes boiling.

Classification. This organism does not conform to any spore-forming, motile, gelatine-liquefying species described by Migula ('00), Chester ('01), Matzuschita ('02), or by Russell ('91). It is probably a new species.

48

Isolated at St. Andrews, N.B., July, 1921. Source—Jelly-fish.

Vegetative cells. Length 2-3 μ. Width .5-.6 μ. Slender, homogeneous rods, with slightly rounded ends. Occasional shadow forms present after 24 hours at 37°.

Motility. Very motile.

Flagella. Peritrichous.

Spore formation. Spores are formed either centrally or towards one end of the mother cell. They are formed abundantly within 24 hours, and are oval, measuring 1 μ x .55-.6 μ. Germination, doubtful.

Agar stroke. Moderate, smooth, opaque, cream-coloured, flat growth, spreading little from line of inoculation except at the base. Consistency, butyrous.

Agar colonies. Surface colonies are smooth, glistening, opaque, as a rule, widely spreading. The non-spreading colonies are circular, convex, or sometimes slightly umbilicate, with an inconspicuous wrinkling in the centre. Edges are entire or undulate. Colour, cream.

Sub-surface colonies punctiform, dense, creamish, and irregular.

Gelatine stab. Faint uniform growth along line of inoculation, followed by a crateriform liquefaction beginning at the surface, and complete in 30 days.

Gelatine colonies. The colonies first appear as a homogeneous, cream-coloured hollow of liquefaction, which spreads rapidly from this central nucleus by long irregular pointed fingers. Some of the colonies remain circular and increase uniformly in diameter, still retaining the cream-coloured centre, and becoming zoned in appearance.

Potato plugs. Thick, creamish, rugose growth. Medium slightly greyed.

Milk. After one week at 37° C. no change, except slight reduction of litmus. After two weeks litmus completely reduced, solid curd formed, and no peptonization.

Fermentation.	Dextrose	Lactose	Saccharose	Glycerin
Gas	—	—	—	—
Acid	+	—	+	+

Production of H_2S. With lead carbonate agar+. With Dunham's solution and lead acetate paper+.

T.D.P. of spores. 5 minutes boiling.

Classification. This organism does not conform to any spore-forming, motile, gelatine-liquefying species described by Migula ('00), Chester ('01), Matzuschita ('02), or by Russell ('91). It is probably a new species.

DETERMINATION OF THERMAL DEATH POINTS

Technique

For the determination of the thermal death point, cultures were used which had been incubated for 36 to 48 hours at 37°, and stored at room temperature from one to two weeks. Young growth on agar slants often tended to be viscid or membranous, but with age became more friable and granular. The latter state was much preferable from the standpoint of obtaining spore suspensions free from large clumps of spores. As will be pointed out later, the difference in age would not affect the thermal death point.

A heavy suspension of spores was made in sterile distilled water, triturating the material with a platinum needle against the side of the tube in order to break up the spore clumps. A direct microscopic examination of this spore suspension showed that even after the most careful trituration with the needle, clumps of spores were still present. The size varied with the consistency of the original inoculum. In organisms like C, where the growth always remained fairly membranous there were several clumps of from ten to fifty spores in every field, frequent clumps of 500, and occasional clumps too numerous to count, probably containing one or two thousand spores. In spore suspensions of organisms showing a soft butyrous growth, numerous clumps containing from nine to fifty spores were present in every field. When a serious difference in the thermal death point of a single spore and spores in clumps was found, further treatment was given the spore suspension to rid it of clumps. Two methods were followed, and their relative efficiency estimated by direct microscopical examination. The first method was mentioned by Harriette Chick ('08), namely, centrifuging the spore suspension for several minutes, and pipetting off the supernatant liquid. The second method was filtering the suspension through filter paper. (In this work No. 1 Whatman filter paper, prepared by W. & R. Balston, Ltd., was used.) The closeness of the weave of the filter paper would probably affect the results. Organisms showing both membranous and granular growths were chosen for the test. Portions of the same spore suspension were centrifuged for three, five and ten-minute periods at about 3,600 revolutions per minute, and filtered once and twice through filter paper. A loopful of the suspension after each treatment was transferred to a slide and allowed to evaporate without spreading. The residue was stained, the number of clumps per field, and the average number of spores in the clumps recorded.

The results showed that absolute efficiency was not obtained by either methods. Both, however, greatly reduced the size and number of clumps present in the suspension. Continued centrifuging lowered the total number of spores in the supernatant liquid, tending to throw out the clumps, rather than to break them up. When chains of vegetative cells were present along with the spores, centrifuging gave rather erratic results. These chains tend to wrap around clumps of spores, and owing to their lower specific gravity, to prevent the clump from being thrown to the bottom of the tube. Filtering twice also had the effect of reducing the total number of spores present, without altering the size of clumps very materially. One filtering showed greater total efficiency in reducing the number and size of clumps than centrifuging for ten minutes. This was more marked in the spore suspensions from a membranous growth than in that made from a granular or butyrous growth. In the case of the last two, the size of the spore clumps ranged from three to twelve in both centrifuged and filtered suspensions. When growth was membranous the number of spores per clump in centrifuged material varied from three to fifty. In the filtered, the average number per clump was about ten, but one clump of forty was observed, showing the possibility of clumps of that size passing through the filter paper. Centrifuged and filtered material were compared experimentally in several cases, resulting in no marked difference of the thermal death point.

As filtering was shown by the microscopic method to be slightly more efficient, and as it required much less time, this method of treating spore suspensions was adopted.

Two c.c. portions of the filtered spore suspension were transferred with sterile capillary pipettes to long-necked, thin-walled glass bulbs of about four c.c. capacity. The bulbs were sealed in the blow-flame, and placed in wire baskets. The baskets were inverted into baths of boiling water in order that the bulbs would be kept completely submerged. One-half minute after the water resumed boiling, the spores were assumed to be at the temperature of boiling water, and the time of exposure was counted from that second. The bulbs were removed at successive periods, at first long, and gradually narrowing down to one minute periods, as some idea of the probable thermal death point was obtained. The neck of the bulb was dipped in alcohol, the top snipped off with a pair of pincers, also dipped in alcohol, and the boiled contents transferred with a sterile capillary pipette to duplicate agar slopes. The agar slopes were incubated and examined up to the end of five days, for the presence or absence of growth. (Both bulbs and capillary pipettes were made by the author, using glass rods, and the blow-flame.)

Results

The results obtained without filtering the spore suspension were extremely inconsistent, as will be shown by the following list of positive results in two tests.

Time boiled	½ hour		1 hour		1½ hrs.	2 hours		2½ hrs.		
	1st test	2nd test	1st test	2nd test	One test	1st test	2nd test	1st test	2nd test	3 hrs.
Growth present from numbers	C	C	201	201	C	C	C	C	C	C
	288	288	K_2	K_2	246	K_2	K_2	K	K	
	201	201	C	C	B	201	201	288	K_2	
	K	K	246		K					
	62	72	K		201					
	B	B	288							
	145	145	136							
	239	239								
	K_2	48								
	136	246								

A special test was made of C, allowing spore clumps of large size to be present in the suspension. Growth was obtained after boiling seven hours. No longer period was tried.

The filtered material gave unexpected results. The thermal death point was found to range from one to ten minutes' boiling in all organisms except C, in which it was over two hours. A comparison of these results with the above will show the serious effect of clumping in raising the thermal death point of spores. Evidently the central spores in the clumps are greatly protected. As was mentioned previously, all these organisms had survived either three hours' boiling in beef broth, or the three hour processing given the canned lobster. Although these results were not obtained four months later, that is, only three organisms survived three hours' boiling, two explanations might be given. The first is loss of vitality due to continued culturing on artificial media. The second is much more probable, that is, the organisms freshly isolated from their natural habitat tended to show much tougher and more viscous growth than they did after four months' continued cultivation. Their survival at higher temperatures was no doubt due to the fact that clumps could not be as efficiently broken up by the platinum needle.

Another important point is the astonishing effect of an increase of several minutes in the thermal death point of the individual spores in prolonging the time required for their destruction in clumps. Spores with a thermal death point of two minutes seldom survived over half an hour's boiling in clumps, those with a thermal death point of four to five minutes, lived after one hour's boiling in clumps, while spores with a thermal death point of seven to ten minutes were capable of growth after two to two and a half hours' boiling in clumps.

If the time required for the destruction of spores in clumps was increased proportionately in organisms like C, in which the thermal death point of individual spores was over two hours, then sterilization by boiling temperature would not be practicable. Probably, tests made of the death point of spore-bearing bacteria in the presence of clumps accounts for the high thermal death points given in articles like W. W. Ford's "Studies on aerobic spore-bearing, non-pathogenic bacteria."

In repeating the determination of the thermal death point several times, absolutely consistent results were not obtained. Occasionally, variations of one to two minutes occurred. This inconsistency may have been due to a difference in concentration of spores (Chick '08) or to an individual variation of the spores of one organism in their power to resist heat.

Experiments were tried with cultures of different ages, to test the effect upon the thermal death point. The experiments were too few to be conclusive, but no constant difference was found between cultures forty-eight hours, two weeks, or two months old. The indications were that spores lose their vitality very slowly.

CONCLUSIONS

The conclusions drawn from this study of marine spore-forming bacteria are:

1. Spore-forming bacteria are found commonly in sea-water, and in the alimentary tract of fish, crustaceans and mollusks.

2. The majority are capable of producing hydrogen sulphide, and consequently, if they are not killed by sterilization, may produce the blackening of canned fish.

3. The three hours' boiling given to canned fish is far more than is necessary to kill the isolated spores of the organisms commonly found in the sea.

4. The growth of freshly-isolated cultures is far more viscous or membranous than that of the later cultures, transferred twenty to thirty times, therefore the tendency to clumping or massing of the spores is probably quite marked in the natural habitat.

5. The thermal death point of spores in clumps is extremely high in comparison with that of the individual spore, and may often exceed three hours' boiling. Consequently, one of the principal factors in the bacteriological spoiling of canned fish is the inefficient method of attempting sterilization by boiling.

The foregoing investigation was carried out under the direction of Dr. F. C. Harrison, and its success is largely due to his suggestion. At St. Andrews, Dr. A. G. Huntsman kindly assisted in the collection and preparation of material. To each of these men, the writer wishes to acknowledge her obligations and to thank them for their kindly assistance.

BIBLIOGRAPHY

1. 1891. Russell, W. Untersuchungen über im Golf von Neapel lebende Bacterien. *Zeitschrift fur Hygiene.* Bd. XI.
2. 1893. Russell, W. The bacterial flora of the Atlantic Ocean in the vicinity of Woods Hole, Mass. *Bot. Gaz.*, Vol. XVIII.
3. 1897. Prescott, S. C., and Underwood, W. L. Micro-organisms and sterilizing processes in the canning industries. *Technology Quarterly*, Vol. X, No. 1.
4. 1900. Migula, W. System der Bakterien.
5. 1901. Chester, F. D. A manual of determinative bacteriology.
6. 1901. Gottheil, O. Botanische Beschreibung einiger Bodenbakterien. *Centralblatt fur Bakteriologie und Par.* Zweite Abt. VII. Bd.
7. 1902. Matzuschita, T. Bacteriologische Diagnostik.
8. 1908. Chick, Harriette. An investigation of the laws of disinfection. · *Jour. of Hygiene.* Vol. 5.
9. 1916. Ford, W. W. Studies on aerobic spore-bearing, non-pathogenic bacteria. *Jour. of Bacteriology.* Vol. VIII.
10. 1919. Berkeley, C. A study of marine bacteria. *Trans. Roy. Soc. of Can.* Ser. III, Vol. XIII.
11. 1920. Bigelow, W. D., and Esty, J. R. The thermal death point in relation to time of typical thermophilic organisms. *Jour. of Infectious Diseases.* Vol. 27, No. 6, pp. 602-617.

Explanation of Plates

N.B.—The number or letter beneath each group of drawings is the same as that under which the organism illustrated in the figure is described in the text.

Reference lettering—

a. Spore in formation.
b. Spore germinating.
c. Cast spore case.

All figures magnified 1,700 diameters.

PLATE I.

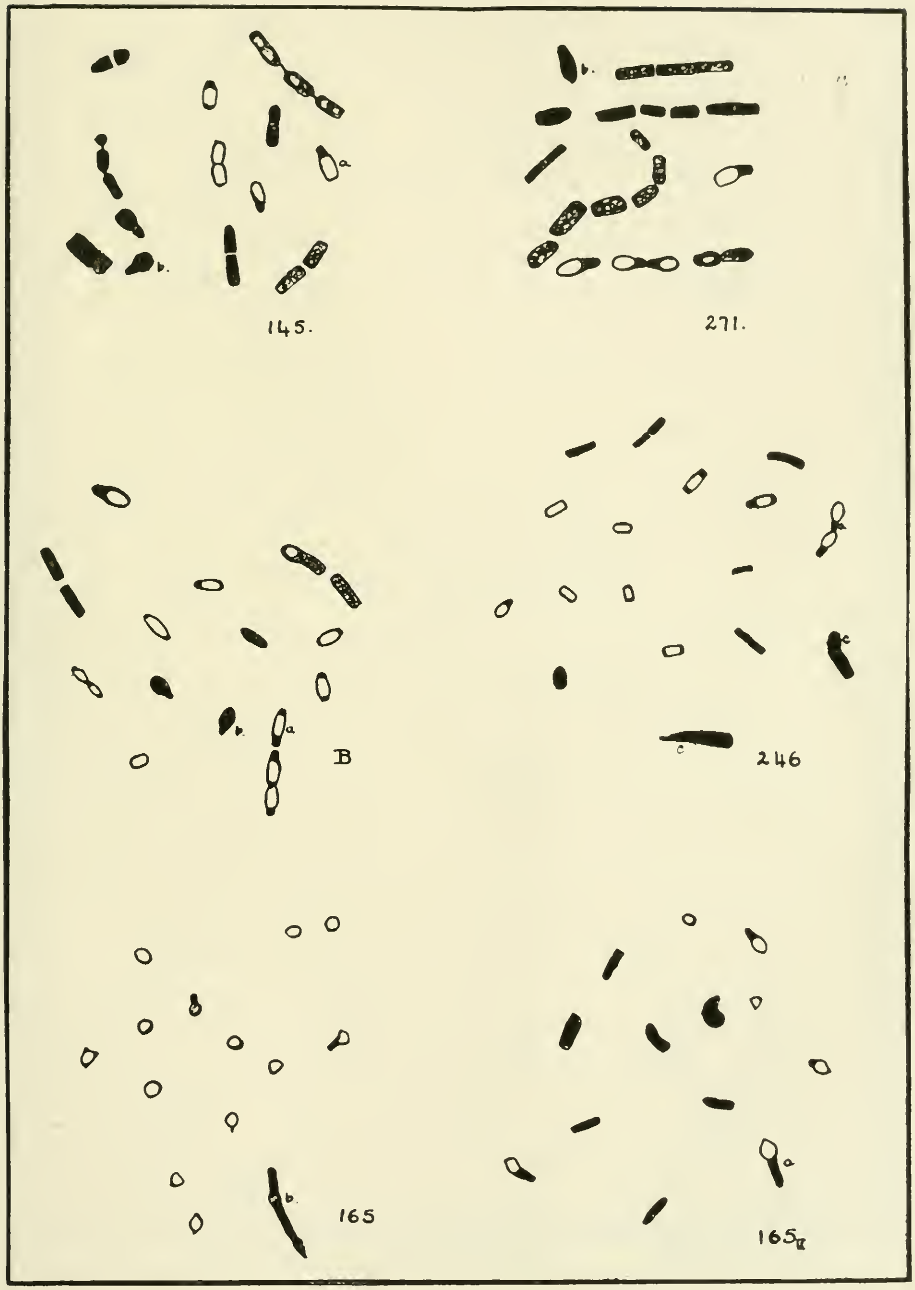
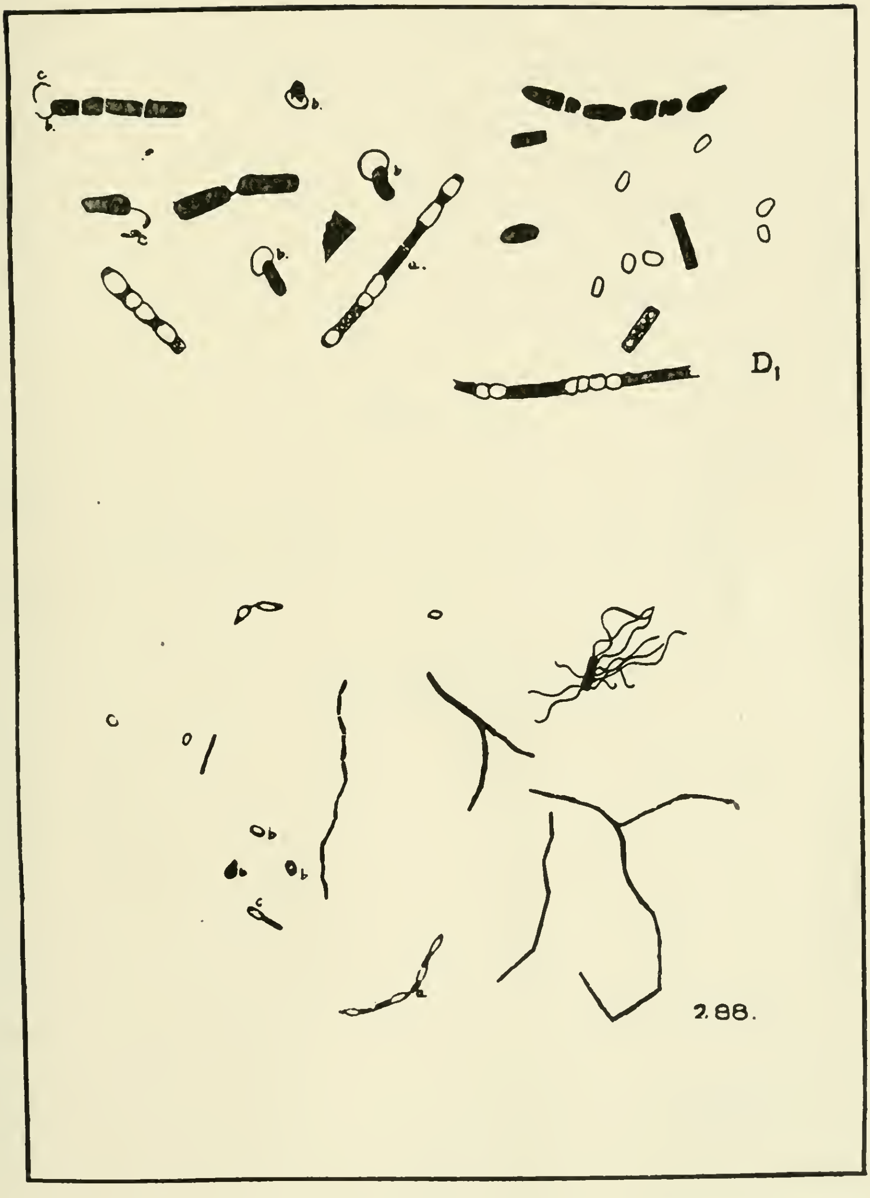


Plate II.

PLATE III.

PLATE IV.



No. 20

UREA IN FRESH AND FROZEN GRAYFISH

BY

C. C. BENSON
University of Toronto

Urea in Fresh and Frozen Grayfish

By C. C. Benson

(*The Lillian Massey Laboratory for Food Chemistry, University of Toronto*)

Grayfish and skate are found in large numbers on our Atlantic coast but find practically no sale in Canada, due mainly to their unfamiliar appearance and to the fear that their flesh may contain materials which are injurious. The muscle of these forms does in fact contain urea, which is commonly an excretory product of animal bodies.

Information has been gathered by Dr. James Mavor (1) as to the uses now being made of the grayfish and his report includes data as to the composition of the muscle and as to its nutritive value. He discusses, also, the objections as to its use as food and brings good evidence to show that there is no difficulty in regard to edibility from the amounts of urea which are usually regarded as being present in its flesh and which he determined by a rough system of analysis. More careful estimations have shown that the amount actually present is always less than the 2 per cent. which he reported.

When it became possible, through the kindness of the A. and R. Loggie Co. of Loggieville, N.B., and the F. T. James Co. of Toronto, to work with frozen specimens of grayfish, this investigation was made in order to compare the amounts of urea and of ammonia in the flesh after freezing and keeping. It is obvious that if this fish can be kept without undergoing change, it may find use at times when others are not available.

The present report is, therefore, concerned with the content of urea and ammonia in the grayfish and with the variations in these constituents on keeping. The grayfish, indeed, with its high urea content, furnishes particularly good material for the study of the influence of storage. The urea can be accurately determined and so also can the ammonia, which is formed from it as it decomposes.

Estimations were, therefore, made of the urea and ammonia contents (1) of fresh grayfish, (2) of frozen grayfish, when first thawed but after it had been kept in cold storage for different lengths of time, and (3) of grayfish which had been frozen and then kept after thawing. A few determinations of total solids and of total nitrogen were also made.

The *Total Solids* were estimated, in the usual way, by drying in the water or steam oven, and the *Total Nitrogen* by the Kjeldahl-Gunning method. *Ammonia* and *Urea* were determined by the methods used by Folin and others, the urea being estimated by the use of urease as recommended by Van Slyke and Cullen (2). In most cases alcoholic extracts were used as recommended by Marshall (3), and necessary precautions were taken to obtain accurate results. (4), (5), (6).

Determinations of total solids and of total nitrogen are recorded in Table I. and, as is usually found in fish muscle, there is considerable variation in water content of the different specimens (7).

In Table II. are given the quantities of urea and of ammonia nitrogen, found in fresh and frozen grayfish muscle and in the same muscle after keeping or cooking. In this Table there are also included values for urea nitrogen, calculated from the values for urea given in Mavor's paper for the fresh material and in canned grayfish from the results obtained by Dr. E. J. Baumann and reported by Mavor (1).

TABLE I

Total Solids and Total Nitrogen in Grayfish Muscle

Frozen Grayfish

	% solids	% Total N. (a)	Ammonia & Urea N. (b)	"Protein" N. (a)−(b)	"Protein" N×6.25	Fat
D 1	30.75					
D 5	27.03	3.01 3.04 deter^{n} on dry material	0.57	2.51	15.46	
D 42		3.88 4.00 deter^{n} on fresh material	0.56	3.43	21.41	
	27.00	4.05				7.80
			(E. F. D.	Martin) (8)		8.39
		4.08				

It is thus evident from Table II. that fresh and frozen grayfish contain practically the same amounts of ammonia and urea, and that the amount of urea is less than 2 per cent. (0.4 to 0.7 of urea N. which is equivalent to about 0.9 to 1.5 per cent. of urea). As the fish remains in cold storage there is a slight loss of urea with a consequent slight increase in ammonia. That this change is slight is seen from the urea values obtained from specimens D 20, D 42, and D 60, where the urea content of the two fish, D 42 and D 60, which were kept in cold storage longest, happened to be actually greater than in the fish which was frozen for a shorter time (D 20). The variations in urea content found in these specimens are not more than are frequently seen in specimens of the fish when fresh.

The amounts of urea found in the two fish which had been frozen for eleven months are actually no less than that in the fresh specimen, D.B., but the ammonia content of these fish shows that some hydrolysis had occurred and apparently this goes on even while the fish are frozen. D 1 may be compared with D 5 and D 20 with D 42. In both cases the ammonia content increased as time passed, though it happens that the urea content of the fish which were longer frozen was no less in either case, probably because, as explained above, the different fish originally contained different amounts of urea.

TABLE II

Urea and Ammonia Nitrogen in Grayfish.

Fresh Grayfish.

No. of Specimen	% of Urea N.	% of Ammonia N.	History and Condition of Specimen.
D. A.	0.61	0.03	Fresh muscle, still active when put into alcohol.
D. A.	0.61	0.03	
D. B.	0.50	0.02	Fresh muscle, but fish dead some hours before being worked with.
D. B.	0.50	0.03	

Frozen Grayfish.

No. of Specimen	% of Urea N.	% of Ammonia N.	History and Condition of Specimen
D 1	0.52	0.03	Shipped frozen from Mulgrave, received in good condition, frozen and with the glaze still on.
D 1	0.54	0.04	
D 1	0.53		
D 5	0.52	0.05	Same shipment as D 1, kept in cold storage in Toronto for 10 days longer.
D 5	0.52	0.06	
D 20	0.42	0.02	Shipment made from Mulgrave in the summer and case not opened until 6 weeks later; kept in cold storage in Toronto and apparently good.
D 20	0.41	0.03	
D 30	0.56		Same shipment as D 20, kept 6 months longer in cold storage in Toronto.
	0.57		
D 36	0.44	0.06	Same fish as D 30, but cut up in warm room and then kept 3 days more in open refrigerator in very cold weather.
"	0.43	0.06	
"	0.44		
"	0.44	0.09	Direct Aeration (muscle not put into alcohol).
"	0.44	0.08	
D 42	0.52	0.06	Same shipment as D 20 and D 30, and kept in cold storage for 11 months.
"	0.48	0.06	
D 60	0.50	0.07	Similar fish to D 42.
"	0.48	0.07	

Grayfish kept in Household Refrigerator

No. of Specimen	% of Urea N.	% of Ammonia N.	History and Condition of Specimen
D 3	0.35	0.10	Same fish as D 1, but kept 4 days in refrigerator.
"		0.09	
D 50	0.31	0.06	Same fish as D 60, kept 3 days in refrigerator.
		0.06	

COOKED GRAYFISH

No. of Specimen	% of Urea N.	% of Ammonia N.	History and Condition of Specimen
D 23	0.42	0.03	Same fish as D 20, boiled and kept 1 day in refrigerator.
"	0.41	0.03	
D 41	0.42	0.05	Same fish as D 42, boiled. (Direct aeration for urea and ammonia.)
"	0.40	0.05	

CANNED GRAYFISH

No. of Specimen	% of Urea N.	% of Ammonia N.	
Red Label I	0.37	0.09	Analyses by E. J. Baumann and reported by J. Mavor. (1)
Red Label II	0.355	0.09	
Blue Label III	0.16	0.145	

Holding in cold storage for eleven months is probably too long and many cold storage plants make a custom of keeping fish not longer than six months. The fish (D 42) which was frozen for eleven months, though it gave values for urea and ammonia very much like those of fish which had been frozen only a short time, had undergone changes in appearance, which made it unattractive. The flesh had become somewhat spongy (reminding one of the spongy frozen hake) and the cut surfaces of the flesh were of a dark yellow colour. The specimen D 60 was still of good appearance, was boiled and had a good flavour. It was in some respects possibly better than fresh grayfish, for the appearance was equally good and the flavour more delicate.

While the grayfish can thus be kept frozen for months without showing serious alteration, this fish once thawed soon undergoes change, and it is evidently quite impossible to keep it for any length of time in a household refrigerator. The fish (D 30 and D 36) showed decided change even though the refrigerator was kept near freezing point.

The cooking of the fish, however, made it much more resistant to hydrolysis, as is shown by D 41, which was kept 3 days; and, contrary to expectation, the heat necessary to boil it did not hydrolyse the urea, which was the same after boiling in D 20 and 23.

Even the temperature of the autoclave, used in canning, had not split up the urea as much as keeping raw thawed fish in the household refrigerator for 3 days. Baumann's analyses of the Red Label Canned Grayfish, gave values 0.37 and 0.355 for urea N. while D 50, kept in the refrigerator, contained only 0.31 per cent. of urea N. (Table II.).

The reaction of fresh grayfish and of the fish when first taken from cold storage is faintly acid. A watery extract reacts acid to litmus (pink), and to phenolphthalein (colourless), but alkaline to methyl orange (yellow), and to alizarin red (red), and has therefore a pH. of 5 or 6. This faintly acid reaction lasted so long as the fish were kept frozen and for a few hours after, but soon changed in the refrigerator, due to the liberation of the ammonia.

In conclusion, I wish to express my thanks to the A. and R. Loggie Co. of Loggieville, N.B., and to the F. T. James Co. of Toronto, for their interest and assistance and for the courteous way in which they have placed the facilities of their plants at the disposal of the workers for the Biological Board. I wish also to thank Dr. A. G. Huntsman, the Curator of the St. Andrew's Station, for all his very valuable assistance.

BIBLIOGRAPHY

(1) J. W. MAVOR. On the Utilization of the Selachian Fishes of Eastern Canada. *Report to Biol. Board of Canada.* 1918.

(2) D. V. VAN SLYKE and G. E. CULLEN. A Permanent Preparation of Urease and its Use in the Determination of Urea. *Jour. Biol. Chem.*, vol. 19, p. 211, 1914.
D. V. VAN SLYKE and G. E. CULLEN. The Determination of Urea by the Urease Method. *Jour. Biol. Chem.*, vol. 24, p. 117, 1916.

(3) E. K. MARSHALL, Jr. A New Method for the Determination of Urea in Blood. *Jour. Biol. Chem.*, vol. 15, p. 493, 1913.
E. K. MARSHALL, Jr., and D. M. DAVIS. Urea: Its Distribution in and Elimination from the Body. *Jour. Biol. Chem.*, vol. 18, p. 53, 1914.

(4) O. FOLIN and A. B. MACALLUM, Jr. On the Determination of Ammonia in Urine. *Jour. Biol. Chem.*, vol. 11, p. 523, 1912.

(5) F. C. WEBÈR and J. R. WILSON. The Formation of Ammonia and Amines in Canned Sardines during Storage. *Jour. Ind. and Eng. Chem.*, vol. 11, p. 121, 1919.

(6) J. B. SUMNER. The Direct Determination of Urea and Ammonia in Muscle. *Jour. Biol. Chem.*, vol. 27, p. 95, 1916.

(7) E. D. CLARK and L. H. ALMY. A Chemical Study of Food Fishes. *Jour. Biol. Chem.*, vol. 33, p. 483, 1918.
E. D. CLARK and L. H. ALMY. A Chemical Study of Frozen Fish in Storage for Long and Short Periods. *Jour. Ind. and Eng. Chem.*, vol. 12, p. 656, 1920.

(8) E. F. D. MARTIN. Unpublished Results.

No. 21

LARVÆ OF THE HALIBUT (*Hippoglossus hippoglossus* L.) ON THE ATLANTIC COAST OF NOVA SCOTIA

BY

PHILIP COX, PH.D.
University of New Brunswick

Larvæ of the Halibut (*Hippoglossus hippoglossus* L.) on the Atlantic Coast of Nova Scotia

By Philip Cox, Ph.D.
University of New Brunswick

As the larvæ of this species have not been heretofore recorded from this side of the Atlantic it was with more than the usual interest in such things that two specimens were discovered in the material collected by the Biological Boat *Prince* on the St. Margaret's bay expedition of 1922. The two records are:

Prince Station No. 353, about 3 miles off Baccaro point, N.S.; June 3, 1922; 18 to 23 metres, closing tow with No. 0 net; 1 specimen, 20 mm. long.

Prince Station No. 363, about 2 miles south of Coffin island, off Liverpool bay, N.S.; June 6, 1922; 23 to 27 metres, closing tow with No. 0 net; 1 specimen, 21.5 mm. long.

These were examined at the temporary laboratory at Hubbards, N.S. The former is just 20 mm. long; the body is ovate oblong, 6 mm. wide at the widest part, or 7.5 mm. when measured between the borders of the dorsal and anal fins. It has not transformed to any extent. The eyes are still right and left, one on each side of the head, the larval median fins are joined to the caudal by a wide strip of membrane, and the sides are alike pigmented.

The rays, however, of the future dorsal and anal fins are so well developed as to be readily counted under low microscopic power, the former showing 100, the latter 76; but it is possible that further development might have added one or two to both counts.

There is a deep angular depression between the eyes and the upturned and pig-like snout, the mandible is straight and makes an angle of about 50° or 55° with the axis of the body; and the mandibular articulation is well marked. When the fish is looked at from the right side, the left eye can be seen as a low swelling; it has just begun to migrate; and, in the absence of any difference in the pigmentation of the two sides, shows that the adult fish will be right-sided, that is, will have the eyes and specific colouration on that side. The eyes are large and densely pigmented with blue, and exhibit a beautiful silvery sheen.

The pectoral fins are very small and their rays are not discernible, while the position of the future ventrals is marked by two little folds or knobs on the ventral margin.

In dim light six little dusky patches can be seen with the naked eye, three on the dorsal border of the body and as many on the ventral. These, when viewed with the microscope, are seen to be groups of pigment cells of the stellate form, and similar to, but larger than, others variously disposed over the body and fins. They are situated on the caudal portion of the body, and invade the adjacent parts of the dorsal and anal fins, as the case may be, dotting the areas with larger points of colour than are seen elsewhere on these fins. The third, or most posterior pair of patches, is smaller and less distinct than the others. The fin membranes are everywhere marked with dark points, and seem bordered by one or two rows of larger ones.

On the caudal portion of the trunk occur also two rows of pigment spots, one at, or rather below, the base of the dorsal, the other similarly disposed as respects the anal. They extend to the base of the caudal fin, and the spots become visibly larger where the series passes through, and becomes a part of, the colour patches already described. Between these rows are three or four other poorly defined series, most noticeable on the caudal peduncle. Scattered spots can be seen elsewhere on the body and on the head, while a double row runs forward from the anus, one series on each side of the ventral margin, and converges at the isthmus.

The determination of this larva was made possible by the description and plates in that excellent review of Dr. Johs. Schmidt's work on the larval halibut in "Notes on the Eggs and Larval Stages of the Halibut," by Prof. E. E. Prince (Contr. Can. Biology, 1914-1915, p. 19). A later comparison with Schmidt's own account (Medd. Komm. f. Havundersgelser, Ser. Fiskeri, Bd. 1, No. 3, 1904) has confirmed the diagnosis.

The second specimen is 21.5 mm. long, and has 102 rays in the dorsal and 75 in the anal fin. It corresponds in all particulars with the first, except that the colour patches show a tendency to scatter, preparatory to a new arrangement of pigment in the more advanced stages.

The correct identification of larval fishes is a difficult matter, but the margin of possible error is narrowed, provided the student is able, by means of plates, descriptions, and correctly determined material to eliminate a few of the closely related species. Only three of our North Atlantic flatfishes have as high a fin-ray formula as the specimen under examination, namely, *Reinhardtius hippoglossoides*, the Greenland halibut; *Glyptocephalus cynoglossus*, the Craig flounder; and our common halibut. *Glyptocephalus* has a much greater number of rays in the anal fin than have these specimens, and the form and pigmentation of its larvæ are decidedly different, as is shown by many specimens taken in St. Margaret's bay during the expedition. *Reinhardtius* might be ruled out as extra-limital, although it occurs around the Newfoundland banks. Schmidt has, however, clearly shown that its larva is extremely elongated, and lacks the hooked snout so characteristic of the larval halibut. It differs from the halibut also in possessing a larger number of pigment spots, four at the base of the anal and five at the base of the dorsal fin.

The larval halibut has never been found in the North Atlantic in America, and very few specimens of it elsewhere, so that little or nothing is accurately known of this period of its life. Nor has the time of its spawning been definitely ascertained, some authorities alleging that it takes place in winter; others, in the spring and summer months.

The discovery of these larvæ so near our coast gives good reason for believing that an investigation of the continental slope off Nova Scotia would lead to the discovery of the eggs of the halibut, now unknown except as found in the female fish.

No. 22

THE BODY TEMPERATURE OF FISHES

BY

S. W. BRITTON
McGill University, Montreal

The Body Temperature of Fishes

By S. W. Britton
McGill University, Montreal

It has been pointed out by Sutherland Simpson (1, 2) that only small differences are found between the body temperature of several types of marine fishes and the temperature of the water in which they live. In a number of fishes examined by him, an excess of body temperature over that of the surrounding water was evident, particularly in the larger specimens, in which it varied between 0.1° and 0.7°.

While engaged in experimental work during the summer of 1922 at the Canadian Government Atlantic Biological Station, St. Andrews, New Brunswick, opportunities were afforded me, through the kindness of the Director, Dr. A. G. Huntsman, of accompanying the fishing expeditions carried out in connection with the work of the Station. Advantage was taken of such occasions for securing exact information regarding the body temperature of fishes found off the North American shores, which differ from those described by Simpson.

The fishes on which observations were carried out were caught in salt water at the mouth of the St. Croix River. An ordinary hand-line was employed for fishing just off shore in shallow water, and a trawl-line, baited with young herring and generally set about one hour, was used in the deeper water. The water temperatures were recorded by a Negretti and Zambra patent deep-sea reversing thermometer, with which the thermometer used for taking the body temperature of the fishes corresponded in readings.

The surface temperature of the water was generally 1°-4° higher than the deep water temperature, and the air temperature was usually a few degrees above that of the surface water. Notwithstanding these circumstances, any acquisition of heat by the interior of the fish would have been inappreciable because of the short time intervening between its withdrawal from the deep water and the taking of its body temperature. The correctness of this assumption was shown on many occasions by the fact that fishes which were already dead on being landed showed rectal temperatures equivalent to the temperature of the deep water from which they were drawn.

On withdrawal from the water, the fish was immediately taken by the snout and gill-covers, and the rectal thermometer introduced to a depth of 6-8 cms., to ensure an accurate register of the deep body temperature being taken. Only the larger specimens were examined, these generally ranging between three and ten pounds in weight.

For the sake of comparison with these records, observations are also given on the body temperature of a number of fishes kept in the large laboratory tanks, the water temperatures in which were somewhat higher.

The temperature differences shown by fish taken from the deeper water were as follows:

TABLE I

Date, etc.	Name of Fish	No. Examined	Temp. of Fish	Temp. of Water	Temp. Diff.
June 28, 1922.	Raja ocellata	4	8.6	7.9	0.7
Water depth:	Aeglefinus melanogrammus	7	8.65	7.9	0.75
17 fathoms.	Gadus morrhua	2	8.75	7.9	0.85
July 12, 1922.	Raja ocellata	4	9.4	8.7	0.7
Water depth:	Aeglefinus melanogrammus	8	9.3	8.7	0.6
17 fathoms.	Gadus morrhua	6	9.4	8.7	0.7
	Zoarces anguillaris	2	9.55	8.7	0.85
	Hemitripterus americanus	1	9.4	8.7	0.7
July 19, 1922.	Raja ocellata	3	10.0	9.4	0.6
Water depth:	Aeglefinus melanogrammus	7	9.9	9.4	0.5
10 fathoms.	Hemitripterus americanus	2	10.1	9.4	0.7
July 28, 1922. Water depth:	Raja ocellata " erinacea	27	10.25	9.6	0.65
17 fathoms.	Aeglefinus melanogrammus	6	10.25	9.6	0.65
	Zoarces anguillaris	1	10.4	9.6	0.8
Aug. 1, 1922.	Raja ocellata	1	10.4	9.7	0.7
Water depth:	Aeglefinus melanogrammus	4	10.45	9.7	0.75
17 fathoms.	Gadus morrhua	1	10.4	9.7	0.7
	Zoarces anguillaris	1	10.6	9.7	0.9
Aug. 9, 1922.	Raja ocellata	8	10.55	10.0	0.55
Water depth:	Aeglefinus melanogrammus	4	10.6	10.0	0.6
17 fathoms.	Gadus morrhua	2	10.7	10.0	0.7
	Zoarces anguillaris	1	10.7	10.0	0.7

The figures indicating the difference between the temperature of the fish and that of the water vary only slightly from those obtained by Simpson for other species. The highest records were those given by *Zoarces anguillaris*, an extremely agile fish, and a vigorous fighter, which consistently showed a greater temperature difference than other fish taken at the same time.

For some distance off shore from the Atlantic Biological Station the water is shallow and usually registers a higher temperature than the deeper water. The following fishes were taken within this shallow area:

TABLE II

Date, etc.	Name of Fish	No. Examined	Temp. of Fish	Temp. of Water	Temp. Diff.
Aug. 2, 1922.	Myoxocephalus greenlandicus	5	13.7	13.3	0.4
Water depth:	" octodecimspinosus	3	13.7	13.3	0.4
2 fathoms.					
Aug. 3, 1922.	Myoxocephalus greenlandicus	6	14.2	13.8	0.4
Water depth:	" octodecimspinosus	4	14.2	13.8	0.4
2 fathoms.					

It is noticeable that these fishes do not show as great body temperature differences as those from water of lower temperature. A more marked decline in temperature difference between the fish and its environment is found in the following readings taken from fishes kept in the laboratory tanks:

TABLE III

Date, etc.	Name of Fish	No. Examined	Temp. of Fish	Temp. of Water	Temp. Diff.
July 6, 1922. Fish in laboratory tank III	Myoxocephalus greenlandicus	3	12.9	12.6	0.3
July 6, 1922. Fish in laboratory tank II	Pseudopleuronectes americanus	6	13.35	13.1	0.25
Aug. 9, 1922.	Myoxocephalus greenlandicus	8	14.6	14.4	0.2
Fish in laboratory	" octodecimspinosus	4	14.6	14.4	0.2
tank III	Hemitripterus americanus	2	14.6	14.4	0.2
Aug. 10, 1922.	Myoxocephalus greenlandicus	5	15.0	14.9	0.1
Fish in laboratory	" octodecimspinosus	3	15.0	14.9	0.1
tank III	Hemitripterus americanus	3	15.0	14.9	0.1
Aug. 10, 1922.	Raja ocellata	3	15.6	15.5	0.1
Fish in laboratory	Myoxocephalus greenlandicus	4	15.6	15.5	0.1
tank II	" octodecimspinosus	1	15.6	15.5	0.1

With Simpson, therefore, one may conclude that the greater number of fishes show a body temperature slightly in excess of the temperature of the water in which they live. This temperature difference appears to be, within limits, inversely proportional to the water temperature.

(1) Simpson, Sutherland, Proc. Roy. Soc. Edin., Vol. XXVIII., 1907-8, p. 66.
(2) Simpson, Sutherland, Jour. of Physiol., Vol. XXXVI., 1908, p. xlii.

No. 23

AN ANNOTATED LIST OF A COLLECTION OF FISHES MADE BY FRANCIS HARPER IN THE ATHABASKA REGION IN 1920, TO WHICH IS APPENDED A LIST OF SPECIES COLLECTED BY DR. R. T. MORRIS IN THE DISTRICT BETWEEN LAKE WINNIPEG AND HUDSON BAY IN 1905

BY

WILLIAM CONVERSE KENDALL
Roosevelt Wild Life Forest Experiment Station, Syracuse, N.Y.

published Mar 24 1924

An annotated list of a collection of fishes made by Francis Harper in the Athabaska Region in 1920, to which is appended a list of species collected by Dr. R. T. Morris in the district between Lake Winnipeg and Hudson Bay in 1905

By William Converse Kendall
Roosevelt Wild Life Forest Experiment Station, Syracuse, N.Y.

In 1921, Mr. Francis Harper turned over to the writer for identification a small collection of fishes which he had made in the Athabaska region, while working there under the auspices of the United States Biological Survey in 1920. This collection supplements another small one which was made in 1914 and reported upon by Francis Harper and John Treadwell Nichols (1).

The present collection comprises 16 species, representing 13 genera and 9 families. The six new species described by Harper and Nichols comprised one sucker (Richardson's gray, *Catostomus richardsoni*), the Athabaska minnow (*Opsopœodus borealis*), Preble's whitefish (*Coregonus preblei*), the Tazin River Cisco (*Leucichthys entomophagus*), the Cisco of Lake Athabaska (*Leucichthys athabascae*), and one Cisco of Great Slave Lake (*Leucichthys macrognathus*).

The specimens of the present collection reveal that these six new species must be reduced to four. Comparison of *Catostomus richardsoni*, as represented by the description and present specimens, with specimens of similar size of the common sucker (*Catostomus commersonii*) show no tangible specific differences. The "Athabaska minnow" (*Opsopœodus borealis*) appears to be simply the young of *Notropis hudsonius selene*. Besides these two species comprised in Harper and Nichols' "Six new species," the present collection appears to contain one other of the six. That is the Cisco of Lake Athabaska (*Leucichthys athabascae*).

Family CATOSTOMIDAE

1. *Catostomus catostomus*. Red-side Sucker; Northern Sucker; Long-nose Sucker; Fine-scaled Sucker.

The collection contained one adult and 3 young of this species. The adult, 397 mm. total length (tag number 40), was caught in a gill-net near shore in about 6 feet of muddy water, on a muddy bottom, in Rivière Coupée, 15 miles northwest of Fort Chipewyan, July 17.

The three young, tag numbers 32, 33, 34, respectively, 77, 76, and 80 mm. total length, were taken by seine in 20 to 24 inches of water at Goose Island, Lake Athabaska, May 26.

The adult fish was a female with small ovaries. The upper lip had two rows of papillae with a row in front of them, the papillae of which alternated with those of the row immediately behind it, thus making practically three rows. The lower lip was divided to the jaw, each lobe with about eight rows of papillae.

The third anterior ray of the dorsal was the longest of the dorsal rays excepting what appeared to be an abnormally greatly produced ray next to the last one.

The head length represented 22.68 per cent. of the length from tip of snout to end of scales at base of caudal (335 mm.). Distance from tip of snout to nape, 20.89 per cent. of the same length, and the distance from tip of snout to the edge of preopercle 76.31 per cent. of the length of the head.

The dorsal was situated exactly midway the distance from nape to upper base of caudal; distance from tip of snout to front of eye exactly the same as the distance from anal to the lower base of caudal and 48.69 per cent. of the length of head. The interorbital width is just about three times the longitudinal diameter of eye, which is a little greater than the vertical diameter, and is 39.47 per cent. of the length of the head.

Dorsal rays 3/9; anal 3/6; pectoral 19; ventral 10; branchiostegals 3; scales 18-106-18.

As is to be expected, the proportional measurements of young individuals are somewhat different from those of the adult. The distance from tip of snout to nape, height of dorsal, length of ventral, length of head and eye are all relatively greater in the young than in the adult. The distance from nape to dorsal, length of pectoral, distance from pectoral to ventral, from ventral to anal, tip of snout to posterior edge of preopercle and length of snout are less than in the large fish.

The colouration of the large specimen is plain, that is, without marking or cloudings, while in the young the back is finely clouded with brownish shades, there are brown dots on the side, and there is a large dusky spot at base of caudal.

2. *Catostomus commersonii.* Common Sucker; Gray Sucker.

Two specimens were in the collection, one, tag number 12, 360 mm. total length, was taken at Goose Island, Lake Athabaska, May 26; another, tag number 39, 390 mm. total length, was caught in a gill-net in about two feet of water in a small tributary nine miles above the mouth of the main branch, Athabaska Delta, on June 11. This specimen was labelled by Mr. Harper as *Catostomus richardsoni.* The first-mentioned individual is a female with small ovaries and the second a male with very small spermaries.

The lower lip is not as deeply lobed as in *C. catostomus*, each lobe having six or seven rows of papillae. The upper lip has three and four rows of papillae respectively in the female and in the male. The length of the head is somewhat greater in the male than in the female, but the interorbital is greater in the female, as are the height of dorsal, length of pectoral, distance from ventral to anal, and size of eye. The specific differences between *C. richardsoni* and *C. commersonii*, upon comparison of the present specimens with undoubted *C. commersonii*, do not hold, but three of these differences obtain in the present specimens, indicating that they are sexual differences. It is stated of *C. richardsoni* that the insertion of the ventral is not so far behind the insertion of the dorsal as in *C. commersonii*, that the pectoral is shorter and the eyes more posterior. These are all true in the male of this pair. The longer snout of the male accounts for the more posterior situation of the eye. Therefore, if the present specimens represent examples of *C. richardsoni*, to hold the name, some other distinctive characters than those enumerated must be found for the Gray Sucker.

Family CYPRINIDAE

3. *Notropis hudsonius selene.* Spot-tail minnow.

The collection contains eight specimens, tag numbers 17 to 24, from 66 to 92 mm. total length, averaging 77 mm., and one specimen, tag number 25, 38 mm. long, which were taken by seine in about 20 to 24 inches of water at Goose Island, Lake Athabaska, May 26. One specimen, number 76, was caught 8 miles N.E. of Moose Island, Lake Athabaska, July 30. Mr. Harper had correctly identified the eight specimens, but the small one had not been identified. It proved to be specifically identical with the others and to correspond with the description of *Opsopœodus borealis* (Harper and Nichols, 1, p. 266). Therefore *O. borealis* appears to be a young *Notropis hudsonius selene.*

As examples of this sub-species, two of the largest specimens afford the following characters. In one (No. 17) the pharyngeal teeth appear to be 0. 4-4, 1. The dorsals and anals of both had eight rays each. The scale count was the same in both, *i.e.*, 7-40-4.

TABLE 1

Table of measurements and proportions of two specimens of *Notropis hudsonius selene.* Body parts are in per cent. of length of body; head parts in per cent. of length of head.

Tag No.	Total length	Length to end of scales	Depth of body	Tip of snout to anal	Tip of snout to ventral	Base pectoral to ventral	Base ventral to anal
17	92	77	23.37	48.05	46.75	23.37	20.77
18	84	68	25.00	47.05	47.05	25.73	19.85

Length head	Eye	Snout	Height of dorsal	Height of anal	Length pectoral	Length ventral
22.72	34.28	28.57	22.07	.....	18.18	16.88
22.05	33.33	30.00	22.05	19.11	20.58	16.17

4. *Notropis atherinoides.* Silver-side Minnow.

The collection comprised 4 specimens, tag numbers 28 to 31 inclusive, which were 76, 74, 72, and 70 mm. total length respectively, taken by seine in about 20 to 24 inches of water at Goose Island, Lake Athabaska, May 26.

The following notes were taken from the largest specimen: Lateral line somewhat decurved anteriorly toward ventrals, thence straight upward to base of caudal; mouth terminal, oblique, lower jaw slightly projecting; maxillary extending to front of eye; no barbel. Faint plumbeous band posteriorly, straight, touching and including lateral line only on caudal peduncle; no caudal spot.

Dorsal rays, 8; anal rays, 11; pharyngeal teeth, 2, 4-4-1.

TABLE II

Proportional measurements of specimen number 28, *Notropis atherinoides*. Body parts are in per cent. of length of body; head parts in per cent. of length of head.

Length to end of scales mm.	Depth of body	Tip of snout to dorsal	Dorsal to caudal	Snout to ventral	Pectoral to ventral	Ventral to anal	Anal to caudal
63	19.04	52.38	30.15	44.44	23.80	19.04	15.87

Least depth caudal peduncle	Height dorsal	Height anal	Base anal	Length pectoral	Length ventral	Head	Eye head	Snout head
9.52	17.46	15.87	15.07	18.25	19.28	11.11	32.14	19.04

5. *Platygobio gracilis.* Flat-head Chub.

The collection contained three specimens, collected in Rivière Coupée, Athabaska Delta, 15 miles northwest of Fort Chipewyan, July 17.

There were two females, tag numbers 41 and 42, 320 and 340 mm. total length respectively. Number 41 was taken by gill-net, close to shore in about 8 feet of muddy water on a muddy bottom. Number 42 was caught on hook and line in about 8 feet of muddy water on a bottom of soft mud, and one male fish, number 43, total length 238 mm., was caught in the same place. The stomach of number 41 contained fragments of insect larvae and insects. The ovaries of number 42 were large but contained small ova. The ovaries were surrounded by peritoneal membrane, but that of the air-bladder formed the upper covering of the ovarian cavity. The stomach contained large scales and meat of some fish. Along the scales of the male are indistinct dark stripes. The spermaries were immature. The alimentary tract contained larval insects.

Branchiostegals, 3-3; dorsal rays, 3/7; anal rays, 3/7½, 2/7 and 3/8 in the respective specimens. Pectoral rays are 19 in Nos. 42 and 43, but in 41 they are 18 on the right side and 9 on the left (evidently abnormal). Ventral rays are 9 right and 8 left in No. 41, 8 on both sides in No. 42, and 8 right and 9 left in No. 43. The scale counts are 8-53-6 in No. 41; 6-57-6 in No. 42; and 8-53-5 in No. 43.

TABLE III

Table of measurements and proportions of *Platygobio gracilis*. Body parts are in per cent. of length of body; head parts in per cent. of head.

Proportional Measurements	No. 41	No. 42	No. 43	Proportional Measurements	No. 41	No. 42	No. 43
Length to fork of tail mm.	284	315	215	Length of ventral	17.60	14.98	15.57
" " end of scales mm.	250	287	199	Distance base ventral to front anal	22.80	26.48	23.61
Distance tip snout to nape%	16.80	16.02	17.08	Length base anal	11.60	9.75	11.05
" nape to front dorsal	33.60	28.91	26.63	Longest ray of anal	17.60	16.02	15.07
Length base of dorsal	12.40	11.49	11.55	Distance anal to caudal	17.60	17.07	16.58
Longest ray of dorsal	20.40	17.42	20.10	Depth of body	25.60	26.13	20.10
Distance from dorsal to caudal	41.60	37.97	40.70	Length of head	20.80	20.20	20.10
Length upper caudal lobe	31.20	25.42	23.62	Tip of snout to edge preopercle	69.23	68.96	72.50
" longest upper caudal ray	27.60	21.95	22.11	Depth of head from occiput	57.69	63.79	55.00
" middle caudal ray	13.60	9.75	8.54	" " " through eye	42.30	39.65	40.00
" lower caudal lobe	28.80	.....	27.15	Width of interorbital	42.30	37.93	40.00
" longest lower caudal ray	25.20	....	25.62	Vertical diameter eye	13.46	15.41	17.50
Least depth caudal peduncle	10.00	10.10	10.05	Length eye	17.30	15.41	18.75
Distance tip of snout to base pectoral	20.00	19.16	20.60	Length snout	32.69	31.03	37.50
Length of pectoral	25.60	25.42	21.60	Length maxillary	32.69	31.18	35.00
Distance base pectoral to base ventral	38.00	28.57	26.15	Length mandible	46.15	41.37	42.50

6. *Hiodon alosoides.* Goldeye.

Three specimens, tag numbers 13, 14, and 15, respectively female 325, female 325, and male 332 mm. total length, were taken in $2\frac{1}{2}$ feet of water at Goose Island, Lake Athabaska, May 26, and one specimen, tag number 103, a male about 375 mm. total length, was caught in a gill-net in a somewhat muddy back-water of Peace River, at Peace Point, on September 8. The ovaries of number 14 were small and immature, but those of number 13 were well advanced in development of ova. The spermaries of both males were small, and those of number 15 apparently lobed.

The branchiostegals were respectively 8-9; 7-7; 8-8; and 8-9 (right and left). Dorsal rays were 3 $8\frac{1}{2}$; 3 9; 3 $9\frac{1}{2}$; and 3 10. Anal rays: 3 32; 3 31; 4 $32\frac{1}{2}$; and 4 32. Pectoral rays are uniformly 12 and ventral rays uniformly 7 in the four specimens. For table of measurements see next page.

Family COREGONIDAE

7. *Prosopium quadrilaterale?* Round Whitefish; Menominee?

Three young individuals, tag numbers 79, 80, 81, respectively 48, 50, and 50 mm. total length, were seined in 1 to 3 feet of clear water on sandy bottom, 8 miles northeast of Moose Island, Lake Athabaska, July 30. The specimens

TABLE IV

Table of measurements and proportions of *Hiodon alosoides*. Body parts are in per cent. of length of body; head parts in per cent. of length of head.

Tag numbers	13	14	15	103
Length to fork of tail mm.	301	298	310	345
“ “ end of scales mm.	275	271	285	317
“ base of dorsal	8.72	10.70	8.07	11.04
“ longest dorsal ray	12.09	12.91	12.28	11.67
“ upper caudal lobe	.....	21.77	22.80	22.39
“ lower caudal lobe	24.00	23.98	23.85	23.97
“ longest upper caudal ray	.....	19.18	19.29	19.55
“ longest lower caudal ray	20.36	21.40	20.30	20.82
“ middle caudal ray	9.49	9.96	8.77	8.83
“ pectoral fin	19.27	19.55	19.64	19.87
“ ventral fin	12.72	12.91	13.33	13.88
“ base anal fin	26.54	24.31	29.12	26.81
“ longest anal ray	10.90	11.81	11.92	15.77
“ head	20.36	19.92	20.70	20.50
Distance tip of snout to nape	12.00	11.81	13.68	13.24
“ nape to front dorsal	54.18	55.35	54.03	55.20
Distance end dorsal to caudal	22.18	23.24	23.85	22.71
“ tip snout to base pectoral	20.36	20.66	21.40	21.45
“ base pectoral to base ventral	26.18	23.98	22.45	22.71
“ base ventral to front anal	22.18	22.14	20.00	20.18
“ end anal to base caudal	9.49	9.96	9.82	7.25
Greatest depth of body	32.70	32.84	30.17	32.17
Least depth caudal peduncle	9.81	9.96	9.47	8.20
Distance tip snout to edge preopercle (*a*)	76.78	74.07	76.96	.....
	96.42	85.18	88.13	81.53
Depth of head through eye	57.14	55.55	55.93	56.92
Interorbital width	29.46	27.77	25.42	29.23
Diameter of eye—vertical	23.21	27.77	.....	.....
	21.42	27.77	23.72	24.61
Diameter of eye—long	23.21	24.07	.....	.....
	19.64	20.37	25.42	24.61
Distance tip of snout to eye	19.64	20.37	20.33	21.53
Distance tip of snout end of maxillary	46.42	46.29	47.45	50.76
Length of maxillary	41.07	40.74	40.66	40.00
Length of mandible	51.78	53.70	52.54	55.38

(*a*) The upper figures represent the distance straight back to the posterior edge of the preopercle; the lower figures, to the lower angle of the preopercle. These two dimensions indicate that the edge of the preopercle extends downward and backward.

were too small and in too bad condition for positive identification. They undoubtedly belong to the *Prosopium* group and may be one or another of three nominal species: *P. quadrilaterale*, *P. kennicotti*, or *P. preblei* (Harper and Nichols).

Number 79 had 4 relatively large dark spots on the middle of the back in front of the dorsal, two at the base of the dorsal, four between the dorsal and the adipose, and two between the adipose and upper base of caudal. Also, on the side were six large spots from the upper end of the gill-opening to base of caudal.

8. *Coregonus clupeaformis.* Whitefish.

Five adult individuals ranging in total length from 348 to 408 mm. were collected. These specimens are undoubtedly specifically identical with those collected by E. A. Preble in the Mackenzie River basin (1903-04) and listed by Evermann and Goldsborough (2) as *Coregonus richardsoni*.

The only other species of *Coregonus* recorded from the Mackenzie basin are: *C.* [*Prosopium*] *kennicotti*, *C.* [*Prosopium*] *quadrilateralis*, and *C.* [*Prosopium*] *preblei*. Concerning *Coregonus richardsonii*, Jordan and Evermann say (3): "A doubtful species, perhaps identical with *Coregonus kennicotti*, or possibly *Coregonus nelsonii*." These specimens are quite clearly neither of the latter species. They resemble very closely the form formerly designated as *Coregonus labradoricus*, which later was decided to be indistinguishable from *Coregonus clupeaformis* (4).

Günther (5) states that *Coregonus richardsonii* is very closely allied to *C. albus*, from which it differs in the form of its maxillary. No locality for *C. richardsonii* is definitely stated. One of the specimens of the British Museum which served as a basis for the description of the species, was presented by J. Rae, Esq. While Rae travelled over considerable Arctic and Sub-arctic territory at different times, the most likely place of collection and preservation of fish was at Moose Factory, head of James Bay, where he spent considerable time. So, if Richardson's *Coregonus labradoricus* from Musquaw River (north shore of the Gulf of St. Lawrence, Quebec), as is likely, is the same species as the whitefishes about the lower end of the Hudson Bay, it is probable that the Athabaska-McKenzie fish is also. If *Coregonus labradoricus* is a synonym of *Coregonus*, *clupeaformis*, the present specimens would therefore be *Coregonus clupeaformis* and are here provisionally so regarded.

The specimen with tag number 38, a female 401 mm. total length, was caught in a gill-net in about 2½ feet of water, at Goose Island, Lake Athabaska, May 28. The outline of the head from the nape to snout is straight. The fins are more intensely dusky than in other specimens. The stomach is "gizzard-like." Branchiostegals, 7-7; dorsal rays, 3 10; anal rays, 3 12; pectoral rays, 16; ventral rays, 11; scales, 10-75-8; those on caudal peduncle from posterior adipose to lateral line downward and backward, 5; and from posterior anal upward and backward to lateral line, 5; with one in lateral line (formula 5-1-5); gillrakers 9+16 on each side, the longest being 53.57 per cent. of the vertical diameter of the eye.

Tag number 100, a female 408 mm. total length, was taken in a gill-net at Fair Point, Lake Athabaska, August 22. The dorsal line of the head is also straight from the nape to the snout. The colouration is light gray on the back, side silvery and belly white. The fins are only slightly dusky. Branchiostegals, 8-9; dorsal rays, 3/10; anal rays, 3/11; scales, 9-76-9; scales on caudal peduncle, 6-1-6; gillrakers 10+18 on each side, the longest being 50 per cent. of the vertical diameter of the eye.

Tag number 102, a male, 378 mm. total length, was taken in a gill-net at Fort Chipewyan, Lake Athabaska, August 30. The dorsal outline of the head slopes somewhat abruptly downward from the nape, over the eye rising in a hump, thence curving to snout. Perhaps this is the form which Preble refers to as a species in the lower Peel and Mackenzie which is locally called "broken nose." (6) The pectoral is falcate. The back is gray, sides silvery and belly white; the membrane of the dorsal slightly dusky; anal still darker, especially upper and lower rays; a narrow terminal margin, and the middle rays dusky. The stomach is "gizzard-like," and the adipose fin comparatively low. Branchiostegals, 7-7; dorsal rays, 3/11; anal rays, 3/12; pectoral rays, 16; ventral rays, 11; scales, 11-76-9; those on caudal peduncle, 6-1-6; gillrakers 10+17 on each side, the longest 42.85 per cent. of the vertical diameter of the eye.

Tag number 104, a female, 361 mm. total length, was taken in a gill-net in Athabaska River, 8 miles above Embarras River, October 2. The stomach and intestines were gorged with insects. There is a very slight depression between the occiput and the supraorbital region. There are "asperities" on the tongue; the colour of the fish is about as in No. 102, but it is a chubbier-looking specimen. Branchiostegals, 7-8; dorsal rays, 3/10; anal rays, 3/11; pectoral rays, 16; ventral rays, 12; scales, 12-74-9, those on caudal peduncle 6-1-6; gillrakers 10+18 on each side, the longest being 50 per cent. of the vertical diameter of the eye.

Tag number 105, a female, 348 mm. total length, taken in the same place as No. 104, on the same date. The dorsal profile of the head is about as in number 102, *i.e.*, depression anteriorly to occipital region and hump or arch over the eye and curved snout. The colour is like that of number 102. Branchiostegals, 7-8; dorsal rays, 3/11; anal rays, 3/11; pectoral rays, 16; ventral rays, 12; scales, 11-76-10, those on caudal peduncle 6-1-6; gillrakers 9+17 on each side, the longest being 43.75 per cent. of the vertical diameter of the eye.

The collection also contained 12 specimens of young individuals of *Coregonus* which undoubtedly are specifically identical with the adults here listed.

One individual, 61 mm. total length, tag number 46, was taken by shotgun, close to shore, in clear water, over rock and sand bottom, 8 miles northeast of Moose Island, Lake Athabaska, July 28.

The eleven other specimens, tag numbers 82 to 92, range in total length from 37 to 65 mm., were taken by seine in the same locality as number 46, in clear water over sandy bottom, July 30. Nine of these individuals ranged in total length from 56 to 65 mm., and averaged 61.66 mm. Two specimens were 37 to 38 mm. in total length. The average length of the 10 larger specimens was 61.7 mm., and of the entire lot of 12 it was 57.66 mm.

TABLE V

Table of measurements and proportions of *Coregonus clupeaformis.* Body parts are in per cent. of length of body; head parts in per cent. of length of head.

Tag numbers	38	100	102	104	105	f. P.
Length to fork of tail mm	372	376	340	325	316	. . .
“ to end of scales mm	350	353	316	305	295	. . .
“ of base of dorsal	12.60	11.60	12.90	13.10	13.90	10.35
“ longest dorsal ray	17.4	18.15	22.20	22.00	21.40	17.65
“ base of adipose	6.28	6.22	6.35	6.22	4.74	4.89
“ upper caudal lobe	21.40	. . . . .	25.60	25.90	. . . .	. .
“ longest caudal ray	18.55	. . . . .	19.30	23.80	. . . .	. .
“ lower caudal lobe	21.40	23.20	26.30	25.90	25.01	. . .
“ longest caudal ray	18.55	20.10	19.90	23.80	22.40	. . . .
“ middle caudal ray	6.28	6.50	7.60	6.55	6.50	. . . .
“ pectoral	16.85	17.00	20.35	18.05	19.30	18.15
“ ventral	18.00	18.40	20.30	20.00	20.00	17.20
“ base anal	13.15	11.90	13.60	13.10	12.55	9.89
“ longest anal ray	13.45	13.05	13.90	15.75	14.60	12.80
“ head	19.15	20.40	19.30	20.35	21.01	20.90
Distance tip snout to nape	14.30	16.15	15.18	14.45	15.95	. . . . .
“ nape to dorsal	30.60	31.20	34.80	31.50	32.20	31.41
“ dorsal to adipose	24.30	34.80	25.00	23.90	22.70	24.90
“ adipose to base caudal	10.00	8.50	7.90	9.50	9.15	9.31
“ tip snout to base pectoral	18.90	21.20	19.60	20.35	20.03	. . . . .
Distance base pectoral to base ventral	30.60	29.20	27.50	28.20	31.60	44.20
Distance base ventral to front anal	29.70	28.60	26.90	30.80	25.92	34.90
Distance end anal to base caudal	10.00	8.20	7.90	7.88	7.12	9.77
Greatest depth body	27.70	26.00	29.10	30.80	30.20	24.90
Least depth caudal peduncle	9.42	8.50	10.70	10.65	11.20	9.08
Distance tip to edge preopercle	70.00	72.20	70.02	74.20	72.60	. . . . .
Depth head from nape	68.60	61.00	64.80	65.03	66.00	64.25
“ “ preocciput	61.20	54.20	55.30	58.00	59.50	. . . .
“ “ through eye	46.60	43.10	41.20	48.40	48.50	44.40
Interorbital width	32.57	29.15	32.80	30.06	29.00	30.00
Vertical diameter eye	19.40	18.05	21.90	19.35	19.35	16.60
Length eye −adipose membrane	20.30	18.05	21.90	19.35	21.00	. . . .
“ “ +adipose membrane	23.90	23.60	26.20	20.50	24.20	. . .
Distance tip snout to front of eye	26.75	29.15	21.90	26.75	29.00	26.65
Distance tip snout to front of orbit	22.40	23.60	26.20	22.40	25.80	. . . .
Length maxillary	26.75	27.80	26.20	20.55	29.00	20.60
Width of maxillary G	38.90	40.00	37.50	19.35	25.80	41.70
Length of supplemental maxillary G	50.30	50.00	56.1	50.30	53.00	54.20
Width of do.	45.00	50.00	38.90	45.00	50.00	46.20
Length of mandible	40.30	38.90	41.	40.30	38.70	39.45

f. P is a specimen in bad condition which was in the collection made by E. A. Preble (1904) in Mackenzie River. Its total length was 470 mm. At the time it was examined the following description was made: “Posterior edge of preopercle makes a broad curve downward and forward; head fairly sharply conical; snout blunt and sloping downward from nostrils; dorsal profile of head straight without supra-orbital hump, same as in *C. labradoricus*. Scales from front of adipose to front of anal, 17; from upper base of caudal to lower base of caudal, 12; usual formula, 11 – 75 + 3 – 9; dorsal rays 2/11; anal rays 2/11; gill rakers 10 + 18 on each side, the longest being 53.33 per cent. of the eye on the right side and left being 46.26 per cent. of the eye.

G—The width of maxillary and width of supplemental maxillary are in per cent. of the length of each respectively.

In a comparison of a young individual, 65 mm. total length, with the average of the 5 adults of the collection, the young one is found to be much more slender, the depth of body and least depth of caudal peduncle differing by 7.39 and 2.69 per cent. of the length to base of caudal. The increased depth of the caudal peduncle in the adult appears to be associated with some shortening of the distances from the adipose and anal fins to the base of the caudal, the differences being something over 2 per cent. less in each case, in the adult.

While as a rule the vertical fins of young fish are proportionally higher than in adults, the present specimens show but little difference. The dorsals show no essential difference and the anal of the young is less than 2 per cent. of the body length higher than in the adult. The pectorals and anal of the young fish are shorter by 3.49 and 3.60 per cent. of the body length than in the adult. The most notable difference is in the greater length of head and larger eye of the young fish. There is a difference of about 6 per cent. in each of the distances from tip of the snout to edge of gill-cover and from tip of snout to nape, in favour of the young fish. As is to be expected, the eye is much larger in proportion to the length of the head in the young fish, the difference being over 12 per cent.

9. *Leucichthys athabascae*. Athabaska Cisco.

Twenty-six specimens were collected which are provisionally identified as *Leucichthys athabascae*, as listed by Mr. Harper.

They are evidently not *L. pusillus* nor *L. lucidus*, and apparently not *L. tullibee*, although they are nearer to the latter, except in size and general shape, than to either of those just mentioned. It is quite probably the same species of "the far north" that has previously been designated as *L. artedi*.[1]

One specimen, tag number 94, is an adult female, 146 mm. total length. It was picked up dead at the water's edge, 8 miles northeast of Moose Island, Lake Athabaska, August 3.

Twenty-five specimens of young, apparently specifically identical with number 94, tag numbers 44, 45, 47, 48 and 50 to 70, ranged in total length from

---

[1] Gilbert describes two imperfect specimens from Great Bear Lake River (Notes on Fishes from the Basin of the Mackenzie River in British America. By Charles H. Gilbert—Bulletin U.S. Fish Commission for 1894, pp. 23-25) and identifies them as *Coregonus lucidus* Richardson. He says: "This species is very close to *Coregonus artedi*, of which it may prove to be a subspecies." His description indicates some resemblances to, but more differences from, the present specimens herein identified as *Leucichthys athabascæ*. Particularly noticeable are the differences in dorsal and anal fin-ray formulas and the number of scales. In Gilbert's specimens: D. 3/12 or 2/11; A. 3/12 or 2/11; scales of lateral line, 85 to 87 with 11 or 12 in oblique series downwards and forwards to lateral line from front of dorsal.

79 to 105 mm., averaging 89 mm. They were seined in about 3 feet of clear water on sand bottom, 8 miles northeast of Moose Island, Lake Athabaska, July 30.

Number 94 had large ovaries and well-developed ova, and would probably have spawned that year. Branchiostegals, 8-8; dorsal rays, 3/9; anal rays, 3/11; pectoral rays, 16; ventral rays, 11; scales, 8-66-7, those on caudal peduncle 4-1-4, before dorsal 24, below dorsal 11, from dorsal to adipose 20, and adipose to caudal 7; gillrakers 16+29 on each side.

TABLE VI

Table of measurements and proportions of *Leucichthys athabascae*. Body parts in per cent. of length of body; head parts in per cent. of length of head.

Tag numbers	51	69	94
Length from tip snout to end caudal mm	105	82	146
“ from tip snout to fork of tail mm	96	76	126
“ from tip snout to end of scales mm	89	71	116
“ base of dorsal	10.11	11.26	10.34
“ longest dorsal ray	14.60	15.49	17.24
“ base adipose	3.93	2.81	4.31
“ upper caudal lobe	22.46	23.94	25.86
“ upper caudal ray	17.97	21.12	21.55
“ middle caudal ray	7.75	7.04	8.62
“ lower caudal lobe	22.46	.....	25.86
“ lower caudal ray	17.97	.....	21.55
“ pectoral fin	12.35	16.90	18.10
“ ventral fin	14.60	15.49	18.10
“ base anal	11.23	9.86	12.06
“ longest anal ray	8.98	9.15	10.34
“ head	24.71	27.46	26.72
Greatest depth of body	20.22	.....	21.25
Least depth of caudal peduncle	7.75	7.74	7.75
Distance tip snout to nape	19.10	19.71	18.96
“ nape to dorsal	29.21	29.57	32.75
“ end dorsal to adipose	24.71	22.52	23.27
“ adipose to caudal	10.11	8.45	9.48
“ tip snout to base pectoral	39.83	25.35	26.72
“ base pectoral to base ventral	28.08	25.35	31.02
“ base ventral to anal	24.71	23.23	25.00
“ end anal to caudal	10.11	9.86	9.48
“ tip snout to edge of preopercle	75.00	71.79	77.41
“ depth head through eye	43.18	46.15	41.93
Interorbital width	18.18	17.94	19.35
Vertical diameter eye	27.27	25.64	25.80
Length of eye	27.27	30.76	25.80
“ “ orbit	...	.....	32.25
“ “ snout to eye	27.27	25.64	29.03
“ “ snout to orbit	.	.....	22.58
“ “ maxillary	36.36	38.46	29.03
“ “ mandible	50.00	48.71	48.38

10. *Leucichthys tullibee.* Tullibee.

One specimen, a female, tag number 106, was collected in Lac La Biche, November 8. This species is locally known as "Tullibee." When the specimen was received it was disintegrating, and in such bad condition it was very difficult to handle and measure. As near as could be ascertained the fish was about 310 mm. total length. Dorsal rays, 4/9; anal rays, 4/11; pectoral rays, 17; ventral rays, 11 on one side and 12 on the other, right and left; gillrakers 14+30 on each side; scales on caudal peduncle, 5-1-5; from posterior end of dorsal to adipose on the back there were 19 scales. From the posterior end of the dorsal to the lateral line there were 8 scales, and the same number from the ventral to the lateral line. The junction of the mandible with the quadrate is about under the middle of the eye; the anterior end of the mandible slightly projecting beyond the premaxillaries; the width of the supplemental maxillary is about 34.6 per cent. of its length. Owing to the bad condition of the fish only a few of the proportional measurements can be relied upon. The distance from tip of snout to nape is 19.10 per cent. of the body length to end of scales (which was 246 mm.?); base of dorsal, 15.85 per cent.; height of dorsal, 26.42 per cent.; caudal peduncle, 12.19 per cent.; base anal, 14.22 per cent.; height of anal, 16.26 per cent.; distance from posterior end of base of anal to caudal, 32.52 per cent.; head, 26.82 per cent. Head to edge of preopercle, 74.24 per cent. of the length of the head; depth of head through eye, 48.48 per cent.; interorbital width, 27.27 per cent.; length orbit, 21.96 per cent.; length snout, 24.24 per cent.; length of maxillary, 30.30 per cent.; width of maxillary, 60 per cent. of length; mandible, 46.96 per cent. of the length of the head.

Family SALMONIDAE

11. *Cristivomer namaycush.* Lake trout.

One specimen, an immature female, tag number 99, in total length 399 mm., was taken with a troll at Black Bay, Lake Athabaska, August 18.

The specimen is very slender, having a proportionally low and broad head, giving it a "snaky" appearance. The gular region is flat, and top of head very flat, and depressed in front of the occipital region. The fins are rather small. The ventral is inserted below the posterior end of the dorsal. Branchiostegals, 12-12; dorsal rays, 3/11; anal rays, 3/8; pectoral rays, 13; ventral rays, 9; scales, 29-180-28, those on caudal peduncle 15-1-15; gillrakers 7+15 on each side; pyloric coeca numerous. An elongate spindle-outlined patch of comparatively strong teeth in three rows on basibranchial.

The colour a long time after preservation was grayish, darkest on head and back, punctulate all over head and body with specks of brown, to base of pectoral, ventral, and anal; belly plain white; moderately large plain spots on sides, down to pectoral and ventral and nearly to anal, but never on back; dorsal dark, with pale spots at base and tips of posterior rays pale; pectoral pale below, dusky behind, or above, with pale posterior and anterior rays; ventral similar; anal dusky, with pale anterior and posterior rays and tips of all rays pale; caudal with widely-spaced pale spots and darker terminal margin.

TABLE VII

Measurements and proportions of *Cristivomer namaycush.* Body parts are in per cent. of length of body; head parts in per cent. of length of head.

Length from tip snout to end of caudal mm.	399
Length from tip snout to fork of caudal mm.	368
Distance end vertebrae to fork caudal	8.55
Length from tip snout to end of vertebrae	339
“ base of dorsal	11.79
“ longest ray of dorsal	14.45
“ base of adipose	2.65
“ upper caudal lobe	23.59
“ upper caudal ray	17.69
“ middle caudal ray	5.30
“ lower caudal lobe	21.53
“ lower caudal ray	16.51
“ pectoral fin	15.63
“ ventral fin	12.68
“ base anal fin	8.84
“ longest ray fin	12.38
“ head	26.84
Greatest depth of body	22.12
Least depth of caudal peduncle	8.25
Distance tip snout to nape	17.99
“ nape to dorsal	35.10
“ end dorsal to adipose	22.41
“ end adipose to base caudal	10.91
“ tip of snout to base pectoral	25.07
“ base pectoral to base ventral	33.92
“ base ventral to anal	20.35
“ end anal to base caudal	11.20
“ tip snout to edge preopercle	80.21
“ depth head through eye	36.26
Interorbital width	25.27
Vertical diameter eye	12.63
Length of eye	15.93
“ of orbit	20.32
“ snout to eye	30.76
“ snout to orbit	26.37
Distance tip snout to end maxillary	51.64
Length of maxillary	40.65
“ of mandible	64.83

Family THYMALLIDAE

12. *Thymallus signifer.* Northern grayling.

One specimen, tag number 49, a female, 375 mm. total length, was taken in a small-mesh gill-net about 15 feet from shore in 6 or 8 feet of water over rocky and sandy bottom, 8 miles northeast of Moose Island, Lake Athabaska. July 30.

Branchiostegals, 9-9; dorsal rays, 22½; the tips of last rays not nearly extending to adipose; anal rays, 3 10; pectoral rays, 16; ventral rays, 10; scales, 9-98-10; pores 95. The smallest scales are on the breast in front of the pectorals; on median line of belly in front of ventrals they are larger than those on the side immediately above, but on the sides above the latter they are largest of all; 21 scales before dorsal, 28 below dorsal, 26 from dorsal to adipose, 4 below adipose, and 12 from adipose to caudal; scales on caudal peduncle, 6-1-6. Gillrakers 6+14 on each side.

The two ovaries are about the same length, extending to about mid-length of ventral fins. Minute eggs are retained in right ovary. The dorsal mesentery extends to within a very short distance of the vent. There is a very thin, narrow ventral mesentery, apparently without blood vessels, beginning about midway between base of ventral and front of anal, narrowing backward so that under the end of the dorsal mesentery to the end of the abdominal cavity the intestine practically adheres to the ventral wall. The stomach was gorged with fragments of insects and there were parasitic cysts in the walls of the stomach and pyloric coeca.

The colour of this specimen was much as in number 93, which follows:

Number 93 is a male, 424 mm. total length, taken in a gill-net about 20 feet from shore in about 8 feet of clear water over rocky and sandy bottom, in the same locality as the above, August 1.

Branchiostegals, 9-9; dorsal rays, 21½, the 8 anterior ones simple, and the tips of the last, when depressed, extending nearly to the middle of the adipose; anal rays, 3 11; pectoral rays, 16 on the right side and 15 on the left; ventral rays, 10; scales, 9-85-10; 85 pores; 20 scales before dorsal, 23 below dorsal, 22 dorsal to adipose, 4 below adipose, and 12 adipose to caudal; scales on caudal peduncle, 5-1-5. The spermaries were large, indicating proximity to breeding season—before or after.

Colour in alcohol: Head dark gray and olive; jaws dark gray; chin, isthmus and tips of branchiostegals white; no spots on head; back gray, grading into lighter shade on sides and belly; belly cloudy-soiled white; 4 or 5 very small round spots forward above the lateral line, and 8 or 9 larger, but still small, below in the space between the upper margin of the pectoral and lateral line; dorsal with dull bluish-gray and pale rays; a narrow margin of dead-blood colour above; 4 longitudinal rows of oblong yellowish spots on basal half of the fin as far back as the 15th intermembrane; then vertically-oblong and elliptical spots of blood-red with pale areola; no spots on other fins; pectoral pale gray, darker above or behind; ventral bluish-gray, with long blood-red marks on rays anteriorly, most pronounced above or behind; posterior rays straw-yellow; anal bluish-gray with pale margin; adipose bluish-gray and reddish; caudal pale, browning with darker midrays.

In addition to the foregoing, 6 specimens of young grayling, tag numbers 71-75 and 101, from 51 to 67 mm. total length, averaged 57.20 mm.

In order that anyone who may come into possession of these specimens may not become confused by the retention of the original tags, it may be well to state that numbers 71 to 75 have the legend "*Cristivomer*." They had been listed by Mr. Harper as *Thymallus*, however. These fish were seined in clear water on sandy bottom 8 miles northeast of Moose Island, Lake Athabaska, July 30.

Number 101, 62 mm. total length, was found washed up on a sandy beach, in a storm, at Cypress point, Lake Athabaska, August 23.

Number 71, a specimen 67 mm. long, showed the following colour markings: A row of vertically oblong spots on side of back below dorsal fin from nape to

TABLE VIII

Table of measurements and proportions of *Thymallus signifer*. Body parts are in per cent. of length of body; head parts in per cent. of length of head.

Tag numbers	49	93
Length from tip snout to end of caudal mm	375	424
" from tip snout to fork of caudal mm	352	391
" from tip snout to end vertebrae mm	321	358
" from tip snout to base middle caudal ray	341	380 –
" base of dorsal	26.16	26.25
" longest ray dorsal	19.31	31.56
" base of adipose	2.80	3.07
" upper caudal lobe	21.80	21.22
" upper caudal ray	16.19	17.31
" middle caudal ray	6.23	6.14
" lower caudal lobe	.....	22.34
" lower caudal ray	.....	18.15
" pectoral	17.13	18.15
" ventral	17.13	19.27
" base anal	10.28	11.73
" longest anal ray	12.14	10.89
" head	.....	19.55
Greatest depth of body	26.16	22.90
Least depth caudal peduncle	8.72	8.37
Distance tip snout to nape	....	15.64
" nape to dorsal	19.62	16.75
" end dorsal to adipose	25.23	25.41
" end adipose to caudal	11.21	10.89
" tip of snout to base pectoral	.....	18.71
" base pectoral to base ventral	35.51	34.35
" base ventral to front anal	29.28	29.32
" end anal to caudal	11.83	10.33
" tip snout to edge of preopercle	.....	75.71
" depth head through eye	.....	55.71
" interorbital width	.....	31.42
Vertical diameter eye	.....	21.42
Length of eye	.....	21.42
" " orbit	.....	26.42
" " snout to eye	.....	31.42
" " snout to orbit	.....	26.42
Distance tip snout to end maxillary	.....	40.00
Length of maxillary	.....	28.57
" " mandible	.....	51.42

tail, becoming rounder and more widely spaced posteriorly. There were 14 short vertically oblong parr-marks. The lateral line passes through the upper part of the parr-marks anteriorly and through the middle posteriorly. In each interspace of 8 or 9 parr-marks, and extending below them was one spot. Some other specimens had variable numbers of parr-marks; as 12 on one side and 14 on the other; also the lateral dorsal spots sometimes extended downward between parr-marks. The general colour in alcohol was darker above and pale below. No spots observed on fins.

The stomach contents of numbers 71 and 72 consisted of a few insects, comprising 1 or 2 small diptera and very small "leaf-hoppers."

Family ESOCIDAE

13. *Esox lucius*. Pike.

One specimen, tag number 16, a small fish 235 mm. total length, was seined in 20 to 24 inches of water at Goose Island, Lake Athabaska, May 26.

TABLE IX

Table of measurements and proportions of *Esox lucius*. Body parts are in per cent. length of body; head parts in per cent. of length of head.

Length from tip of snout to end of caudal mm	235
" from tip of snout to fork of caudal mm	231
" from tip of snout to end of scales mm	211
" base of dorsal	13.27
" longest dorsal ray	12.79
" upper caudal lobe	21.32
" upper caudal ray	14.69
" middle caudal ray	9.47
" lower caudal lobe	20.37
" lower caudal ray	16.11
" pectoral fin	11.37
" ventral fin	13.27
" base anal	10.42
" longest anal ray	13.74
Greatest depth of body	.....
Least depth of caudal peduncle	6.16
Length of head	26.54
Distance tip snout to nape	22.74
" from nape to dorsal	46.44
" dorsal to caudal	9.47
" tip snout to base pectoral	25.11
" base pectoral to base ventral	26.06
" base ventral to anal	21.80
" end anal to caudal	7.10
" tip snout to edge of preopercle	77.41
Interorbital width	16.11
Vertical diameter eye	12.93
Length of eye	16.11
Length of snout	41.93
Distance tip snout to end maxillary	46.77
Length of maxillary	35.48
Length of mandible	64.51

Cheeks completely scaled; opercles with scales on upper part only. Branchiostegals, 14-14; dorsal rays, 4/15; anal rays, 3/12; pectoral rays, 15; ventral rays, 11. Scales in a lengthwise row just above lateral line, about 120 downward and forward, to and including lateral line 16; ventral to lateral line, 14; scales before dorsal, 77; about 10 rows on cheek.

Colour: About 18 oblique pale bars downward and forward, becoming nearly vertical posteriorly; dark interspaces 3 or 4 times as wide as the pale bars. The wavy irregular and somewhat broken pale bars extend to level of the upper margins of the pectoral, ventral and anal. The back is dark and the belly pale, with sides shading from the dark of the back to pale of the belly. A black spot on upper posterior edge of opercle; a very faint dusky downward streak below eye. No sign of a light, longitudinal dorsal line. Dorsal with faint dark cloudings, and anal similar forward. Pectoral and ventral of a dusky shade, but mainly pale; caudal, olive brown with 4 longitudinal interrupted blue-black bars.

Family GASTEROSTEIDAE

14. *Pungitius pungitius*. Nine-spined stickleback.

Sixteen specimens from 38 to 52 mm. total length, averaging 47.30+mm. were collected. Ten of the specimens had 9, five had 10, and one had 8 dorsal spines.

Tag numbers 1 to 11, 45 to 52 mm. long, were from East Branch, Athabaska Delta, 9 miles north of Jackfish Lake, May 23.

Tag numbers 35 to 37, 38 to 48 mm. total length, were seined in 20 to 24 inches of water at Goose Island, Lake Athabaska, May 26.

Tag numbers 77 and 78, 46 and 40 mm. long, respectively, were seined in 1 to 3 feet of clear water on sandy bottom, 8 miles northeast of Moose Island, Lake Athabaska, July 30.

Family PERCIDAE

15. *Stizostedion vitreum*. Pike perch.

Two specimens of young, tag numbers 26, about 98 mm. total length, and 27, about 89 mm. total length, were seined in about 20 to 24 inches of water at Goose Island, Lake Athabaska, May 26.

Number 26 had two large pyloric cœca. The stomach contained 2 small minnows (*Notropis hudsonius selene*).

Number 27 had 3 pyloric cœca.

Family COTTIDAE

16. *Cottus cognatus*. Millers Thumb.

Four specimens, tag numbers 95 to 98, from 40 to 60 mm. total length, averaging 46.75 mm., were collected at Poplar Point, Lake Athabaska, August

5 and 7. Numbers 95 and 96 were taken in a dip-net in a shallow little cove on a stony beach. Number 97 was taken by shotgun, and number 98 by forceps, in shallow edge of the lake, August 7.

Numbers 95 and 96 had 3 ventral rays on each side; numbers 97 and 98 had 4 ventral rays on each side. All had 12 anal rays each.

The following notes were made on number 98: Concealed spines on preopercle, the upper one curved upward, moderate length, not nearly as long as eye; some prickles in axle of pectoral; pectoral extending to vent; length from tip of snout to base of caudal, 48 mm.; head, 15 mm.; eye, 4.5 mm.; dorsal rays VIII., 17; anal rays, 12; pectoral rays, 15; ventral rays, 4.

Colour in formalin, brownish above, white below; 7 or 8 broad wavy cross bars on body and base of tail; pectoral, dorsal and caudal barred.

DISTRIBUTIONAL LIST OF SPECIES OF THE HARPER COLLECTION

		Page
Athabaska River		
Coregonus clupeaformis	Whitefish	9
Athabaska Delta		
Catostomus commersonii	Common or "Gray sucker"	4
Pungitius pungitius	Nine-spined stickleback	19
Rivière Coupée		
Catostomus catostomus	Northern sucker	3
Platygobio gracilis	Flathead chub	6
Peace River		
Hiodon alosoides	Gold-eye	7
Lake La Biche		
Leucichthys tullibee	Tullibee	14
Lake Athabaska		
Catostomus catostomus	Northern sucker	3
Catostomus commersonii	Common sucker	4
Notropis hudsonius selene	Spot-tail minnow	5
Notropis atherinoides	Silverside minnow	5
Prosopium quadrilaterale?	Round whitefish?	7
Coregonus clupeaformis?	Common whitefish	9
Leucichthys athabascae	Cisco	12
Cristivomer namaycush	Lake trout	14
Thymallus signifer	Northern grayling	15
Hiodon alosoides	Gold-eye	7
Esox lucius	Pike	18
Stizostedion vitreum	Pike perch	19
Pungitius pungitius	Nine-spined stickleback	19
Cottus cognatus	Millers Thumb	19

List of Species Collected by Dr. Robert J. Morris in the District Between Lake Winnipeg and Hudson Bay in 1905

On November 16, 1905, Dr. H. C. Bumpus, then Director of the American Museum of Natural History, submitted the collection referred to in the above heading to the U.S. Fish Commission for identification, and it was my privilege to examine and identify them. The collection was composed mostly of dried skins in poor condition, but easily identifiable. No other data than that indicated in the foregoing heading was furnished. It is thought desirable to include the list in connection with this paper, however, as it is not known that they have been previously recorded, and all records of northern species are valuable even though they be more or less indefinite.

With the fishes were 4 specimens of frogs, one of which was undoubtedly *Rana septentrionalis*; the other 3 were probably the same, but the identification was not positive. The list of species of fish is as follows:

1.	*Acipenser rubicundus*	Sturgeon	1 specimen
2.	*Catostomus catostomus*	Northern sucker	1 specimen
3.	*Moxostoma lesueuri*	Piccanou	1 specimen
4.	*Notropis cornutus*	Redfin shiner	2 specimens
5.	*Hiodon alosoides*	Gold-eye	1 head
6.	*Coregonus clupeaformis*	Whitefish	2 specimens
7.	*Salvelinus fontinalis*	Brook trout	1 specimen
8.	*Esox lucius*	Pike	1 specimen
10.	*Stizostedion canadense*	Pike perch	1 specimen

LITERATURE

1. F. Harper and J. T. Nichols. Six new fishes from Northwestern Canada. Bull. Amer. Mus. Nat. Hist. Vol. XLI, 1919.

2. B. W. Evermann and E. L. Goldsborough. A check list of the fresh-water fishes of Canada. Proc. Biol. Soc. Washington. Vol. XX, 1907.

3. D. S. Jordan and B. W. Evermann. The fishes of North and Middle America. Bull. U.S. Nat. Mus. No. 47, 1896.

4. T. H. Bean. The identity of the common and Labrador whitefish. Science, N.S. Vol. IX, 1899.

5. A. Günther. Catalogue of the Fishes of the British Museum. Vol. VI, 1866.

6. E. A. Preble. A biological investigation of the Athabaska-Mackenzie region. North American Fauna. No. 27, 1908.

No. 24

A NOTE ON THE POLYCHAETOUS ANNELID *Eudistylia gigantea* BUSH

BY

CHAS. H. O'DONOGHUE, D.SC., F.Z.S., F.R.S.C.
University of Manitoba

A note on the Polychaetous Annelid *Eudistylia gigantea* Bush

By Chas. H. O'Donoghue, D.Sc., F.Z.S., F.R.S.C.
University of Manitoba

Dr. Katherine Bush (1) in a very useful paper (1904) described a number of tubicolous Marine Annelids from material mainly collected in Alaska by the Harriman Expedition, but including also a few specimens from Pacific Grove, California. Among other additions to previously known forms are five new species of Sabellid worms for which the author has constituted a new genus, *Eudistylia*, of the Family Sabellidæ and in this genus she also included the species formerly known as *Bispira polymorpha* (Johnson). The type of the genus is *E. gigantea* which she records from Orca, Prince William Sound (Type locality), Yakutat and Virgin Bay, Prince William Sound. While this species is not recorded from British Columbia, two other members of the genus, viz., *E. tenella* and *E. polymorpha*, were collected at Victoria, indeed this is the type locality of the former.

My colleague Professor A. T. Cameron (2) has made considerable use of the type species of this genus in his biochemical investigations and in the first paper in which he dealt with it (1915) it is termed *Sabella columbiana*, a name given in MS. pending closer identification. He suggested to me that, in view of the fact that this interesting species is but little known, it might be as well to put on record such additional facts as are now available. I am the more willing to do this since there is a noticeable gap in our knowledge of these forms in their living condition. I have seen and taken the animals at various places, kept them alive, examined and dissected them in the laboratory, but the following notes incorporate also Professor Cameron's observations which he freely placed at my disposal. His information regarding the peculiar "grove" of these worms near Vancouver is of particular interest.

The material was obtained while working at the Dominion Biological Station, Nanaimo, B.C., and I wish to express my thanks to the Biological Board of Canada for making it possible for me to visit the Station.

Eudistylia gigantea Bush Harriman Alaska Expedit. XII., 1910, p. 210
Type locality Orca, Prince William Sound, Alaska
Genotype by original designation of *Eudistylia*

The body of the worm is elongated, sub-cylindrical but slightly compressed dorso-ventrally; it tapers very gradually over the hinder half of its length and finishes in a blunt point. It is capable of considerable expansion and contraction, so that any measurements simply represent its size at the time when measured. Four typical, fairly large specimens, after preservation in formalin, were found to measure 29 cm., 32 cm., 37 cm., and 42 cm.,[1] exclusive of the

---

[1] There is a specimen in the collection of the Biological Station at Nanaimo which measures 48 cm. in length.

branchiæ, while the thickest was about 18 mm. in diameter at the widest part. The largest of these (42 cm.) was thus considerably longer than Bush's specimen of 12 ins. (circa 31 cm.) and about the same breadth; but this was not the largest seen and apparently they may reach a length of nearly 2 feet (circa 64 cm.) well deserving their specific name *gigantea*. The worm unfortunately is very brittle when preserved and is apt to break across in transport or when being examined.

The body of the worm is of a yellowish grey colour, the tube of a horn brown colour and the gill plumes when expanded were black with three bands of deep maroon, one at the tip, one half way down and one lower still near the base. When removed from the tube and examined, another and narrower band will be seen at the base of each plume. When growing as it frequently does upon a wharf pile which is covered with white barnacles this beautiful feathery gill circle stands out in marked contrast to the background and forms a very striking object almost 2½ inches in diameter. Unfortunately the two colours being black and red do not show up differentially in a photograph. After preservation for a short time the black colour disappears and the basal colour of the plumes becomes the same yellowish grey as the body, but the maroon bands retain their colour for two or three years at any rate.

The first eight segments differ slightly from the remainder, constituting a distinct thoracic region. The remaining segments are well marked at the anterior end, but in the tail region they become closely crowded together and numbered in the four specimens mentioned above about 290, 292, 294 and 320 respectively. The total number of segments varied therefore from 298-328, so that none quite reached the total of 340 given by Bush, but it is possible that this number might even be exceeded in a really large specimen.

Along each ventro-lateral line of the abdomen lies a series of outstanding groups of setæ, one pair to each somite. Starting from this and running along the middle of the lateral portion of the somite lies a slightly raised ridge, the torus uncinigerus, which also bears setæ. In the thoracic region the outstanding groups pass in an oblique line dorsally and the torus lies on their ventral side, but they will be described more fully when dealing with the setæ. In the hinder end of the abdominal region the tori are closely crowded together and right at the extremity they are little marked and so the tip appears smoother than the rest of the body.

In the mid-dorsal line at the anterior end is a deep well-marked dorsal groove and its commencement is exaggerated by the dorsal lobes of the collar. It gets shallower and narrower in segment four and in segment seven passes sharply to the right, reaching the posterior border of the segment on its lateral aspect. It runs in the intersegmental groove to the ventro-lateral region and then passes obliquely across the first abdominal segment and on into the second, where it turns sharply in the middle line and runs on backwards to the posterior end as a shallow but distinct ventral groove. In the mid-dorsal line a line passes backwards from the point where the dorsal groove turns, but it disappears after about 20-25 segments.

The anterior end of the worm is surrounded by an outstanding collar composed of four lobes. The dorsal lobes are small, about 2-3 mm. long and 1.5 mm. high, and lie laterally one on each side of the deep anterior end of the dorsal groove. Separated from this by a notch is the main latero-ventral lobe, which projects on each side as an undulating membrane 3-4 mm. from the side of the worm. These lobes pass right round to the ventral side and expand slightly at their end into angular processes which are separated in the mid-ventral line. From a point just anterior to each ventral end of the collar, a slightly folded membrane arises which passes inwards to the branchial spire and follows this to its summit.

The small mouth lies nearly in the centre of the somewhat truncated anterior end and adjacent to it are two small, leaf-like tentacles.

The branchial lobes have a very characteristic arrangement quite unlike those of *Sabella*. They start near the anterior end of the dorsal groove as flanges that pass first laterally and ventrally and then continue on as spiral spires of about two and a half turns and from 15-18 mm. high when expanded. The branchial plumes are arranged in single series along the edge of this flange. The total number given by Bush is 125-135 in each lobe, but in the present specimens they are about 150. Each plume consists of a median rachis, rounded on the back and flattened or slightly grooved on the inner side, which bears a double row of pinnæ. These pinnæ decrease rapidly in length near the end and leave the tip of the rachis projecting. Rarely the rachis may bifurcate about half way along, but this was not observed in more than 3-4 per cent. of the total number of plumes. The longest plumes may reach a length of 38 mm. On the back of some of the rachises are the small eye spots, but these are very irregular in their distribution and number on the plume. There is also considerable variation in the number and position of the eye bearing plumes in different specimens.

Tube.—The tube is a tough semi-elastic structure of a greyish-brown horn colour and in appearance not unlike indiarubber, although it is not so distensible. In some cases there are opaque white patches present, suggesting the inclusion or deposition of calcareous matter within the tube. It is longer than the worm itself, which can be completely withdrawn into it and it may reach a length of 68 cm. The internal diameter may be 18-20 mm. at the upper end, where it is generally of a uniform thickness of about 5 mm.; at the lower end it is somewhat thinner and often in the portions where it may happen to be applied to a rock or wood it may be quite thin. When the worm is quite small, the tube is correspondingly small, but its diameter increases with growth. While in the adult the lower end is smaller than the upper, usually small enough to prevent the worm passing out, it is not nearly so small as in the young worm, so that a considerable length of tube must be secreted during development and disintegrate. The animal also possesses the power of repairing its tube, for tubes are sometimes found that have in them splits that have been repaired by the secretion of new tube material from within. The tube is apparently laid down in oblique concentric layers. Little is known as to its actual chemical constitution, but Cameron (2) has called attention to the remarkable fact that, while the dried worm contains about 0.03 to 0.06 per cent. of iodine, the dried tube contains from

.4 to .6 per cent.; about ten times as much. Professor Cameron has recently informed me that in later work an accurate analysis of the iodine content of a very large number of the tubes from the grove in Vancouver Harbour has shown it to be as high as .8 per cent. This is higher than he has found elsewhere in the animal kingdom.

The upper end of the tube, which projects freely for some distance, offers a suitable resting place for various encrusting organisms, but the last inch or so is practically always clean; perhaps because of the fact that it has been but recently formed or because of the proximity of the actively moving gills. The common forms that have been noticed on the tube include: Algae, *Ulva sp* and *Polysiphonia sp*; Diatoms, various stalked species; Protozoa, two or three species of Foraminifera; Porifera, several small encrusting sponges, but apparently only of one or two species; Coelenterata, one or two species of Hydrozoa; Bryozoa, the ubiquitous *Schizoporella hyalina*; Mollusca, small specimens of *Mytilus sp*; Arthropoda, a few small specimens of *Balanus sp.*

Habitat.—Bush says of this form, "Tube solitary, more or less bent, of a tough brownish chitinous substance."

I have seen and collected specimens of the species at various points from Departure Bay to Degnan's Bay. Professor Cameron has collected it in Departure Bay; at False Narrows; Banfield Creek, Barclay Sound; near Porlier Pass on Galiano Island and particularly in Vancouver Harbour.

As a general rule the tubes are solitary and single and grow partly embedded in crevices of the rock and their shape depends on that of the crevice. They also occur on piles, often in the crack between the bark or loose external layers and the inside. Sometimes, but rarely, two or three may be found close enough to touch each other. They are found in pebbly beaches among rocks and the debris of shells, and when in this situation they are usually almost straight with the top 2/3 projecting. It may be stated that as far as our observations go they do not frequent sand beaches or very muddy localities.

Their grouping in Vancouver Harbour, however, is quite different from this. On the Stanley Park side of the Narrows of Vancouver Harbour, near the Huntsman's Arch, the beach is mainly composed of pebbles with practically no sand and only a little mud. Its slope is quite gradual and at the lower limits of this there is exposed at the lowest spring tides what can only be termed a "grove" of *Eudistylia gigantea.* The grove is about 500 yards long and from 30 to 40 yards at its widest points, but even where it narrows at the ends it is still quite wide. Its limits are fairly set, it does not straggle, its lower edge is apparently never completely exposed and similar groups of tubes are not known to occur anywhere else in the neighbourhood. The species does not appear to be more than usually common in adjacent localities. In the grove itself the worms occur in large clumps each containing from 60 to 100 tubes and from two to three feet in diameter. The clumps may either touch one another or be separated from one another by a clear space of 3-4 feet. The tubes are from 12 ins. to 18 ins. or even more in length and free save for a few inches at the bottom. The tubes near the centre are vertical and become more and more inclined as they pass to the outside, where they are almost horizontal. Thus the whole clump is more or less semi-globular in form and the entire grove suggests a growth of strange cacti.

The tubes are easily removed from the beach and their lower somewhat frayed extremities, into which the bodies of the worms do not extend, are not connected with one another in any way, so that even while growing in masses each one is quite independent and not in any sort of communication with its neighbours.

A remarkable point about the clumps is that while the tubes vary in internal diameter from 3/8 in. to just over 1/2 in. they are all of approximately the same length and the animals they contain are presumably of about the same age—at any rate they are all fully grown. Practically nothing is known of the life history of the species, but this absence of young forms in the clumps cannot be attributed to the time of year, since at the same time in the rocks in and around Departure Bay young specimens only 6 or 7 ins. long were obtained. Here in this large grove, however, containing something like 375,000-500,000 individuals at a very conservative estimate, young specimens were conspicuous by their absence.

Worms that have been watched individually in Departure Bay for some weeks exhibit scarcely any sign of growth, so that it appears that the animals in the grove are all relatively old—that is to say probably some years old. The grove has been in the same position for some years at any rate, although no precise records are available and there does not appear to be any reason why young individuals should not be present either in the groups with the older ones or in groups of their own.

The whole matter of this grove is frankly puzzling and presents a series of questions to which, so far, no answers can be given. Why should a species ranging from Alaska to the Southern end of Vancouver Island as a solitary form appear in this one place in masses that together constitute a "grove" without exact parallel, so far as I am aware, among the tubicolous Annelids? Why should this particular situation be more favourable than numerous others where, so far as can be ascertained, the conditions appear to be similar? How comes it that the grove is so strictly delimited and yet within the limits so crowded? Why are all these worms of approximately the same size and age with no young individuals about? The whole grove as an ecological entity would well repay close watching and study, but meanwhile it seems desirable to call attention to it by setting forth such facts as are available.

Setæ.—The setæ are arranged in a very characteristic manner in this species and exhibit a considerable amount of variation according to their position in the body and in the somite.

In the first thoracic segment there is a small but prominent oval group of setæ situated in the dorso-lateral line immediately under the dorsal end of the latero-ventral lobe of the collar. Closer examination shows that this group is composed of an antero-dorsal, crescentic fascicle of long setæ and a postero-ventral, oval fascicle of slightly shorter setæ. The crescentic fascicle contains about 60 setæ; each consists of a long rod-like stalk deeply embedded in the body musculature and its projecting end gradually passes off to a sharp point.

The tapering end portion is slightly curved and bears a narrow tapering blade on one side, which exaggerates the curvature of the stalk. On the opposite side of the stalk is a shorter and very much narrower flange, which can readily be overlooked. The oval fascicle is separated from the other and partially protected by an auriform membrane. Its setæ number about 100 and are shorter and a little more abruptly curved than those of the crescentic fascicle, but otherwise they are of the same type. The setæ of the oval fascicle do not project from the surface of the body so far as in the crescentic fascicle.

The second thoracic segment possesses a similar group of setæ, composed of a crescentic and oval fascicle, but it is situated a little nearer the ventral side of the worm. The crescentic fascicle contains about 70-75 setæ similar to those of the first thoracic group. The oval fascicle contains from 170-180 setæ, but of a type not represented in the first somite. Each seta consists of a stalk as before, but the tapering at the end is much more abrupt and the curvature is practically absent. A shorter but much broader and more sharply curved blade-like flange is developed equally on each side of the end. The two flanges and the stalk finish in a sharp point so that this type of seta might well be described as lanceolate.

Just ventral to this group of setæ in the second somite lies a fairly long raised ridge passing ventrally. Examination under the dissecting microscope shows that this is a torus uncinigerus with two parallel rows of tiny setæ running along it. The anterior row consists of from 88-90 setæ. Each seta has a cylindrical stalk, quite short compared with those previously described, embedded in the body wall. Its free end tapers fairly rapidly and exhibits a characteristic sigmoid curvature; along the lower part of this is a curious, short, spirally arranged flange occupying the lower curve of the S. From the presence of this flange Bush has termed this type a pennoned seta. The posterior row of setæ on the torus numbers about 82-84 and they are of a totally different shape, somewhat resembling hooks and so they are termed uncini. The stem is short, but relatively broad and flat and marked by a series of parallel lines in its central region. The projecting part has two sharp almost right-angled curves and the end piece tapers quickly to a sharp point. A short flange is present on the outer side of the last bend. The uncini get slightly smaller and their stems relatively less stout as they pass towards the mid-ventral line.

The arrangement of the setæ in the remaining thoracic segments is similar to that described for the second segment, but the oval group, always composed of crescentic and oval fascicles, becomes slightly larger and its position moves more and more towards the ventral side. In the eighth segment it is practically ventro-lateral in position and the linear torus is correspondingly shortened. It contains about 75 pennoned setæ and 79 uncini, but in both cases they are more closely packed than in the anterior tori. The oval groups of setæ in the thoracic segments form a readily noticeable series passing obliquely from dorso-lateral to ventro-lateral in position.

With the first abdominal segment we meet a different arrangement of the setæ. The oval group contains only one fascicle, which entirely lacks the broad lanceolate setæ of the posterior thoracic groups. It is decidedly ventro-lateral in position and there is a sharp break between it and the thoracic series. The oval fascicle of this segment contains from 102-105 setæ, all of the same genera shape and all fairly similar to the setæ of the first thoracic group, save that the curvature at the end is more marked and the second flange-like blade is a little more strongly developed.

The torus in the first abdominal segment is situated on the dorsal side of the oval fascicle, not on the ventral side as in the thoracic segments. It is long, but contáins only a single row of about 155-160 setæ of an uncinate type, similar to those of the posterior row in the thoracic tori and there are no pennoned setæ present.

This arrangement of both oval fascicle and torus is retained throughout the remainder of the abdomen and even two-thirds of the way back we still find that the oval fascicle contains from 80-90 setæ and the torus about 140. It is only at the extreme posterior end that the two groups get noticeably smaller.

Internal Structure.—The body wall of this animal is extremely thick and muscular, so that the body cavity is relatively quite small. It is roughly elliptical in transverse section, with its dorso-ventral diameter much longer than its transverse one. When the body is opened up the muscles will be seen to be arranged in the form of six longitudinal bands. On each side of the mid-ventral line is a narrow ventral muscle band about 1 mm. wide, running the whole length of the worm, but it is thicker at the anterior end. These two bands are separated in the middle line and from the next bands by grooves. To the sides of these lie the ventro-lateral muscle bands, which are from 2-3 mm. wide and run the whole length of the animal. These bands in their turn are separated from the remaining latero-dorsal bands by a groove. The latero-dorsal bands occupy the whole of the lateral regions of the body wall and also the dorsal regions save where they are separated by a groove, somewhat wider than the other grooves previously mentioned. These bands reach a thickness of about 5 mm. and form the main mass of the body of the worm. In the thoracic region the body wall becomes extremely thick and the body cavity almost obliterated.

The alimentary canal in the abdominal region is relatively quite small and oval with its long diameter dorso-ventral and it is of a dark green colour. In each segment it forms a flattened sack-shaped expansion on each side. It is attached to the dorsal and ventral body wall in the middle line by longitudinal dorsal and ventral mesenteries, which pass into the dorsal and ventral grooves between the muscles. In the thoracic region where the body wall is very thick the alimentary canal becomes much reduced in size and assumes a greyish-white colour very similar to that of the body wall itself and so not easy to follow.

The transverse section of this species presents a very characteristic appearance. The epidermis does not appear to be covered with a cuticle and exhibits a series of differentiated areas in the periphery. On the dorsal side it is composed of highly cylindrical cells with their nuclei about in the middle. Their distal ends contain elongated oval vacuoles indicating that they have a secretory function. But in addition to this type of glandular cell there are scattered through the epithelium a number of cells that secrete a large quantity of deeply staining material, which in section appears as a network of interlacing granular fibres. This epithelium covers most of the dorsal and lateral surfaces of the worm, including the tori, but between the tori its cells increase in height and become more markedly glandular. The group of long setæ in the abdominal region are situated just outside the line of separation between the ventro-lateral and latero-dorsal bands of muscles, indeed the inner ends of these setæ project a considerable way into the groove. In the neighbourhood of this group the epithelial cells become still larger and help to form a ridge-like glandular ridge around the setæ.

It is on the ventral surface, however, that the most marked modification of the epidermis takes place. The middle region is occupied by a pad of glandular tissue which extends across from a point outside the ventro-lateral muscle band on each side. This tissue is quite deep also and on each side sends a tongue up in the groove between the ventral and ventro-lateral muscle bands. This glandular tissue stains very deeply with ordinary stains such as haematoxylin and stands out from all the remaining tissue in a very striking manner. The whole tissue is so densely packed with masses of secretion, similar to those that occur occasionally in the ordinary epidermis but much larger and more intensely stained, so that the nuclei and cell limits cannot be made out. The secretory masses are arranged in lines passing inwards approximately at right angles to the surface, so giving a suggestion of columns which is heightened by the occurrence of a certain number of fibrillar-like structures running parallel with the masses. Right on the outside the secretion is packed in short columns in such a manner that it suggests that it is included in columnar epithelial cells; but even here neither cell walls nor nuclei can be made out with certainty.

In the middle of the region outside this glandular area lies the ventral groove, which is a ⊥-shaped structure in cross section. The walls of the outermost portion of the groove are similar to those of the surrounding epithelium, so full of granular secretion that the cell boundaries and nuclei cannot be made out; they are also so closely approximated that they practically touch one another. A little lower down they begin to separate and the cells and their nuclei again become more distinct, although they still contain plenty of secretory granules. The cells in this lower region also are ciliated, the cilia increasing in length as they get nearer the inner end. At the bottom the groove expands slightly and opens out transversely on each side so that it has the form of an inverted T. The cells at the inner side of the transverse limb of the groove are very highly cylindrical, with elongated oval nuclei lying near their centre. They are not noticeably granular and bear very long cilia. The interior of the groove was free of secretion in the sections studied. From its characteristic shape and differentiated structure it would appear that the groove is of considerable importance, but the only function that suggests itself is that it may serve as a sort of tube down which a supply of aerated water may be kept moving by means of the cilia. When the worm is retracted it fits closely against the wall of the tube, but the end of the groove lying near the collar would always be open and thus could allow of the ingress of water.

Turning once again to the body wall we find that a group of circular muscles lies beneath the epidermis and this passes completely round the worm, though interrupted at the points where the basal extremities of the large bundles of setæ project into the body. Underneath the tori and in the region of the ventral glandular area the circular muscles drop down some distance from the external epidermis and lie just above the longitudinal muscles.

Immediately underneath the circular muscles lie the longitudinal muscle bands and their arrangement into five longitudinal bundles, already described, is very clearly shown. In the anterior region of the worm they occupy more than half the total area of the transverse section. Their individual fibrillæ appear to be very irregularly arranged and not in such regular lines as in *Lumbricus*, for example. On their inner side the muscle bundles are bounded by a very thin layer of flattened peritoneal cells.

The double ventral nerve cord lies at the bottom of the groove separating the two ventral muscle bands, but these have grown inwards to such an extent that they completely cover it and it cannot be found when the body cavity is opened up. Each cord consists of a mass of fibres surrounded on its lateral and ventral aspect by a layer of ganglion cells. A band of fibres stretches across between the two fairly widely separated cords. In the connective tissue internal to the median corner of each cord lies a well marked blood vessel.

As pointed out above the alimentary canal is held in position by a dorsal and a ventral mesentery. The ventral mesentery arises from the middle of the groove between the two ventral muscle bands. Its centre is occupied by a series of fibrillar cells that may be non-striate muscle fibres. The coelomic peritoneum is reflected up on each side of the mesentery and its cells become very much altered. The cells are very large, almost globular, their protoplasm is very thin and their nuclei large and spherical. They recall the chloragogen cells of *Lumbricus* in some respects.

The coelomic epithelium covering the alimentary canal is composed of small cells, almost square in section but not sharply defined and containing ovoid or spherical nuclei. Beneath the peritoneum is a muscular layer composed almost entirely of circular muscles; there may be longitudinal muscles present, but, if so, they are very few and not easily distinguishable. Within the muscle layers is the very characteristic enteric epithelium. It is composed of greatly elongated cylindrical cells with faintly staining, slightly granular protoplasm. Their nuclei are much elongated and basally situated and along the cell edges facing the lumen is a darkly stained line. Along the ventral and lateral regions of the intestine the muscle layer separates into two, a thinner layer accompanying the coelomic epithelium and a thicker layer lying upon the enteric epithelium. The space between them is narrow laterally but quite wide ventrally and is filled with a blue stained highly granular substance not at all resembling the secretion of the cells of the skin. Scattered through this material are small spherical nuclei but it is too granular for any cellular structure to be made out even if such be present. The origin or function of this material could not be ascertained.

The section of the alimentary canal is never simple, but always passes through one or both of the lateral sack-like expansions and the complication thus produced is increased by the epithelium in both intestine and expansions being thrown into a series of folds.

Within the section of the body cavity are sections through what are apparently parts of the excretory organs and also through folds of the intersomitic septa. All these are covered with large polygonal cells with spherical nuclei similar to those on each side of the ventral mesentery.

The animal is not hard to keep alive in an aquarium for a few days, but it is very susceptible both to the stagnation and rise in temperature consequent upon its being kept in a relatively small vessel in warm weather. In captivity and under natural conditions it reacts very rapidly to both vibrations and shadow. A knock on the wall of the aquarium or on the rock near the specimen causes an instant withdrawal of the branchiæ. The same is true also of a shadow falling upon it. The suddenness of the withdrawal is very marked, while the expansion again takes place much more slowly and this, together with its colouration, makes it difficult to obtain a satisfactory photograph of this beautiful species in the expanded condition.

Another reaction of this worm is quite interesting. If the hinder end be touched or the tube squeezed it moves up the tube, so that it is only necessary to repeat this manoeuvre a number of times and the worm can be "persuaded" to leave its tube. When this is done the worm remains almost motionless save for an occasional wriggle. As Cameron has pointed out, if such a worm be left in sea water in the laboratory it is able in the course of 12 hours to secrete a new but extremely thin tube for itself. This tube is complete and so, apparently, the material of which it is composed can be secreted by the whole of the epidermis and not exclusively by the highly glandular ventral area near the glandular anterior end of the worm.

It is to be hoped that this interesting species will be more fully studied.

LIST OF REFERENCES

(1) Bush, K. J. Tubiculous Annelids of the Tribes Sabellides and Serpulides from the Pacific Ocean. Harriman Alaska Expedition, Vol. XII, pp. 169-346, 1904.

(2) Cameron, A. T. Contributions to the Biochemistry of Iodine. II. The Distribution of Iodine in Plant and Animal Tissues. Jour. Biol. Chem., pp. 1-39, Vol. XXIII, 1915.

EXPLANATION OF THE PLATES

Plate I

Fig. 1. A general view of the "Grove" of *Eudistylia gigantea;* some idea of its extent may be gathered from the fact that just below the trees under the mark X a man is standing.

Fig. 2. A closer view of the central region of the "Grove" to show the relation of the clumps to one another. The tide has turned and has covered the lower limit of the area.

Plate II

Fig. 3. A still closer view of an individual clump to show the way in which the individual tubes are grouped. Under normal conditions, *i.e.*, when submerged, all the tubes would be more upright.

Fig. 4. Three fairly large specimens of *Eudistylia gigantea* removed from their tubes; the ruler which is six inches long will allow of an estimation of their size. These worms had been preserved in formalin and as described above this makes them brittle so that in arranging them in the dish they broke across.

Figs. 1-3 are from photographs by Professor A. T. Cameron; Fig. 4 was taken at the Biological Station.

Plate III

The drawings on this plate were all made with the aid of a camera lucida at the magnifications indicated.

Fig. 5. The free end of a long seta from the crescentic portion of the fascicle of the first thoracic segment x 200.

Fig. 6. The free end of a long seta from the oval portion of the fascicle of the first thoracic segment x 200.

Fig. 7. The end of a pennoned seta from the torus of the second thoracic segment, back view x 333.

Fig. 8. The end of a pennoned seta from the torus of the second thoracic segment viewed in profile x 333.

Fig. 9. The end of a pennoned seta from the torus of the second thoracic segment viewed from the side x 333.

Fig. 10. An uncinus from the torus of the second thoracic segment viewed from the side x 333.

Fig. 11. A broad lanceolate seta from the fascicle of the last thoracic segment, back view x 333.

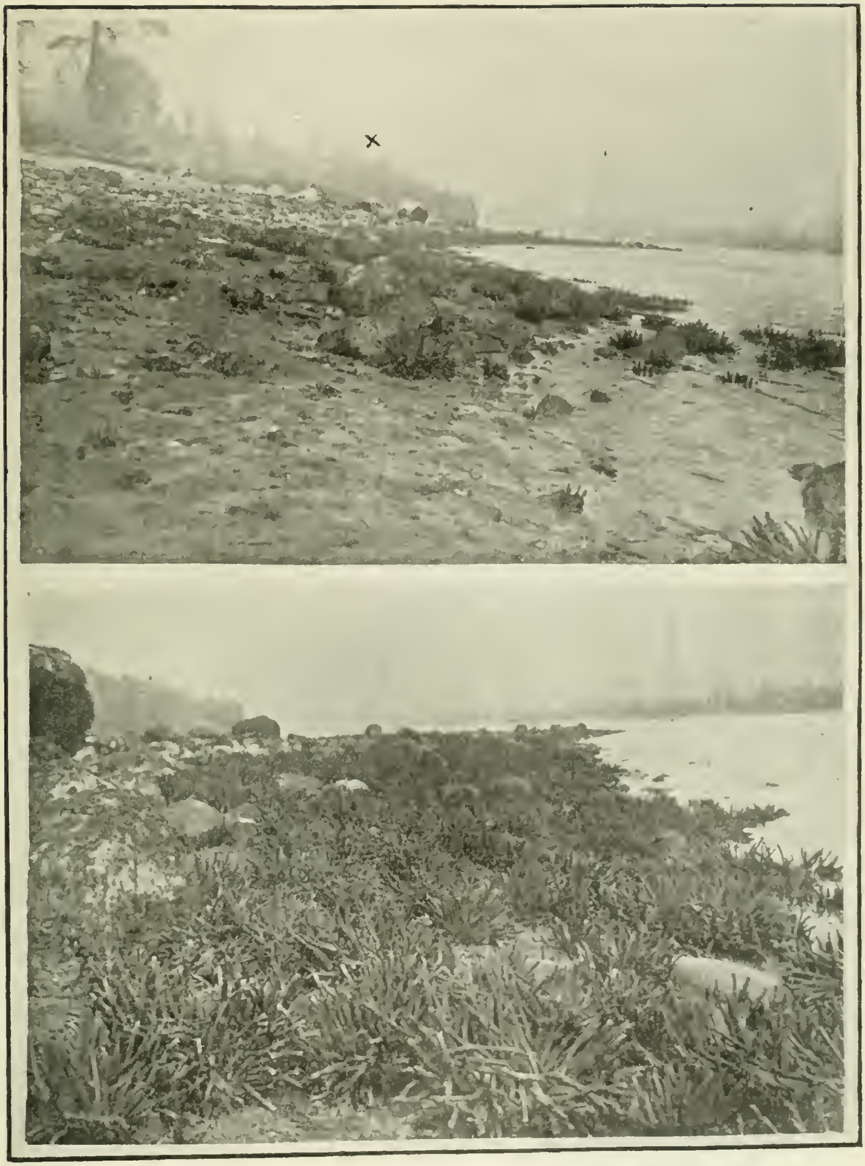
Fig. 12. Another and modified form of the lanceolate setae from the fascicle of the last thoracic segment, back view x 333.

Fig. 13. The end of a long seta from the fascicle of an abdominal segment about half way back x 333.

Fig. 14. A broad lanceolate seta from the fascicle of an abdominal segment about half way back x 333.

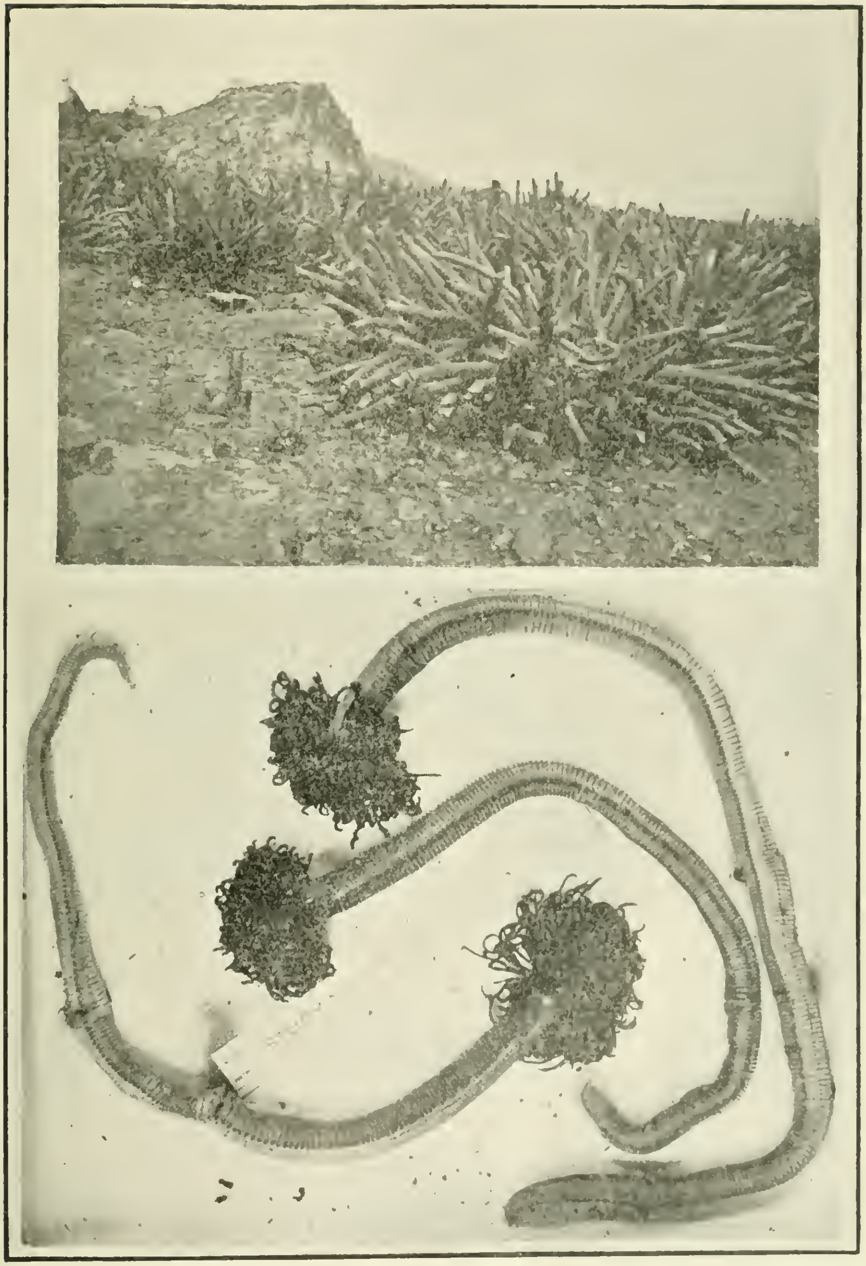
Fig. 15. An uncinus from the torus of an abdominal segment about half way back x 333.

PLATE I.



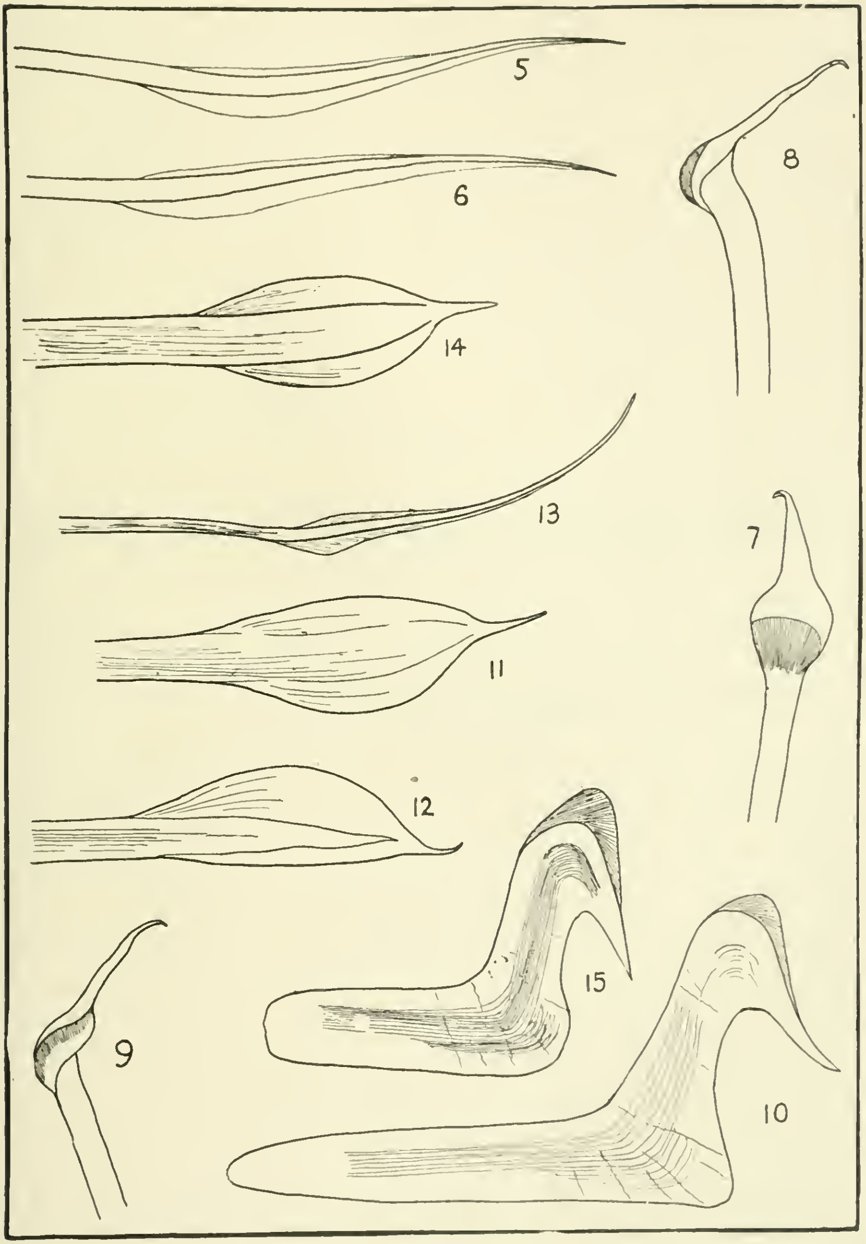
Figs. 1 and 2.

PLATE II.



Figs. 3 and 4.

PLATE III.



No. 25

ON THE SUMMER MIGRATION OF CERTAIN STARFISH IN DEPARTURE BAY, B.C.

BY

CHAS. H. O'DONOGHUE, D.SC., F.R.S.C.
University of Manitoba

On the Summer Migration of certain Starfish in Departure Bay, B.C.

By CHAS. H. O'DONOGHUE, D.Sc., F.R.S.C.
University of Manitoba

The sea shore offers an almost inexhaustible supply of problems to the Biologist, and among some of the most fascinating are those relating to the many aspects of its ecology. The particularly rich fauna of the neighbourhood of the Biological Station near Departure Bay, Nanaimo, B.C., offers plentiful opportunities for work and since first visiting the place it has always been the desire of the writer to carry out a general ecological survey of certain characteristic and well defined areas there. So far, however, this has proved impracticable for various reasons. In the first place the fauna is so rich and so incompletely known that the task of identifying the species is a very formidable one. Then again, the actual number of individuals is so large that it requires the co-operation of a number of workers. As an example of the former we may take the starfish (Asteroidea) with which we are more particularly concerned with here. Allee (1), as the result of the "Collaboration of eighteen staff members and about four hundred students" collecting systematically in the littoral zone of the Wood's Hole region over a period of eight years, records three species belonging to two genera, *Asterias forbesi*, *Asterias vulgaris* and *Henricia sanguinolenta*. Over a fairly comparable range of localities in the region of Departure Bay, only three of which were studied systematically, the present writer found in one season eleven species belonging to nine genera, viz., *Pisaster ochraceus*, *Pisaster brevispinus*, *Evasterias troschelii*, *Orthasterias leptolena*, *Pycnopodia helianthoides*, *Henricia leviuscula*, *Solaster dawsoni*, *Solaster stimpsoni*, *Mediaster aequalis*, *Hippasterias spinosa* and *Dermasterias imbricata*. It should be borne in mind also that the area considered lies within the known range of two varieties of *P. ochraceus*, five varieties of *E. troschelii* and eight varieties of *H. leviuscula*.

The second difficulty is emphasized by the fact that in one of the three localities chosen with an area of approximately 4,270 square yards 1,264 specimens were counted and the time required to check these over and examine the damaged and abnormal ones is quite considerable. Since reading Allee's excellent papers (1 and 2) I have much envied the opportunities he had and of which he made such good use.

Sooner than leave the field untouched, however, the writer, in spite of the fact that the greater part of his time was occupied with other problems, thought it advisable to take up a more circumscribed question in which it might be possible to make some headway and leave the more general ecological survey until such time as the co-operation of a number of workers can be secured.

I desire to express my thanks to Mr. A. Fee of the University of British Columbia for assistance in making the first count; to my wife for help in various ways all through, and to the Biological Board of Canada for the facility of working at the Station.

In the vicinity of the Biological Station several of the starfish listed above are common and on the shore just under the laboratory itself *Pisaster ochraceus* and *Evasterias troschelii* are very plentiful within the tide limits in the early part of the year. As summer comes on they get fewer and fewer only to return again later in the year. Indeed it is fairly generally recognized that bathing in comfort can commence when the starfish start to disappear. The problem of the distribution of these and other starfish and the cause of their migration suggested itself and observations were made upon three areas which will be described briefly.

The laboratory is built a short distance up on the bank and the foreshore under it faces almost due magnetic south, *i.e.*, about 25 degrees west of true south so that it is exposed to the sun for the greater part of the day, a point which will be referred to again later. A short distance west of the laboratory a pier runs out from the shore, roughly at right angles to the general shore line, into deeper water and this was chosen as the side line of two of the areas examined. Just near the shore end of the pier is the contact between a basal conglomerate on the west and a hard greenish grey limestone on the east (vide Burwash, 4, for further particulars of the geology of the environs of Departure Bay). Two of the areas selected were (1) situated east of the pier and (2) under the pier and to the west.

Area 1 was a strip of the coast running out about 61 yards along the pier from high water and extending eastwards 70 yards to an arbitrary point on the shore marked by a fir tree and an outstanding rocky point. The shore here is composed, as noted above, of hard greenish grey limestone in which are some deep clefts at right angles to the shore. It has a slope of about 25 degrees to the horizontal for about one-fifth of the distance and then becomes more level, forming a kind of beach composed of sandy gravel with but little mud or vegetable growth. This gravel beach extends further eastwards and gets wider, but an arbitrary line across it was taken as the limit in order to keep the area of a workable size. The outer limit is marked by a bed of *Zostera marina* and here the gravel becomes more mixed with mud and sand. As is frequently the case the *Zostera* bed is divisable into two portions, an inner zone of very short plants which are partially or in extreme cases entirely exposed at low spring tides and right at the outside, not even brought to the surface at the lowest tides, a second zone. At the east end of the beach there is a little seepage of fresh water from a small stream that empties a few yards further along the shore. The stones of the gravel are covered with small barnacles and also small mussels, presumably young *Mytilus edulis*, and in addition there are a few clams in the more sandy portions.

Area 2 was a strip of the coast running out a similar distance (61 yards) along the pier and including the ground under the pier itself and westwards for 75 yards. The end of this was marked by a rather large boulder and for a short distance beyond it is a strip of shore on which starfish are quite uncommon. The shore line here is mainly composed of the basal conglomerate, sloping to the sea at approximately the same angle as in the other area. It curves back into a small bay, upon the beach of which empty clam shells accumulate in considerable numbers. The rest of the beach is composed of a soft sand and mud mixture unlike the gravel of area 1, and it has growing upon it *Ulva sp.* and often has *Fucus sp.* washed on to it. Near the land edge of the level beach are a number of boulders a foot or eighteen inches across. Unlike the other area this one has not a *Zostera* bed at the outside, but passes off gradually into deeper water and the float at the end of the pier lies just beyond its outer limit. The stones of this muddy sand also have barnacles on them, but they are not nearly so plentiful as on the gravel. The piles of the pier introduce a new factor here for their lower ends are coated with barnacles and some mussels, but what is perhaps more important they provide a certain amount of shade.

The two areas then are very similar, both have the same aspect, on both the shore crabs *Hemigrapsus nudus* and *H. oregonensis* are common and small individuals of *Cancer productus* are less plentiful and the same shore fish are to be found on both. The main differences are the gravel bottom and *Zostera* bed in area 1. The third area, however, is of a totally different character.

This last area was on the shore of Brandon Island, a small rocky islet running almost due east and west, about 350 yards south of the former areas and separated from them by a channel about 12 fathoms deep. Brandon Island is about 660 yards long and at high tide is cut into two, a larger western end and a smaller eastern end, the latter about 280 yards long by 35-40 yards wide. The south shore of the islet slopes into the sea at about 25 degrees, but the north shore is practically vertical. The actual area taken was about 150 yards of the north shore of the eastern end of Brandon Island, starting from a small gravel beach near the eastern end and running west to a point where the shore actually overhangs the sea. The shore line is composed of rocks of basal conglomerate and hard grey sandstone, with large boulders here and there that have fallen off from the main mass. While it is practically vertical, it has a number of crevices and small flat ridges and two tiny gravel beaches. The rocky wall is covered with a close growth of barnacles and mussels over much of its length and in some places with *Fucus evanescens.* Below low water the rocks bear various other algæ such as *Costaria sp.*, *Laminaria sp.*, a little *Codium* and in one or two places a short distance from the shore small clumps of kelp, *Nereocystis luetkiana.* The main points to be noted are that there is practically no beach save at two small points and that as the shore faces practically due north it never receives the direct rays of the sun.

In all cases the examinations were made at a moderately low tide, but not at the lowest tides when other work necessitated collecting further afield. Allowance was made for this, so that the strips taken were the inter-tidal zones, *i.e.*, that part of the shore line between the uppermost high water and low spring tide limit.

The following species were observed: on area 1, *Pisaster ochraceus* and *Evasterias troschelii;* on area 2, the same species and in addition on 18th May one specimen of *Pisaster brevispinus* and on 25th August one example of *Dermasterias imbricata* were seen. It is probable that both of these were stragglers, if not indeed individuals that had been brought from elsewhere and dropped off the float. On area 3 the following were seen: *Pisaster ochraceus, Evasterias troschelii,* *Pycnopodium helianthoides, Henricia leviuscula, Solaster dawsoni, Solaster stimpsoni* and *Dermasterias imbricata.* On 19th May also, about 5 yards beyond the end of the area and in seven feet of water, two specimens of *Orthasterias leptolena* were observed. Strictly these are outside the scope of the present note, as they were just beyond the area and also they were below the level of the lowest tides. They are mentioned here, however, to call attention to the fact that they might occur in the area at some time or other.

At the commencement a good deal of time was spent trying to identify the species from Verrill's "Shallow Water Starfish" (13), but some difficulty was found and this was more apparent in the case of the sub-species. For example, when two specimens of *E. troschelii* were selected because they differed considerably, they might be fitted into sub-species fairly well but, on the other hand, if a fair number was taken, say five or six hundred, at random their separation was far more difficult, if not impossible. The varieties intergrade and mix to such an extent that their satisfactory recognition is extremely hard. Fortunately Dr. W. K. Fisher of Pacific Grove, California, spent a few days at the station collecting and examining the starfish early in the season. He regards all the *Pisaster* forms (except of course *P. brevispinus* about which there is no difficulty) as being *P. ochraceus* and all the *Evasterias* forms as belonging to *E. troschelii.* So that subsequently no attempt was made to sub-divide these forms. We are concerned with the following species, then, listing them according to the classification of Verrill (13).

FAMILY ASTERIIDAE

Sub-Family Asteriinae

Species 1. *Pisaster ochraceus* (Brandt) 1835

This is a very common form on the areas under consideration and taking the whole region around Nanaimo probably the commonest species. It is a stoutly built animal with a fairly large disc. According to Verrill (13, p. 70) it may reach a diameter of 22 inches, but I have never seen one as large as that and in Departure Bay one 15 inches in diameter would be noticeably large. The dorsal surface is reticulated by prominent spines and ossicles. As a general rule its colour is a deep violet on which the white ossicles and spines stand out strongly. A few are of a muddy chocolate brown colour, as a rule about 2-3% but not more than 5%. Yet others are of a yellowish brown, in those examined about 1% and two specimens in all those on the areas were of a yellow ochraceus colour. On my remarking that the specific name did not appear very appropriate I was surprised to learn from Dr. Fisher that in the Californian region they are nearly all bright yellow and a dark form is the exception. Of one variety of this, namely *P. ochraceus var nodiferus*, Verrill remarks that "Six-rayed specimens are not rare." In the hundreds of individuals noted below only 1 six-rayed one was found; it is also worthy of note that 2 four-rayed specimens were encountered. As a rule this species is found in crevices, in the corners under and behind rocks and right at the bases of the piles of the pier.

Species 2. *Pisaster brevispinus* (Stimpson) 1857

This is much like *P. ochraceus* in general form, but it is of a pinkish colour and the one specimen observed was 20 inches across. It was found on the flat beach at low tide level.

Species 3. *Evasterias troschelii* (Stimpson) 1862

This is a common starfish on the three areas and is second only to *P. ochraceus* in numbers. It is a moderately stoutly built form, but its disc is relatively much smaller than in *P. ochraceus* and its arms relatively longer, rounder and narrower at the base. The whole upper surface is areolated and reticulated with spines arranged in rows, but this condition is not so strongly marked in the living specimens as it is in the dried ones. Verrill (13, p. 157) reports a specimen from Esquimalt measuring 20 inches in diameter, but none that size was found on the areas studied, where an individual 15 inches across would stand out as exceptionally large. The general colour of this species is a dark, dull orange or orange-red but it exhibits considerable variation in this respect. Two well marked colour varieties are encountered, namely a distinctly brown form which was found in about 5-6% of the specimens and a greenish grey mottled colour in about 4-5%. In addition to this a number of intermediate colours between the typical and varietal colour were found, but unless they were strongly marked they were counted in with the typical. The greenish grey colouration is very interesting, since on the gravel area east of the pier such individuals are distinctly protectively coloured, indeed, if they lie under a few inches of water with a slight ripple on the surface they are almost indistinguishable. Among the specimens from the three areas only one four-rayed and two six-rayed individuals were encountered. This species is much more commonly found in a damaged condition, *i.e.*, with one or more arms missing, than *P. ochraceus* but all such specimens were carefully examined and the position of the missing arm could be seen from the junction of the ambulacral grooves on the disc and the pattern of the spines on the back. The four-rayed specimen referred to above did not show the remotest trace of ever having possessed a fifth arm. In general *E. troschelii* is found on the flat beach, sometimes on the piles of the wharf but not so commonly on the rocks.

Sub-Family PYCNOPODIINAE

Species 4. *Pycnopodia helianthoides* (Brandt) 1835

This is one of the most striking starfish in the region. Verrill (13, p. 200) states that it may reach a diameter of four feet, but 22 inches was the largest noted and this not on one of the chosen areas. It was only found on area 3 and then just at the limit of the low tide. Apart from the fact of its size and the large number of its rays, from 15-24, it is also conspicuous by its colour. Rarely it is an orange yellow, sometimes red or reddish orange, or even a kind of leaden violet. Very frequently it is much darker along the middle region of the ray and shades off to the lighter colour at the edge. In spite of its large size it is easily broken even when lifting it out of the water. Furthermore it shrinks and splits badly when drying so that it is not a good subject for museum study. It feeds largely on mussels and clams and it is not uncommon to find several entire molluscs, shells as well, in the stomach. When and how it ejects the shells was not seen. In this it differs from the other starfish which almost invariably open the shell and evert the stomach to surround the animal within it.

FAMILY ECHINASTERIDAE

Species 5. *Henricia leviuscula* (Stimpson) 1857

This species also was only found on area 3. It is a small form, the largest measuring about 5½ inches in diameter. The disc is small and the arms long, round and narrow. The dorsal ossicles are thick and so closely united as to form a hard external covering not easily bent. Its general colour was deep orange red or red but a number of examples were marked with pale lavender grey areas. These areas varied from just over the disc itself to over the disc and a quarter of the way down the arms. Usually this species was found on the vertical face of the rock on small horizontal ledges, sometimes on overhanging surfaces.

FAMILY SOLASTERIDAE

Species 6. *Solaster dawsoni* (Verrill) 1879

Species 7. *Solaster stimpsoni* (Verrill) 1879

These two species may be considered together as they are somewhat similar in appearance and just a few specimens of each were noted on area 3. *S. dawsoni* has generally 12 rays, a moderately large disc and narrow, round arms. The largest from area 3 was 7 inches in diameter. Its colour is a fairly uniform yellow fawn. *S. stimpsoni* is about the same size, has generally 10 rays, the disc is relatively smaller. The colour is brighter yellow or red with a line of leaden grey or violet grey passing from the centre of the disc along the middle of the back of each arm. All specimens of both species were seen just under the water.

FAMILY ASTEROPODIDAE

Species 8. *Dermasterias imbricata* (Grube) 1857

This species is a little more common than any of the preceding four but not nearly so plentiful as *P. ochraceus* or *E. troschelii* and, with one exception, found only on area 3. While of moderate size, a large one measuring about 9½ inches in diameter, it is relatively plumper than the other species considered. It has a large disc and the rays are correspondingly short, broader at their bases and they taper rapidly. In life the skin is tough and slimy, hence its common name of "leather star". The colour is rather a striking patterning of pale slatey grey and red or orange, but the dried specimens are usually various shades of dull red, orange or fawn. It is most frequently found on the vertical or even overhanging rocky walls.

Before considering the actual counts that were taken two further points call for consideration and these are the orientation of the animal as a whole and its method of locomotion. The first has to be noticed before discussing the damaged specimens, in order to indicate the missing rays. The most obvious mark upon the dorsal surface of these starfish is the madreporite plate which lies in an interradius. It was observed, more particularly in *P. ochraceus* and *E. troschelii*, that the animal could move in any direction, *i.e.*, with any ray or any interradius at the front end. In spite of this, however, when actually migrating it most frequently moves with the interradius bearing the madreporite plate or the interradius to the left of this directed nearly forward, so that in locomotion the functionally anterior end appears to be the ray to the left of the madreporite plate. So, in dealing with the loss of rays this ray has been termed the anterior ray (A.); the one to the right of it and on the other side of the madreporite plate, the first right ray (R.1); and the next R.2. Those on the other side of the animal are referred to as L.1 and L.2 respectively. This nomenclature was adopted in the field as the result of general observations but without taking an accurate and extensive series of counts, and on returning from the station and looking up the literature I found that Cole (5) and Kjerschow-Agersborg (11) had reached the same orientation, basing their conclusions upon physiological considerations. Cuénot (7) and Delage and Hérouard (8) have also put forward the same idea but upon morphological grounds. This interpretation has been employed in the present note, although it should be borne in mind that it is not in agreement with the views of Agassiz (3) or Ludwig (11).

When picking up the starfish from the ground for examination, again principally *P. ochraceus* and *E. troschelii*, it was noticed that if they were resting they were generally hard to remove and sometimes clung very tightly and, if on the gravel, they came up with numerous small pebbles adhering to their tube feet. On the other hand, if a moving form under water was carefully approached it could be picked up quickly without any trouble as it was not adhering to the substratum. This was a surprise at the time but was cleared up afterwards on reference to Jennings (10, p. 98, etc.) who showed that in ordinary walking the suckers of the tube feet are not used for clinging. Of course in climbing a vertical, moderately smooth surface like a pile, and more especially in crawling along an overhanging surface, there can be little doubt that the suckers are called into play in order to support the weight of the animal. However, when travelling on the level the weight is borne automatically and my own observations are in agreement with those of Jennings for *Asterias forreri* that in ordinary locomotion on a level surface the sucker action of the tube feet is not brought into play.

The first census of areas 1 and 2 was taken on 18th May just before and after 1.0 p.m. Low tide occurred at 1.02 p.m. and its height was 1.5 feet above the average level of the lowest low water for the month; the maximum air temperature was 60.5° F.; the temperature of the sea 12.6° C. (morning temperature about 11.5° C.); the Hydrogen-Ion concentration pH as determined colorimetrically by Clark and Lub's indicators was, with Thymol Blue 8.5+and Cresol Red 8.5+and the specific gravity of the sea water 1.0197.

AREA 1	
Pisaster ochraceus	130
Evasterias troschelii	579
TOTAL	709

AREA 2	
P. ochraceus	129
E. troschelii	337
Dermasterias imbricata	1
TOTAL	467

As noted above the *D. imbricata* may have been an imported example.

Abnormalities. These were only found in *E. troschelii* and consisted of two moderate sized, perfect, six-rayed individuals.

Damaged specimens. Two different types of damage were encountered; in the rarer of the two, a part of a ray had been removed and the end healed over. This was found in two examples of *E. troschelii.* The more common type is for one of the arms to have been completely removed and either their points of abscission healed over, or tiny new rays developed to replace them. This also occurred in *E. troschelii* and in the manner and frequency noted below, using the terminology suggested above.

A. only 5; R.1 only 3; R.2 only 3; L.1 only 3; L.2 only 2; both R.1 and L.2 1; both R.1 and L.1, 1; all of A., R.1 and L.1, 1; all of R.1, L.1 and L.2, 1.

The total number of specimens damaged in this second way was therefore 20 or 2.17% of the total number examined.

The first census of area 3 (Brandon Island) was taken on 19th May just before and after 1.30 p.m. Low tide occurred at 1.39 p.m. and its height was 1.6 feet above the average level of the lowest low water for the month; the maximum air temperature was 57.0° F.; the morning sea temperature was 12.8° C.; the pH was with Thymol Blue 8.5 and with Cresol Red 8.5 and the specific gravity of the sea water 1.0205.

AREA 3		
Pisaster ochraceus	986	
Evasterias troschelii	33	
Pycnopodia helianthoides	5	all under water
Henricia leviuscula	7	
Solaster dawsoni	1	under water
Solaster stimpsoni	1	under water
Dermasterias imbricata	21	
TOTAL	1054	

Most of the specimens were out of water except as noted above; those of *E. troschelii* were mainly on the two small beaches or flat rocks.

Abnormalities. None.

Damaged specimens. One example of *P. ochraceus* with a stump of ray R.2 and one with rays R.2 and L.2 missing were found. Among the *E. troschelii* were two individuals with arm R.2 missing and one with rays R.1 and L.1.

The starfish on the two beach areas, *i.e.*, areas 1 and 2, were slowly migrating out into deeper water and by the 29th May they were noticeably reduced in numbers. It will be seen that in order to leave area 1 the animals were almost forced to pass into the *Zostera* bed where *E. troschelii* is not usually common. Some of them apparently chose the path under the pier which is free from *Zostera*, for during this period they were more plentiful between the piles than at first. No striking change of conditions seemed to have influenced this movement. The sea temperature on 20th May was 14.0° C., the highest in the year so far, but during the period of most active movement, *i.e.*, from 27th to 31st May, the temperature had dropped from 11.75° to 11.0° C. The air temperature reached 67.5° F. on the 24th May, but again dropped to from 49.5° to 61.5° F. during the dates just mentioned. Similarly the pH reached 8.6 on the 24th May but dropped to 8.5 on the 29th and 30th May and the specific density reached its maximum of 1.0252 on the 21st May and during the dates 27th to 31st May varied between 1.0221 to 1.0248. Thus with the possible exception of the specific density it does not appear as if any of the above factors can be considered responsible for the migration.

By the 3rd June practically all the starfish had moved from these two beach areas out into deeper water and not more than 20 to 30 were left and these were mainly at the bases of the piles of the pier.

No such marked migration was obvious in the case of area 3, where a partial count taken on 3rd June showed that the diminution was not more than 10%; but later in the month still more had disappeared.

The animals remained away from areas 1 and 2 for the rest of June, July and the beginning of August. During June the air temperature reached 88.5° F. and the water temperature 18.0 C. By the end of June the water temperature was 19.75° C. and during July and August it several times reached 20.0° C. The pH varied between 8.6 and 8.8 and the density between 1.0098 and 1.0198.

On the 13th of August it was noted that both *P. ochraceus* and *E. troschelii* were becoming more plentiful on the piles of the end of the pier, but this was beyond the areas considered. By the 19th August both species were beginning to come back on to the areas and on the 25th a count was taken. The census was taken before and after 10.30 a.m. and low tide occurred at 10.38 a.m., its height being 2.4 feet above the average level of the lowest low water for the month; the maximum air temperature was 76.0° F.; the temperature of the sea, 18.7 C.; the pH by Thymol Blue 8.8 and by Cresol Red 8.8 and the density 1.0180.

AREA 1	
Pisaster ochraceus	32
Evasterias troschelii	465
TOTAL	497

AREA 2	
P. ochraceus	129
E. troschelii	159
Pisaster brevispinus	1
TOTAL	289

Abnormalities. None.

Damaged specimens. These all belonged to *E. troschelii* and all were examples of the complete loss of one or more arms. They were as follows: A. only 3; R.1 only 2; R.2 only 1; L.1 only 2; L.2 only 1; both R.2 and L.2, 1.

The corresponding census on area 3 was taken on the 26th August before and after the low tide which occurred at 11.20 a.m. Its height was 2.8 feet above the average level of the lowest low water for the month. The maximum air temperature was 76.0° F.; the temperature of the sea 18.5° C.; the pH by both Thymol Red and Cresol Blue 8.6 and the density 1.0175.

AREA 3

Pisaster ochraceus	637
Evasterias troschelii	12
Pycnopodia helianthoides	1
Henricia leviuscula	9
Solaster dawsoni	1
Dermasterias imbricata	23
TOTAL	683

Abnormalities. None.

Damaged specimens. Only one such was encountered, a *P. ochraceus* lacking rays A. and R.1.

From this time onwards the starfish on all areas steadily increased in numbers and not only that, but they also moved further and further up the rocks or beaches. This meant that they were exposed to the air for longer and longer periods when the tide fell. Finally they became more plentiful than when the original count was taken.

The last census of areas 1 and 2 was taken on the 8th September before and after the low tide which fell at 9.32 a.m. and its height was 2.9 feet above the average level of the lowest low water for the month. The maximum air temperature was 79.5° F.; the temperature of the sea was 17.5° C.; the pH as indicated by Thymol Blue 8.4 and by Cresol Red 8.4 and the density of the water 1.0177.

AREA 1		AREA 2	
Pisaster ochraceus	143	*P. ochraceus*	149
Evasterias troschelii	1121	*E. troschelii*	428
TOTAL	1264	TOTAL	577

Abnormalities. These were found in both species; in *P. ochraceus* one specimen with four rays and one with six rays were taken; in *E. troschelii* one example with four rays.

Damaged specimens. One individual of *P. ochraceus* was found with R.1 missing. The others all belonged to *E. troschelii* and occurred as follows: A. only 5; R.1 only 5; R.2 only 4; L.1 only 3; L.2 only 3; both A. and R.1, 3; both A. and R.2, 1; both R.1 and L.1, 1; R.1, L.1 and L.2 all three 1.

The final census of area 3 (Brandon Island) was taken on the 9th September before and after the low tide coming at 10.18 a.m. and its height was 2.7 feet above the average level of the lowest low water for the month. The maximum air temperature was 80.0° F.; the temperature of the sea was 17.5° C.; the pH as indicated by both Thymol Blue and Cresol Red was 8.6 and the density of the water was 1.0180.

AREA 3

Pisaster ochraceus	972	
Evasterias troschelii	20	
Pycnopodia helianthoides	7	(4 under water)
Henricia leviuscula	10	
Solaster dawsoni	1	
Solaster stimpsoni	1	under water
Dermasterias imbricata	26	
TOTAL	1037	

Abnormalities. One specimen of *Pisaster ochraceus* with only four rays was found.

Damaged specimens. These were only found in *P. ochraceus* and were as follows: R.1 only 1; A. one specimen with the ray severed half way along; one with A. and R.1 both missing together with the madreporite plate.

Thus it will be seen that by September 8th the starfish on areas 1 and 2 had returned until they were even more plentiful than on the 18th May, which perhaps indicates that the migration had already commenced by that date or that conditions in September were unusually favourable. On area 3 the starfish population at the September count was almost the same as on the 19th May, not only in total but also in the numbers of the various species represented.

With this statement of the actual counts we can turn to consider two questions: 1, that of abnormality and damage; and 2, that of the movement of the animals.

1. There is no means of knowing whether the same animal was counted twice, save in the case of abnormalities when the specimens were taken and preserved. Their total therefore is accurate, but it seems very probable that the same individuals of the general population on areas 1 and 2 were included in both the August and September counts since there was no indication of a reverse movement on the part of the starfish already on the beach. For this reason the August total is left out of account. On the other hand we have, at present, no means of telling whether the same individuals that were on the beaches in May returned in September, so that the two counts are taken as separate. In the same way only the May and September counts are considered in the following totals.

The total number of individuals of *P. ochraceus* was 1,537 and in this number there were one with six arms and one with four arms, or if we assume that the one taken in August would have remained until September then we should have two with four arms.

The total number of invididuals of *E. troschelii* was 2,498 and among them were one with four rays and two with six rays.

While Verrill states that in *P. ochraceus* six-rayed specimens are not rare, he was probably referring to those collected and sent in for examination when the unusual forms would naturally be taken in case they were new. From the figures that are given above, however, I think it may be safely said that neither four-rayed nor six-rayed specimens are common in the two species on the areas considered.

When we turn to damaged specimens we notice that the 1,537 *P. ochraceus* included only 6 while the 2,498 *E. troschelii* included 49 or approximately 2%; a very noticeable difference. It is true that the rays of the latter are more easily broken off than those of the former, but at the same time I cannot help thinking that this alone does not account for the great difference and there must be some factor in the life of the latter to account for the more frequent loss of complete rays.

In taking into account all the damaged specimens of *E. troschelii* that were obtained in the three counts and considering all the arms that were lost, regardless of whether they occur on the same animal or not, we get the following totals: A., 18; R.1, 20; R.2, 12; L.1, 14; and L.2, 10. It is not possible to generalize on such small numbers, but they suggest that the loss of rays is not quite a haphazard phenomenon. The greater number of arms are lost on what has here been regarded as the anterior side of the animal and the two lowest are R.2 and L.2. It would appear as if in the course of locomotion the animal moves into some danger that most frequently results in the loss of the anterior members.

2. Lastly we have to consider the question of migration. All the species dealt with show undoubted evidence of a movement towards deeper water during the summer. On area 3 this is not nearly so striking as on areas 1 and 2, which became destitute of starfish population during the summer months. Even on area 3, however, there is a decided migration which is most marked in *P. helianthoides, S. dawsoni, S. stimpsoni*. At the present time it is not possible to assign a cause for this migration in the case of the species just mentioned. It is conceivable that it may coincide with some important phase of their life history or perhaps be a direct result of the environmental changes. A similar movement in area 3 is observed in the case of a certain number of *P. ochraceus; E. troschelii* also gets noticeably less, but by no means disappears. If we consider the obvious factors in the environment, *i.e.*, water and air temperatures, Hydrogen-ion concentration and specific gravity of the sea, the same conditions obtain in all three areas. Let us glance at these factors in turn, particularly as they affect areas 1 and 2.

1. Sea temperature. While it is true that when the first count was taken on 18th and 19th May and the following day the water temperature rose from 11.0° C. to 14.0° C. yet it fell afterwards and during the period of active migration it was back at 11.0° C. again. When the starfish commenced to return the temperature varied between 18.0° C. and 20.0° C., so that as far as sea temperature alone is concerned there is no reason why they should have left, as only on the 17th of August was the temperature of 20.5° C. reached.

2. Hydrogen-ion concentration. The pH at the beginning of May was

frequently 8.8 and at the time the first count was made 8.5 to 8.6. It might appear as if this played a part, save that by the 6th June the pH was again back to 8.8. Then too during the period of return it was also 8.6 or 8.8, so that this change does not appear to play a part.

3. Specific gravity. Two days after the first count the maximum density was recorded, *i.e.*, 1.0252, but then this was followed by a fall to 1.0182 on the 25th May and a return to 1.0248 on the 31st May. These changes did not appear to increase or retard the rate of migration. During the period of return the density varied from 1.0158 to 1.0205 without apparent effect.

4. Air temperature. The air temperature on the 17th May was 64.0° F., but it had been 71.0° F. on the 8th May and during the period of active movement it dropped as low as 49.5° F. When the second count was taken the temperature was 78.0° F. and 76.0° F. and during the final count it was 79.5° and 80.0° F. Again then as far as temperature alone is considered there seems to be no reason why the animals should have left the beaches until the temperature reached 80.0° F. or, in other words, only for one or two days during the whole summer.

None of these four factors nor any combination of them appears to be the causative agent either in the movement from the beaches or the return to them. The one explanation that does seem satisfactory is related to the characteristic tides on this part of the Pacific Coast. It is not possible to go into full details of this interesting question here, but certain outstanding points need consideration. The dominant element in these tides is the moon's declination and actually in the Strait of Georgia the obliquity of the moon's attraction when it is in its extreme declination gives rise to a diurnal inequality in the tides that obscures all other tidal features. The result is that there appears to be one low tide in the twenty-four hours and a second considerably higher low tide. Thus for example on the 31st May the main low tide was at 12.15 p.m. and its height .1 of a foot below the average level of the lowest low water for the month. The second low tide was at 12.09 p.m. but it was 8.4 feet above the same point. From the point of view of shore collecting in the intertidal zone there is then only one low tide in the twenty-four hours. A second interesting feature worthy of notice is that in the present year this low low tide on the 3rd January came at 3 minutes to midnight, by the end of May it occurred at 15 minutes past midday, by the 9th September it was at 10.18 a.m. As a result of this the beaches were under water during the daytime in the early part of the year. By the middle of May, *i.e.*, the 16th, as low tide came 6 minutes before noon the beaches were left dry during the middle of the day. This was also true for the remainder of May, for the whole of June, for the whole of July and the beginning of August. By the 21st August, however, the low tide had switched round and came at 7.10 a.m., so that the beaches were more or less covered during the middle of the day. On the 9th September low tide was at 10.18 a.m., but this was 2.7 feet above the low tide point, so that again the beaches were covered during the day and at no time between these dates were uncovered at or near mid-day.

In describing the areas it was pointed out that both 1 and 2 faced almost due south, so that during the middle of the summer the sun was shining directly upon them while they were bare. The dark grey rocks and still darker mud therefore must get quite hot. Unfortunately this was not noticed in time to take records of the temperature of the beach itself. Area 3, as has been noted, is an almost vertical rock surface facing almost directly north and so, even when bare, it only receives the sun's rays for a brief spell early in the morning or late in the afternoon upon its outstanding surfaces. From the foregoing observations I have been led to conclude that the important factor in causing the migration of the starfish on the two areas 1 and 2 is either the direct action of the sun itself shining strongly upon the animals when unprotected by water or else the rise in temperature of the sub-stratum, or both.

This received an interesting confirmation in a small local movement that was noticed at the beginning of September on the rocks immediately to the east of the shore end of the pier. It was noted that on the 4th September an unusually large number of *E. troschelii* were on the rocks at the place just noted, but higher than usual. On the 6th September they began to move down some distance and by the 10th September they had all moved right down on to the beach. Actually there was during this period a fall in the sea temperature from 16.5 C. to 15.2 C. and a rise again to 17.5 C.; the density fell from 1.0196 to 1.0173 and rose again to 1.0191; the pH altered from 8.6 to 8.4 and back to 8.6. So that if any of these factors had been directly concerned the movement might have been down and back again. However, when we see the tide changes for the period we find that at the beginning the low tide (4.5 feet above low point) came at 5.53 a.m. so that the beach was covered again by the time the sun was shining strongly on the spot. On the 7th September the low tide, now 3.3 feet above low point, was at 8.42 a.m. and on the 10th September the low tide, now only 2.7 feet above low point, was at 10.02 a.m. So that as the days passed the sun shone for a longer and longer time upon the rocks while they were exposed. This was the only local migration that was noticed and it appears to have been brought about by the same cause or causes that actuate the summer migration.

The most striking migrations in the animal kingdom are those of birds and fishes and these, particularly in the case of the latter, are closely connected with reproduction. This is noticeable on the Pacific Coast in the case of the various Salmon and of the Lamprey *Entosphenus tridentatus*. It is perhaps only natural then that it should be more or less assumed that the seasonal migrations of various other groups of animals is connected with the same phenomenon. This does not appear to be the case with the starfish *P. ochraceus* and *E. troschelii*, however, for while they tend to migrate into deeper water and in exposed situations actually do so during the summer, the reproductive products are produced regardless of where the animal happens to be. Those that are under water and those that remain behind on the rocky coast of area 3 have ripe sexual cells during July and August. This function does not determine their movements. So far as can be found little attention has been paid to seasonal migrations of the Invertebrata although they have been generally recognized.

Fraser (9) has pointed out the fact that a series of animals do exhibit seasonal movements and concludes: "In practically all the main classes of marine forms represented in the waters along this coast (*i.e.*, in the region of Nanaimo) in which the adults are not sessile or very sedentary, examples may be found that indicate a tendency to migrate periodically. The instances given may or may not be typical of the classes, but they are all common species. If as much attention were given to life-history in any of these classes it is at least possible that there would be as much indication of migration as in the fishes." In the paragraph dealing with the Echinoderms he notes that "It is common to find certain species in much shallower water in the early spring than at other times of the year." *Mediaster aequalis* and *Orthasterias leptolena* are quoted as examples of this. *Pisaster ochraceus* is described as the commonest of all, and it can be found "at or above low water at all times of the year." No observations were made to ascertain the cause of the movements. The migration of *M. aequalis* and *O. leptolena* is apparently similar to that of *P. helianthoides* and *S. stimpsoni* and *S. dawsoni* as noted above.

Crozier (6) has discussed the movements of a Nudibranch *Glossodoris* (*Chromodoris*) *zebra* (Heilprin) as he observed them at the Bermuda Biological Station for Research and he comes to the following conclusion: "In the case of *Chromodoris zebra*, it seems to me definitely established that the periodic flocking of individuals into very shallow water has no immediate connection with reproduction." An interesting observation that parallels my own conclusion in the case of two species of starfish. He does not, however, suggest what the cause is.

With regard to the other suggestion it is interesting to note that Allee comes to a similar conclusion on more general grounds. He says (13, p. 243): "Temperature serves as a limiting factor for these associations, during the season of the year studied, in the tide pools and more particularly on the flats. There in the *Scolopus acutus* association above the dense eel grass mats at low tide the high temperature (32° C.) that may be reached must serve to kill off the more sensitive sessile animals *as it drives the motile ones below the surface layer to the cooler water in the shade of the eel grass*. The temperature to which animals may be exposed at low tide increases as one leaves open water conditions in both series." The italics are mine.

SUMMARY

1. The common shore forms of Asteroids near Nanaimo are *P. ochraceus* and *E. troschelii*.

2. During the greater part of the year these may be intertidal animals and a small area is capable of supporting a large population.

3. There is evidence of a certain amount of migration of these two species during the summer months, but where they are exposed to the direct sunlight at low tides the entire population migrates.

4. The cause of migration in the latter case appears to be either the actual sunlight itself or the high temperature it produces on the substratum.

5. *E. troschelii* is far more subject to mutilation resulting in the entire loss of one or more rays than *P. ochraceus*.

6. There is a certain polarity exhibited in the movement and in injury and the ray to the left of the madreporite plate appears to be at the anterior end of the animal.

REFERENCE LIST

(1) Allee, W. C. Studies in Marine Ecology I. The Distribution of Common Littoral Invertebrates of the Woods Hole Region. *Biol. Bull.* Vol. XLIV, No. 4, 1923.

(2) Allee, W. C. Studies in Marine Ecology III. Some Physical Factors Related to the Distribution of Littoral Invertebrates. *Biol. Bull.* Vol. XLIV, No. 5, 1923.

(3) Agassiz, A. North American Starfishes. *Mem. Mus. Comp. Zool. Harvard.* Vol. 5, 1877.

(4) Burwash, E. M. The Geological Environment of the British Columbia Biological Station at Departure Bay, Vancouver Island. *Cont. Canadian Biol.* 1906-1910.

(5) Cole, L. J. Direction of Locomotion of the Starfish (*Asterias forbesi*). *Jour. Exp. Zool.* Vol. 14, 1913.

(6) Crozier, W. J. On the periodic shoreward Migrations of Tropical Nudibranchs. *American Nat.* Vol. LI, No. 606, 1917.

(7) Cuénot, L. Etudes morphologiques sur les Echinodermes. *Arch. biol.* Vol. II, 1891.

(8) Delage, L. et Hérouard, E. Traité de zoologie concrète. Paris, 1903.

(9) Fraser, C. M. Migration of marine animals. *Trans. Roy. Soc. Canada.* 3 ser., Vol. IV, 1918.

(10) Jennings, H. S. Behaviour of the Starfish *Asterias forreri* de Loriol. *Univ. Calif. Publ. Zool.* Vol. 4.

(11) Kjerschow-Agersborg, H. P. The Relation of the Madreporite to the Physiological Anterior End in the Twenty-Rayed Starfish, *Pycnopodia helianthoides* (Stimpson). *Biol. Bull.* Vol. XLII, No. 4, 1922.

(12) Ludwig, H. Die Seesterne *Bronn's Klassen und Ordnungen des Thierreichs*, B.2. Leipsig, 1899.

(13) Verrill, A. E. Monograph of the Shallow-water Starfishes of the North Pacific Coast from the Arctic Ocean to California. *Harriman Alaska Expedit.* Vol. 14, 1914.