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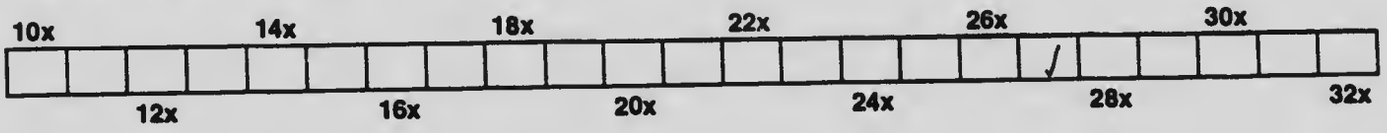

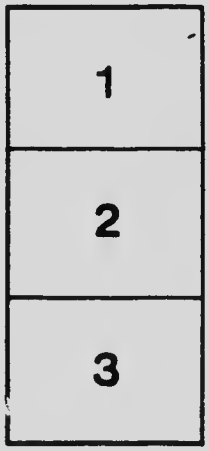

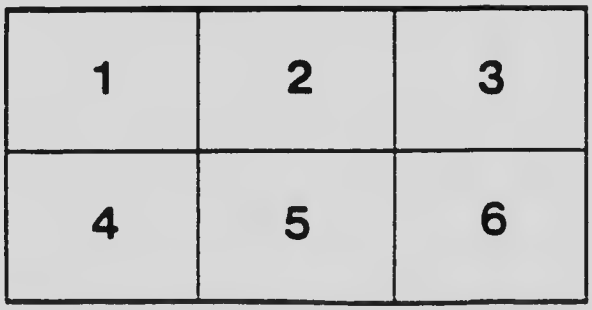

BIOLOGICAL CONTRIBUTIONS
1915-17

NOTES

ON THE

HABITS AND DISTRIBUTION OF TEREDO NAVALIS ON THE ATLANTIC COAST OF CANADA

BY E. M. KINDLE Ph.D., etc.

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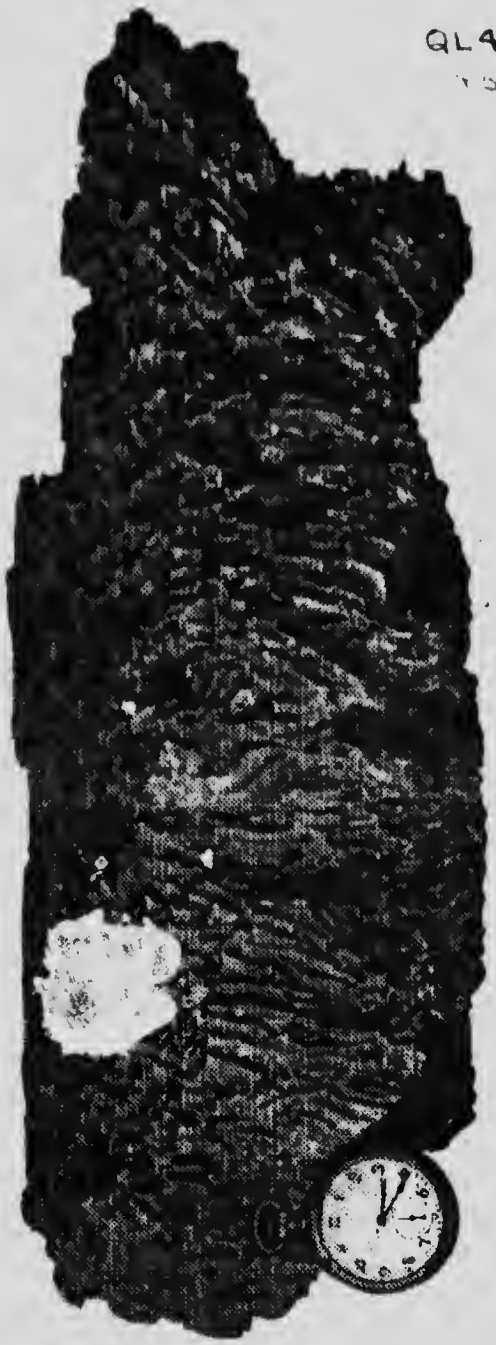

Fig. 1.

Fig. 1.—Wood bored by *Teredo navalis* at Charlottetown, P.E.I., within a period of sixteen months.

IV

NOTES ON THE HABITS AND DISTRIBUTION OF TEREDO NAVALIS ON THE ATLANTIC COAST OF CANADA.[1]

By E. M. Kindle, Ph. D., etc.

INTRODUCTION.

A specimen of the boring work of the "ship worm," *T. navalis* was recently presented to the Museum of the Canadian Geological Survey by Mr. H. E. Miller, accompanied by notes showing the dates within which the destructive work had been accomplished. Although a considerable literature exists on the destructive work of Teredo, records of its habits and work in Canadian waters are sufficiently scarce to justify recording some of the interesting facts which have been communicated to the writer by Mr. H. E. Miller. In the course of his work as an engineer in the Department of Public Works in renewing wharves, piling, and other seashore structures in Prince Edward Island, Mr. Miller has had unusual opportunities to become acquainted with the work of the Teredo. The data relating to the habits of the boring mollusc, popularly known as the ship worm, which are recorded in this paper have been supplied chiefly by Mr. Miller.

The distribution of *Teredo navalis* presents some novel features. It affords an example of discontinuous distribution which parallels that of the common oyster in Canadian waters. It is associated with the gulf of St. Lawrence colony of the Acadian fauna, but its distribution varies rather widely, as will be pointed out, from that of some of the other species of this northern Acadian colony.

HABITS.

Considerable human interest attaches to the boring work of the mollusc, *Teredo navalis*, because it is equally capable of destroying wharves, or railway bridges, or sinking ships when precautions to check its ravages are neglected. The depredations of Teredo are not confined to any particular parts of the world's coast lines. Its work is well known on the Pacific coast, where the Isopod, *Limnoria tenebrans*, is locally even more destructive.[2] In Europe an extraordinary increase in the numbers and abundance of Teredo at various widely separated periods have several times brought it into very prominent notice. During one of these periodic increases in its numbers —about 1730-32—Holland was imperilled by the threatened destruction of its sea dykes.[3]

The rapidity with which timbers are frequently destroyed by *Teredo navalis* is shown by the accompanying photograph (fig. 1) of a portion of a beech timber which was 12 inches square when placed in the water. The timber was perfectly sound when placed in the tidal zone just west of the entrance to Charlottetown harbour, Prince Edward Island. The completely honeycombed condition shown in the figure was accomplished in a period of sixteen months. This is a much more rapid rate of

[1] Published with the permission of the Director of the Geological Survey.

[2] Harrington, N. R., and Griffin, B. B. Notes on the distribution and habits of some Puget Sound Invertebrates. Trans., N.Y. Acad. Sci., 1897, pp. 208-9.

[3] Van Baumhauer, F. H.—The Teredo and its Depredations (translated from Archives of Holland, Vol. I). Popular Science Monthly, Vol. XIII, 1878, pp. 400-410, 545-554.

destruction than has been ascribed to its ally *Limnoria lignorum*, which Murphy[1] states can, when abundant, destroy soft timber at the rate of half an inch or more every year. Stearns[2] has recorded two interesting examples of the work of Teredo. He states that "upon the seafront of San Francisco I have known piles of Oregon pine and fir over a foot in diameter rendered worthless in eighteen months." Dr. Dall is quoted by Stearns as having noted a case of the destruction of the supports of a small pier made of piles 6 to 8 inches in diameter near the entrance to Chesapeake bay in six weeks. Prof. A. E. Verrill writes that "*T. navalis* is very abundant and destructive on the southern coast of New England. At my summer home on an island near New Haven it will reduce 2-inch planks and 4-inch stakes to a honeycomb condition in one season—1st July to September—as I have often proved by experience."[3] Although only a very thin film of wood separates the innumerable burrows, they in no case intersect or cut into each other.

The time of year at which timber is cut, according to Mr. Miller, is an important factor in determining the extent to which it is subject to or immune from the ravages of the Teredo. "Trees cut during the months from October to January give much greater resistance or are less attractive to the Teredo than the trees cut from February to May. The Teredo is practically inactive during the cold of winter."

One of the peculiarities of the boring habits of Teredo is its aversion to boring from one timber to another, no matter how firmly attached and adjusted they may be. "Over a shipbuilding experience of fifty years our general foreman of works, Mr. John White, observed only two cases where worms have worked from the hull planking into the timbers of vessels.

"Spawning time appears to be about July. Vessels launched in spring and hauled out before July, and those launched in October are practically free of the Teredo; those exposed during the latter part of June and during July, if not protected, being very freely attacked."

"To a great extent the Teredo will attack unprotected vessel hulls as freely as fixed timber, particularly if remaining idle for any length of time. Constant motion through the water, however, appears to hamper the attachment of the spawn to some little extent. Such protection, however, as tarring, copper or marine painting and creosoting proves an effective measure as long as the protecting agent remains intact."

"The point of entry of the borer spawn into the timber is below half-tide mark. A peculiarity is that standing timbers show a severed condition (very much after the fashion produced by the beaver), at from one to two feet above low-water spring tide mark in localities where spring tides have a range of 9 to 11 feet. From this point down the borers work entirely within the timber, not passing the line of the bottom, where this is muddy, but not having the same objection to sand, as shown by the specimen forwarded."

"Mr. Crandall, of the Crandall Engineering Concern, Boston, Mass., has made the statement to me, that if timber could be kept covered with a film of mud, it would be kept immune through the entry of Teredo spawn being prevented. Certain it is, that all other things being equal (particularly temperature and saltiness) the Teredo is much more prevalent and destructive where the surrounding shore and bottom is sandy. In twenty years' experience this office has never observed a creosoted stick affected by the Teredo. The impregnation used is fourteen and sixteen pounds to the cubic foot."[4]

A small amount of creosote appears to be not very effective, since Stearns states that at Christiania, where the Teredo is very destructive, he was told that "all the

[1] Proc. and Trans. N.S., Inst. Nat. Sci., Vol. V, 1851, p. 365.
[2] Stearns, R. E. C.—The Teredo or Ship-worm. American Naturalist, Vol. XX, 1886, pp. 134-135.
[3] Verrill, A. E. Letter to the author, February 21, 1917.
[4] Letter from H. E. Miller, to the author.

piles had been creosoted (ten pounds to the square foot) before they were driven in, but not to much purpose."[1]

The palmento of the southern states and some of the Australian woods are said to be immune from the attacks of Teredo. The papers by Putnam[2] and Cunningham[3] contain much information on the habits of Teredo.

An Icelandic naturalist[4] has made some interesting observations and experiments on the habits and biological characteristics of *Teredo norwegica*, the species found on the southern and western coasts of Iceland. Mr. Frits Johansen has kindly furnished the following translation and summary of these from the Danish: "The propagating (spawning) season continues through the whole summer (April-August). No larvæ are found in the mantle-cavity or in the sea; but numerous very small ones (burrows 1mm. long 0·5mm. wide) are found in driftwood from Faxebugt (W. coast) at the end of July.

"The growing period is mostly limited to two years as shown by experiment: I kept some pieces of wood with Teredo taken from the false keel of a fishing boat and kept it in a shaded cool place; the animals remained alive ten days; but inside of two weeks all were dead. Kept in a temperature of 6° C. for two days they all froze stiff, but were alive when thawed out again. In fresh water they only lived two to three hours; three hours in half sea and half fresh water or in putrid sea water.

"It is mostly only on two places that ships are attacked; at the waterline and in the false keel (or if this is missing the lower part of the keel itself). That this keel part is attacked is because it is buried in the sand, when the ship is beached, and thus gets no paint or tar. The "waterline" part of the ship gets easily its protection of paint or tar scraped off when loading, anchoring, etc. Plank edges are first and most attacked.

"The Teredo avoids leaving the wood in which it bores. Hence from the false keel only a few had penetrated to the true keel, and the burrows avoided the outer surface of the false keel. Where two parts of the false keel joined, the burrows never went through the contact but stopped short of a couple of inches. But how does the Teredo know when to stop burrowing? Maybe by sound-sense? In piers at Reykjavik, where *Limnoria lignorum* Ratk. burrows together with Teredo, one frequently sees that Limnoria eats away the woodparts surrounding the Teredo burrows and the calcareous lining of the Teredo burrows are exposed. Teredo therefore protects itself by thickening its calcerous lining 3 to 4 times the usual thickness by internal secretions.

"Boats on the water at the south and southwest coast are attacked by it.

"In later years it has been very numerous and destructive in sea-going ships belonging to the southwest coast; in many cases Teredo has been imported with ships bought in England, but some ships built in Iceland or lumber put into ships in Iceland have been attacked. Ships belonging to the north and northwest coasts (beached during the winter) seem to be free of Teredo. Maybe the many English ships bought and the unusually mild winter, and the fact that the ships are on the sea all winter are the causes of its frequency at the southwest coast for the last five or six years.

"The largest Teredo I have seen measured 27·5 cm. (to the base of the siphons) siphons ca. 2·5 cm.; average size of Teredo 16-18 cm., built in 1892."

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[1] *Ibid*, p. 135.

[2] Putnam, J. W.—The Preservation of Timber. Scientific American Supplement, Vol. X, No. 236, July 10, 1880, 3762-3763.

[3] Cunningham, J. T.—Teredo. Encyclopaedia Britannica, 9th Ed., Vol. XXIII, 1888, pp. 184-186.

[4] Saemundson, B. Zoolog. Meddel. fra Island (Zool. Notes from Iceland, p. 43, pp. 51-56). Vidmskab. Meddel. fra Naturhist. Foren. Kbhn. for Aared 1903 (Scientific papers from Natural History Society in Copenhagen for year 1903).

BATHYMETRIC RANGE.

There is but little information on the depth to which Teredo can work below low tide level in Canadian waters beyond Murphy's[1] photograph of a piece of bored spruce which was submerged two years, four feet below low water at Pictou, N.S. At Woods Hole, Mass., it has been found living at a depth of 13 fathoms[2] and in New York harbour at 25 fathoms.[3] Three well-known rock and clay-boring molluscs are found in the same general region with *Teredo navalis*. These are:—

Petricola pholadiformis.
Zirfaea crispata.
Saxicava arctica.

P. pholadiformis appears to be most common near the inter-tidal zone, but it has been dredged at a depth of 30 fathoms in St. Marys bay by Dr. A. G. Huntsman. The recorded range of *Z. crispata* is from low tide to 70 fathoms in Canadian waters. Off the Maine coast it is recorded by Verrill[4] at from 22 to 44 fathoms. At Woods Hole it also occurs at a considerable depth below low tide. *Saxicava arctica* is another rock boring shell which has a considerable range below the tide line. On the Iceland coast it is found between tide marks[5] while off the Labrador coast it is common at 10 to 50 fathoms.[6]

Honeyman reported limestone boulders bored by Saxicava which were found at a depth of 65 fathoms off the Nova Scotia coast.[7]

The rock-boring habit gives to molluscs which practise it a special geological significance, as pointed out by Barrows.[8] The rock cells of such molluscs gradually expand as the rock is entered from the small aperture on the surface drilled by the very young shell into chambers corresponding to the size of the adult molluscs which thus leave no avenue of escape for the shell even after its death. The improbability of the removal of boring shells by current action to waters deeper or shallower than the living animal occupied permits the fossil molluscan rock-boring shells to yield information which is precise within the limits of their vertical range concerning the depth of the sea in which they lived.

DISTRIBUTION.

The genus Teredo has a wide distribution around the coasts of the North Atlantic. None of its several species however belong properly to the Boreal fauna although there are outlying colonies of some species which are surrounded by the boreal fauna. *T. norvegica*, which is the prevailing indigenous species on the eastern side of the North Atlantic, affords in its European distribution an interesting example of such discontinuous distribution toward the northern limits of its range. This species ranges through the Mediterranean and up the west coast of Europe into the waters of S.W. Norway. But G. O. Sars[9] states that "the only place inside of the Arctic

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[1] Proc. and Trans. N.S. Inst. Nat. Sci., Vol. 5, 1881, p. 376, fig. 4.

[2] Summer, F. B. Osburn, R.C., Cole, L. J. A Biological Survey of the Waters of Woods Hole and vicinity. Bur. of Fisheries, Bull. 1913, Vol. XXXI, Part II, Sec. III, p. 702.

[3] Proc. and Trans. N.S. Inst. of Nat. Sci., Vol. V, 1881, p. 376, fig. 14.

[4] Am. Jour. Sci., Vol. 7, 1874, p. 503.

[5] Johansen, A. C. On the Mollusca between tide marks at the coasts of Iceland. Videnskabelige Middelelser fra den Naturhistoriske Foresig I. Kjobenhaon, 1902, p. 386.

[6] Mem. Bos. Soc. Nat. Hist., Vol. I, p. 282.

[7] Honeyman, Dr. D. Glacial Boulders of Our Fisheries and Invertebrates, Attached and Detached. Trans. Nova Scotian Institute of Natural Science, Vol. VIII, Part III (1888-89), p. 210.

[8] Barrows, A. L. The Geologic Significance of Fossil Rock-Boring Animals (read before the Palaeontological Society of America). Bull. Pal. Soc. Amer., Vol. 28, 1917.

[9] Mollusca regiónis Arcticæ Norvagiæ, p. 98, Christiana, 1878.

region where this form has been noticed is at Oexfjord in West Finmark, where my father found it boring in piles."

This Finmark colony of *Teredo norvegica* is far to the north of the northern margin of the continuous distribution zone of the species on the Norwegian coast.

B. Saumundson[1] writes as follows regarding the occurrence of Teredo in Icelandic waters: "The Icelandic name of Teredo, 'tremadkur,' was first mentioned as Icelandic by E. Olafssen in his journey through Iceland Soroe in 1772: *'Teredo navalis intra lignum* is the bad worm, which spoils the driftwood' (West Iceland). Later it is mentioned by Mohr, 1786 (Icelandic Natural History) and by Morch (Fauna Mollusc. Island), 1868, both on the authority of Olafssen, so that neither of these two men have noticed it in Iceland themselves.

The species was found living in a pier at Reykjavik by me five years ago, and definitely determined by Ad. Jensen as *T. norweviga* Spengl.

The species is found in driftwood all around the island. It was found by me only in standing lumber (piers) at Reykyavik (West coast)."

A Teredo listed as *T. navalis?* and *T. denticulata* is included in Mollier's[2] and Morch's[3] lists of the mollusca of Greenland. Posselt[4] refers Moller's *T. navalis* to *T. denticulata* which he records from a single locality in S. Greenland,—avigtut.

The distribution of *Teredo navalis* along the Atlantic coast of Canada and New England affords an excellent example of discontinuous distribution. The essential features of this distribution are indicated in the sketch map (fig. 2), showing the distribution of Teredo in these waters. The map includes south of the Bay of Fundy the recorded occurrences of two or three species besides *T. navalis* but it clearly shows that the coast line distribution of this species is broken by 400 miles or more of coast line along which it is either absent or very rare. This mollusc is present in great abundance around the southern shores of the gulf of St. Lawrence and the coast of Cape Breton island. But southwest of the Str. of Canso it becomes scarce. In the Bay of Fundy, *T. navalis* is either very rare or entirely absent. South of this bay, however, it again becomes common on the Maine coast and from Frenchman's bay southwest appears to be generally present along the New England coast.

Mr. H. E. Miller has furnished the following notes on the distribution of *T. navalis* on the coast of Prince Edward Island: "Teredo is present in all waters surrounding the Prince Edward Island and up the inland tidal waters as far as the salinity of the water is sufficient.

"Regarding the coast of New Brunswick to the westward of this province, I cannot speak from personal observation never having visited that coast but from what I can learn the borer is to be found along the whole coast of Miscou and Shippigan and for at least a short distance along the Chaleur Bay coasts. I understand they do not work as far up to the rivers, as in this province. This is readily understood from the fact that the rivers are practically fresh very nearly to the outlet, draining immense areas and salinated by a very small range of tide.

"At Rustico Harbour on the North side of the island, there is great activity. The locality is entirely sandy. At Tignish, on the other hand, another sandy locality, the destruction is much less, but there is a very strong current, much sand in suspension, and considerable fresh water. The same comparison is true between localities of a muddy nature. Considering two localities, one sandy and one muddy, each with a considerable constant suspension of the material forming the bottoms, the destruction appears to be greater in the sandy locality."[1] The photograph here shown in fig. 1 indicates the great activity and abundance of *T. navalis* at Charlottetown on the south coast of the island.

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[1] Letter to the writer.
[2] Index Molluscorum Groenlandica, 1842, p. 21.
[3] Middeleiser au Gronland, Vol. XXIX, 1905, pp. 289-362.
[4] Meddel. or Gronland, Band 23, 1898, p. 101.

Dr. Martin Murphy who made a special investigation of the distribution of Teredo in Nova Scotia stated that at Sydney Harbour, Cape Breton island, Nova Scotia, *T. navalis* is "as destructive if not more so than at any of the points on our coast."[1] It is abundant along the coasts of Northumberland strait as far west at least as Shediac." How much farther northwest its range extends is not known but probably not much farther. Murphy states that the zone of Teredo's operations on the east coast of Nova Scotia begins about Musquodoboit harbour and extends from there to Whitehaven.[2] He found that it became scarce on the Atlantic coast between the strait of Canso and Halifax. From Halifax southwest along the Nova Scotia coast only traces of Teredo are found and they are neither numerous nor destructive according to Murphy. The writer has not observed Teredo on the Bay of Fundy coast of Nova Scotia and Murphy does not appear to have seen it there. Dr. A. G. Huntsman of the St. Andrews biological station informs the writer that "we obtained it once near one of the Western isles, that is very close to Frye's island, in some sunken timber, and at another time we obtained it from some floating blocks which had, quite evidently, drifted in from outside, probably from the Gulf Stream. It is very probable therefore, that Teredo is not indigenous to the Bay of Fundy, but comes in periodically in floating wood." Professor Ganong reported in 1885 that "a broad and strong tide-dam was completely undermined and destroyed by them (*T. navalis*) within the space of six years,"[3] at Frye's island which is located in the lower and wider part of the bay. This author at a later date however modified this statement by saying that the destruction of Frye's island was the combined work of Teredo and the crustacean *Limnoria lignorum*. It is possible that it was altogether the work of *L. lignorum* as suggested by Verrill. Whiteaves[4] records *T. navalis* from St. John in a ship's hull. But that this record represents exotic specimens appears certain from Professor Ganong's statement that in St. John harbour the Teredo is not only absent but "ships which enter the harbour infested by them are free from them within two days."[5] The testimony of Professor Verrill regarding the occurrence of Teredo in the Bay of Fundy is important because of his intimate knowledge of the Bay of Fundy fauna. He writes that "so far as I remember I did not find *Teredo navalis* in Bay of Fundy during the seven summers I collected there. I think I did find *T. norvegica* a few times in buoys." . . . "At Eastport, Me., I found Laminaria very abundant in piles, fish-weir stakes, etc., but found no Teredo with it there."[6]

At least three factors are probably active in excluding *T. navalis* from the Bay of Fundy. Temperature is doubtless one of these. The area in which Teredo is most abundant is, speaking broadly, essentially the same as that of the isolated colonies of oysters in the waters about the southern shore of the gulf of St. Lawrence. Although the waters in winter are much colder than those of the Bay of Fundy, during the critical period of the spawning time they are warmer. Professor E. W McBride[7] has pointed out how the existence of the oyster in this region depends upon the warming of the water in the shoal areas where alone they can exist during the spawning season. Whiteaves[8] still earlier called attention to the special temperature conditions which afforded on the south side of the gulf of St. Lawrence a congenial environment for a northern colony of the Acadian fauna.

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[1] Murphy, M. On the Ravages of the Teredo Navalis and Limnoria lignorum on Piles and Submerged Timber in Nova Scotia and the means being adopted in other countries to prevent their attack. Proc. and Trans. Nova Scotian Inst. Nat. Sci., Vol. V, Part IV, 1882, pp. 357-376.

[2] Murphy, M. Supplementary Notes on Destroyers of the Submerged Wood of Nova Scotia, Proc. and Trans. N.S. Inst. Sci., Vol. 8, p. 218.

[3] Ganong, W. F. The Economic Mollusca of Acadia, N.B. Nat. Hist. Soc. Bull. No. VII, 1888, p. 111.

[4] Catalogue of Marine Invertebrates of Eastern Canada, 1901, p. 151.

[5] Ganong, W. F. Nat. Hist. Soc. N.Y. Bull 4, p. 89, 1885.

[6] Verrill, A. E. Letter to the author, February 21, 1917.

[7] The Canadian Oyster, Can. Rec. Sci., Vol. IX, 1905, pp. 154-5.

[8] Catalogue of Marine Invertebrata of Eastern Canada, p. 15, Can. Geol. Survey, 1901.

Another factor of importance in controlling the distribution of Teredo is salinity. There appears to be general agreement among shipping men and others familiar with the work of Teredo that any considerable amount of fresh water is fatal to it. On this point, Mr. H. E. Miller states that "where the flow of fresh water is sufficient to have any effect on salinity there is an entire absence of Teredo."[1]

The speedy destruction of *T. navalis* already alluded to which results when it is brought into St. Johns harbour on ships is doubtless due to its inability to withstand brackish water. While this factor would explain its absence from certain bays and estuaries of the Bay of Fundy, neither salinity nor temperature will afford a satisfactory explanation of the general scarcity or absence of Teredo in these waters. If temperature alone were sufficient to bar Teredo from the Bay of Fundy it is difficult to understand how *Illyanassa obsoleta*, one of its congeners in the Acadian colony of the gulf of St. Lawrence should be able to make its way into the shallow bays on the east side of the Bay of Fundy, where I have found it at most points where I have dredged. This species on the opposite side of the Bay of Fundy is rare or absent.[2] One of the peculiarities of *T. navalis* is its aversion to water containing sediments or other impurities in suspension. Various writers have noted this aversion. The waters of the Bay of Fundy are unique in their extreme turbidity: no other waters on the American coast approach them in this respect. This is due to the very high tides, and the correspondingly swift currents in the estuaries which keep the waters near the coast everywhere turbid with sediment. In the Bay of Fundy there is a tidal range of 40 to 60 feet. In Northumberland Strait where Teredo is abundant the tidal range is in the neighbourhood of 10 or 12 feet. The turbidity of the Bay of Fundy waters, particularly in the upper and narrower portion of the Bay, exceeds that of Northumberland strait in somewhat the same proportion as its tides exceed those of the strait. The high turbidity of the estuarine waters of the Bay of Fundy is believed to be chiefly responsible for the general absence or scarcity of Teredo. Barrows[3] has pointed out that a definite correlation exists between the rock boring habit and a location on the open coast. The need of protection from the waves at and near the tide line on open coasts doubtless developed rock boring as a protective measure. This normal open-coast environment which involved exposure to the surf included the normal salinity of the open sea and comparative freedom from silt. The heavily silt laden waters of the upper part of the Bay of Fundy afford the very antithesis of the open coast environment which is normal to rock boring molluscs and in this fact is to be found the explanation of the absence or scarcity of *T. navalis* as well as the rock borers *Zirfaea crispata* and *Petricola pholadiformis* in the Bay of Fundy.

ASSOCIATED SPECIES.

A small crustacean, *Limnoria lignorum*, is associated with Teredo in some parts of its range whose wood-destroying habits are similar to those of Teredo. These two species which are similar only in habits, differ sufficiently in their preference for certain environmental factors to lead them to reach their maximum numbers and development along different parts of the coast line. Their zones of habitat, however, overlap according to Murphy. This author states regarding the areas occupied by these two species that "wooden wharves or bridges along the Bay of Fundy and from there along the Atlantic coast as far as Whitehaven suffer from the Limnoria, while the location of the Teredo is farther east and north." . . . "There is no neutral ground between them. Their domains overlap for a few miles, each of the little borers becoming less abundant as we advance farther into the territory of the other."[4]

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[1] Letter to the writer.
[2] Huntsman, Dr. A. G. Letter to the writer, February 5, 1917.
[3] Barrows, A. L. The Geologic Significance of Fossil Rock-Boring Animals. Bull. Geol. Soc. Amer., Vol. 1917.
[4] Proc. and Trans. N.S. Inst. Sci., Vol. 8, 1895, p. 218.

It is interesting to note that one of the molluscs which is common in Sydney harbour, Cape Breton island, where Teredo has perhaps its maximum abundance, is the rock borer *Zirfaea crispata*. Although reported rarely in the gulf of St. Lawrence by Whiteaves I have found it rather abundant near low-tide mark at North Sydney. Along the Bay of Fundy coast of Nova Scotia, however, I have found no trace of it. Stimpson reports it to be very rare at Grand Manan. Verrill has recorded it at from 8 to 70 fathoms in the Bay of Fundy. But it does not appear to occur in the Bay of Fundy near tide mark, as it does at Sydney. Like Teredo, *Z. crispata* appears to be absent or rare along the Atlantic coast south of the Bay of Fundy. This species, like *T. navalis*, has a wide distribution. On Pacific coast it is reported from Vancouver to San Diego, California, by Carpenter.[1] It is distributed along the European side of the Atlantic from France to northern Norway.[2] Although found in an elevated beach near Christian shoal, Greenland, Jensen states "that *Zirfaea* (*Pholas*) *crispata* no longer lives at Greenland may be regarded as a fact."[3]

Another boring shell which is associated with *T. navalis* around the shores of Prince Edward Island is *Petricola pholadiformis*. The Canadian Geological Survey Museum collections include a specimen of hard red shale with shells of this mollusc from Charlottetown, P.E.I. Concerning this shell, Dr. A. G. Huntsman[4] writes: "*Petricola pholadiformis* is abundant in the lower part of the gulf of St. Lawrence around Prince Edward Island, and occurs boring in the red sandstone there. It has been reported by Verkruzen from St. Marys bay, Nova Scotia, and I have myself dredged it there in 30 fathoms hard clay bottom. I have not found it in the Bay of Fundy proper." Dr. Huntsman's observations on this shell indicates pretty clearly the discontinuous distribution of *T. navalis* and *Z. crispata*, which eliminates them from the fauna of the upper part of the Bay of Fundy.

Teredo navalis belongs in the gulf of St. Lawrence to an isolated faunal group which is confined to Dawson's warm "Acadian bay." The subboreal or syrtensian fauna of the central and northern part of the gulf of St. Lawrence are excluded from this fauna. Concerning this fauna, Dawson[5] wrote: "It thus forms a peculiar and exceptional zoological province" . . . "It affords to the more delicate marine animals a more congenial habitat than they can find in the Bay of Fundy or even on the coast of Maine."

Among the characteristic species which comprise this Northumberland strait colony of the Acadian fauna are the following:—

Ostrea virginica.
Venus mercenaria.
Zirfaea crispata.
Astarte undata.
Crepidula fornicata.
Crepidula plana.
Ilyanassa obsoleta.

Some of these species, as *O. virginica* and *V. mercenaria* are entirely absent from the Bay of Fundy waters. Some others, like *I. obsoleta* are entirely absent on the west coast of the Bay of Fundy but present in the warm shallow inlets on the eastern side of the bay. The Northumberland Strait colony is separated from the northeastern border of the New England zone of the Acadian fauna by the deep basin of the Bay of Fundy and the Atlantic coast waters of northern Nova Scotia. The

1 Dall considers the Pacific Coast form to be a species distinct from *Z. crispata*.
2 Adolf S Jensen, Middeleiser on Groenland, Vol. XXIX, 1905, p. 296.
3 *Ibid.*
4 Letter to the author, February 12, 1917.
5 Dawson, J. Annual address. Can. Nat. Ser. 2, Vol. VII, 1875, p. 2[illegible]-8.

reason for this isolation becomes apparent on examination of a bathymetric chart of the waters of the Maritime Provinces. The whole of Prince Edward island and Northumberland strait lie inside the 20-fathom line, and much of the broad s. .it has a depth of 10 fathoms or less. On the southeastern coast of Nova Scotia, however, the 20-fathom line frequently approaches to within one-half mile of the coast, and there is everywhere a narrow zone of shoal water inside the 100-fathom zone which renders it colder than the broad shallow warm waters of Northumberland strait. It illustrates well the fact that a zone of shallow water if sufficiently close to and unprotected from deep waters may serve as a faunal barrier as effectively as a land barrier. This example of an ' lated colony of the northern New England shallow zone marine fauna surrounded by a sub-boreal fauna is worthy of the attention of palæontologists who are prone to predict land barriers as offering the only possible explanation of faunal differences similar to those described above.

FORMER DISTRIBUTION OF THE NORTHUMBERLAND FAUNA.

There are several bits of evidence which seem to indicate that the present isolation and limited distribution of the colony of comparatively warm-water molluscs now living in the Northumberland strait with which *T. naralis* is associated is of recent origin. *Ostrea virginica*, the most strikingly southern type of this assemblage, appears to have extended as far westward as Montreal at one time during the Pleistocene. Several years ago Sir William Dawson wrote: "I have picked up a loose specimen at Saco which has the appearance of being a fossil specimen from the Leda clay, and Mr. Paisley has sent me specimens from Chaleur bay which are said to have come from Pleistocene beds 16 feet from the surface."[1] More recently Edward Ardley[2] has reported finding Ostrea near Montreal, 9 feet below the surface, associated with *Mya truncata*, *Macoma calcarea*, *Astarte*, *Laurentiana*, and *Saxicava rugosa*. At Cole Harbour on the east coast of Nova Scotia the flukes of anchors bring up numerous dead oyster shells, where the living oyster is unknown.[3]

On the east coast of Nova Scotia, Mr. W. J. Wintemburg of the section of Archæology of the Geological Survey, has found in an old Indian shell heap on Mahone bay, 40 miles southwest of Halifax, shells of *Ostrea virginica* and *Venus mercenaria*. Neither shell is known south-west of Halifax, on the east coast of Nova Scotia at present, but their discovery in the shell heap appears to indicate that they lived in the bay when the shell heap materials were accumulating.

It may be suggested tentatively that the beds containing *O. virginica* at Montreal are synchronous in time with the Don River interglacial beds at Toronto. It is probable that the milder climatic conditions which prevailed during the early part of the Don River interval[4] rendered the temperature of the Atlantic coastal waters of the Maritime Provinces sufficiently mild to give the oyster and its congeners continuous distribution from southern New England to the gulf of St. Lawrence.

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[1] Dawson, J. W. Ice Age in Canada, 1893, p. 242.

[2] Ardley, Edward. "The Occurrence of Ostrea in the Pleistocene Deposits of the Vicinity of Montreal." Ottawa Naturalist, Vol. 26, 1912, p. 67.

[3] Proc. and Trans. N.S., Inst. Nat. Sci. Vol. I, 1863, p. 98.

[4] A. P. Coleman, Int. Cong. Geol., Guide Book, No. 6, 1913, pp. 15-31.

Fig. 2.—Sketch map showing the discontinuous distribution of Teredo around the coasts of Nova Scotia and New Brunswick. The habitat of teredo is shown by black border on coast line. Area where Teredo is absent or rare is shown without black border.