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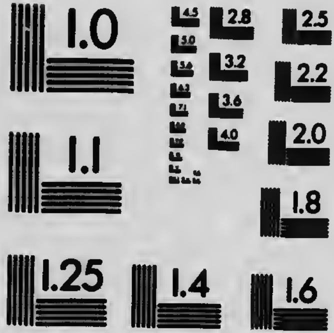

BIOLOGICAL CONTRIBUTIONS
1917-18

THE PEARLY FRESHWATER MUSSELS OF ONTARIO

By J. D. DETWEILER, M.A.

(With one figure in the text.)

OTTAWA
J. DE LABROQUERIE TACHÉ
IMPRIMEUR DE SA TRÈS EXCELLENTE MAJESTÉ LE ROI
1918

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III

THE PEARLY FRESH-WATER MUSSELS OF ONTARIO.

By John D. Detweiler, M.A., St. Andrew's College, Toronto.

(With one figure in the text).

INTRODUCTION.

As a part of the pearly fresh-water mussel investigation, conducted by the Biological Board of Canada, a number of localities, from which promising reports had come in, were visited in August, 1916.

The investigation had a twofold object: first, to determine the abundance, species and commercial value of the mussels; and, second, to ascertain whether it would be advisable to introduce artificial propagation in any Canadian waters.

In order to facilitate the work, the Board decided to send the author to the Fairport Biological Station at Fairport, Iowa, so that he might thoroughly acquaint himself with the problem in hand.

THE UNITED STATES FISHERIES BIOLOGICAL STATION, FAIRPORT, IOWA.

This station was established in 1908, and is the centre of mussel propagation and of the investigation of problems relating thereto.

In the practical propagation of mussels the station serves as headquarters for field operations conducted throughout the Mississippi basin, including the Mississippi river and its tributaries. There may be in the field at one time from two to six field parties operating near the station or at a distance of several hundred miles. For full account see United States Bureau of Fisheries, Document 829, by Dr. Coker.

METHODS AND TECHNIQUE OF ARTIFICIAL PROPAGATION.

The methods of propagation are based upon the peculiar character of the normal course of development of the fresh-water mussels. The young mussels, with rare exceptions, when first liberated from the mother clam must become parasitic upon a fish in order to pass through the next stage of their development. To this end these young mussels—glochidia, as they are called at this stage—attach themselves to the fins or gills of a fish, if the opportunity presents itself. They already have two shells which under proper stimulus work like a small trap, and a very slight wound seems to be produced which after attachment begins at once to heal over. In this way the glochidia become more or less safely encysted and now virtually live the life of parasites, subsisting on the juices of the fish. In the course of two weeks, more or less, having completed their metamorphosis, they break away from their host, drop to the bottom and begin an independent existence.

If not over-infected, the fish seem to suffer no injurious effects. Naturally, the limit of successful infection depends on the size and nature of the fish. Careful investigation of natural and artificial infection has shown that a moderate-sized fish may carry successfully from 1,000 to 2,000 glochidia.

Mussels do not attach themselves indiscriminately, but for each species of mussel there is a limited number of species of fish that may serve as host. In some cases the number that may act as a host is apparently very exclusive. In this connection it may be mentioned that the gar, including at least the two species *L. platostomus* and *L. osseus*, has been found to be practically the only host for one of the most desirable of shells, the Yellow sand-shell *(Lampsilis anodontoides)*.

In actual artificial infection of fish the operation is essentially as follows: The gravid mussels and their suitable fish hosts are placed in a vat or tub containing a requisite amount of water. The mussel is now opened, the marsupial pouch split open along its ventral border and the glochidia are squeezed out into one of the valves of the mussel, which valve also serves as a small water container. The glochidia are then poured into the tub and the water agitated, more or less, so that they will be kept in suspension. From time to time individual fish are caught and gills examined to determine the extent of infection. The optimum amount of infection varies for different sizes and species of fish and also for the condition the fish are in. It is generally accomplished within the limit of 5 to 20 minutes. Over-infection must be guarded against.

Naturally, there cannot be any definite rule as to the number of glochidia to be used with any number of fish, the person in charge must be guided by his experience.

When sufficiently infected, the fish are removed to the river or pond. If development in the gills is to be watched, they may be transferred to crates anchored in the river or pond.

The gravid female clams may generally be found by looking over material where fishermen are at work. Unless the glochidia are sufficiently developed, the operation is useless, for not until then will they open and close their valves when stimulated. The fish are caught with the seine or net.

From this it will be seen that the experimental shell-fish station and the fish-cultural station go hand in hand. In fact it is a point of economy to combine the two.

Although artificial infection would appear to be a comparatively simple operation, a working knowledge of the process has only been obtained as a result of careful and laborious research. As yet only a few species of mussels are thus propagated. The search for natural hosts is still being prosecuted. Experimental work is also being carried on with the object of determining the period of parasitism, and the life history of the young mussel after parasitism, and to lead to such improvements of methods as will make the work most productive of practical results.

It is interesting to note that within a period of two years, young mussels of sufficient size to cut and finish buttons from their shells were reared at the station. These were raised from artificially infected fish, which were kept in floating crates or in earth ponds. They are not only the first mussels to be reared to such a size from artificial infection, but they are the first commercial forms known to have been grown in ponds.

RESULTS OF ARTIFICIAL PROPAGATION.

Although there is no means of definitely checking up the results of artificial propagation on a large scale, where the mussels already exist, yet the extent of the confidence the United States Government has in the undertaking may be shown by the fact that during the last fiscal year, 331,451,490 glochidia, in round numbers, were liberated in the parasitic condition and 424,550 fish were employed in the operations.[1] It is believed that a considerable proportion of the glochidia fall upon unfavourable ground, or fail to reach maturity from other causes. However, since a large number can be liberated at a comparatively small cost, the attempt is deemed justifiable. So far restocking, only, has been attempted, and in general fishermen report that where artificial infection has been carried on, more young shells are found

[1] Annual Report of the Commissioner of Fisheries to the Secretary of Commerce for Fiscal Year ended June 30, 1916.

than ever before. Such encouraging reports have come in from Lake Pepin, Wisconsin; White and Black rivers, Arkansas, and from Fairport, in the vicinity of the station.

THE SOJOURN AT THE STATION.

My sojourn at the station, July 25, August 3, was both highly profitable and very pleasant. Laboratory accommodation and facilities were freely offered. Valuable instruction, demonstrations and advice were gladly given by the Director and his staff. By assisting in the examination of gills for natural infection, and in carrying out artificial infection under the supervision of an experienced man, I was enabled to get a working knowledge of the operations, which would have been quite impossible to obtain otherwise.

The kindness with which I was received, the consideration shown for my wants and comfort, and the pleasure taken in facilitating the object of my visit were beyond my highest anticipations. In this connection I wish to particularly mention Mr. A. Shira, the Director; Mr. Canfield, Superintendent of Fish Culture; Pro[illegible] ark and Dr. Howard, Scientific Assistants; Mr. Gorham, Foreman, and Mr. Son[illegible] hell Expert. The Station has also kindly sent me a set of classified shells, [illegible] facilitating classification here.

ORIGIN OF OUR LARGER MUSSEL FAUNA.

The identity of the mussel fauna of certain Canadian areas with that of the Mississippi waters at once suggests a probable common origin. Our forms no doubt migrated northward on the retreat of the ice cap which is believed to have covered northern North America during the great ice age. As this ice field retreated toward the North West, numerous lakes were formed, now represented by our modern Great Lakes, and these probably all except lake Ontario drained into the Mississippi system. Several of the old drainage courses have been discovered, among them being the ancient Lake Erie outlet, by way of the Wabash into the Mississippi river, and the glacial lake Chicago along the Chicago river. Even lake Superior appears to have had a watercourse into the Mississippi by way of the St. Croix river.[1] Numerous species of mussels no doubt found their way up these waterways into the ancient lakes, and ultimately populated the rivers now flowing into them.

THE GRAND [illegible] R.

As far as I have been able to ascertain, the Grand river contains more mussels of commercial value than any other Ontario waters. This river rises in the township of Melancthon, Dufferin county, within a distance of almost twenty-five miles from Georgian bay. Its source, at an elevation of approximately 1,700 feet above sea-level may be said to mark the highlands of the southwestern Ontario plateau. From its source to its outlet into lake Erie, at Port Maitland, by the river, the distance is 175 miles and the drainage area is approximately 2,500 square miles. The drainage basin is wide at its headwater area, and narrow in the lower flat country, where most of the rivers flow directly into the lake.

The river may be topographically divided into two parts—upper and lower. The upper part extends well into Waterloo County and includes the Conestogo tributary. Here, on the flat headwater table lands, the declivity is small; then for a distance becomes quite steep. At Elora, for example, there is a single drop of over 40 feet where the river enters a limestone gorge. The fall of the lower river is gradual and uniform, and generally becomes flat towards the lake. The following table will show the approximate fall of the whole river.

[1] Pop. Sc. Monthly XLVI No. 2, p. 217. U.S. Geol. Survey Monographs, XXXVIIa.

TABLE I.—DISTANCE from Port Maitland approximate in sea level.

Place.	Mileage.	Difference	Elevation	Difference, Lake Erie Level.
Port Maitland	0	7	573·94	0
Foot dam, Dunnville	7	0	573·94	7·06
Water above dam	7	22	581·00	13·00
York	29	5	594·00	16·00
Foot dam, Caledonia	34	0	610·00	8·00
Top dam, "	34	0	618·00	0
Behind dam, "	34	16	618·00	1·00
At mouth, Fairchild's	50	10	619·00	20·00
Cockshutt Bridge, Brantford	60	4	639	5
Foot lower dam, "	64	0	644·00	14·00
Behind " "	64	3	658·17	17·00
Behind upper dam, "	67	9	675·00	5·00
Below dam, Paris	76	0	680·00	8·00
Behind dam, "	76	7	688·00	114·00
Bridge, Glenmorris	83	7	802·00	51·00
Foot dam, Galt	90	0	853	9·00
Above dam, "	90	30	862·00	156·00
At Bridge, Conestogo	120	15	1018·00	....
At Elora	135	Total head 5	....	Both dams 56 ft.
At Fergus	140	Total head 7	....	" " 38 ft.
At Bridge, Belwood	147	Water level	1367·00	....

In the upper stretches of the river, including its tributaries, extending roughly to the vicinity of Paris, the stream-bed is composed of rocks and course gravel almost throughout, and flows in places over exposed limestone for considerable distances. From Paris southward the bed consists chiefly of:—

TABLE No. 2.

Vicinity—	*Nature of Bed—*
Paris to Brantford	Gravel, sand.
Western Counties canal	Gravel, sand, silt and clay.
Brantford to 12 miles below	Gravel, sand and clay.
To Caledonia	Fine gravel, sand and silt.
Caledonia to York	Gravel, exposed limestone.
York to Dunnville	Fine gravel, sand and silt.
Dunnville to Lake	Largely silt.

This section of the province, in common with all southwestern Ontario, is occupied throughout by comparatively undisturbed limestone and other Silurian and Devonian strata with overlying drift, clays, sands and more recent superficial deposits. The deep deposit of drift material naturally lends itself to erosion, and consequently the river carries considerable quantities of sand and gravel during heavy floods, scouring the channel from the headwaters to below Brantford. Below this point a large area of the river channel with the small declivity produces such a condition that light deposits may take place rather than the scouring of the bed to any extent. All the tributaries also bring down large quantities of material.

DISTRIBUTION OF MUSSELS.

Some years ago when repairs were being made on the feeder canal at Dunnville, shells were found in such abundance that they were picked up by the wagon load. This discovery led to the establishment of a small shelling industry at this point. Last year (1915) 265 tons were shipped from Dunnville, and this year approximately 260 tons.

Two or three years ago, during low water, three men picked up and shipped five or six car-loads from a point about one or one and one-half miles below York, and shipped, it is reported, to Buffalo.

From the lower dam at Brantford to the old power-house at Echo Place, there is what was at one time a barge canal, about 1⅜ miles long. Where cuts were made it is about 50 feet wide and 5 or 6 feet deep. There is still in this system Mohawk lake, three-eighths of a mile wide by one-third mile long and 20 to 30 feet deep in places. Six or seven years ago, when the water was let out for repairs, this was the best place in the immediate vicinity of Brantford for clams, as to size, quantity and variety.

It is said that about ten years ago clams were abundant at a point about half way between Brantford and Paris, called Mulloy's Farm.

I am also informed by the city engineer of Brantford that large numbers of clams are to be found in the vicinity of Bow Park farm.

The fall on the Speed river, a tributary of the Grand, is well utilized, and clams of good size are found behind nearly all the dams which hold back the water over a considerable area of storage basins.[1]

SPECIES AND CHARACTERISTICS OF SHELLS.

I have twice visited the Dunnville area, and found a considerable variety of mussels of commercial value. My investigation there was much facilitated by Mr. H. Clark, who superintends the shell-fishing. In discussing the mussel fauna, only such species as are of commercial value will be considered.

In the following list common names are also given along with the scientific ones:—[2]

Scientific Name.	Common Name.
Lampsilis alata, Say	Pink heel-splitter.
Lampsilis luteola, Lam.	Fat mucket.
Lampsilis recta, Lam.	Black sand-shell.
Lampsilis venticosa, Barnes	Pocketbook.
Obliquaria reflexa, Raf.	Three-horned warty-back.
Quadrula lachrymosa, Lea	Maple leaf.
Quadrula plicata, Say	Blue-point.
Quadrula rubiginosa, Lea	Wabash pig-toe.
Quadrula undulata, Barnes	Three-ridge.

No doubt this list does not contain all the species of commercial value found in this district. I have, in fact, picked up the Fluted-shell, *Symphynota costata*, Raf., a good many miles north of Dunnville, and it likely occurs here. I might in passing mention *Lampsilis gracilis*, Barnes, (Paper shell), a large mussel found here, but which is of no practical value on account of the thinness of its shell. Of the above species those most commonly occurring are *L. alata*, *Q. plicata*, and *Q. undulata*. *L. alata* is a good-sized heavy clam, quite a large number of the shells weighing in the neighbourhood of a pound, but its value is much reduced for button manufacture on account of its usual pink or purple colour. *Q. plicata* and *Q. undulata* are similar in appearance and comprise the chief commercial species of this area. They grow to a large size, and as a rule have a good white lustre. I have in my collection one of the former species weighing 1⅝ pounds, and of the latter, one 1³⁄₃₂ pounds in weight. *L. luteola* is naturally a valuable shell, as its quality is excellent, and it cuts and finishes with least waste. The area around Dunnville, however, does not appear to be particu-

[1] I am indebted to the Hydro-Electric Power Commission office at Brantford for valuable data, and also for reports on clam distribution on the Grand river system.

[2] For nomenclature see Synopsis of Naiades, or pearly fresh water mussels. Proceedings, U.S. National Museum, Vol. XXII, No. 1205, 1900, Charles T. Simpson.

larly favourable to its development. It may perhaps be found more plentifully and of better quality farther up the river in localities more nearly approximating the condition in lakes. The other species are of good quality, but owing to their scarcity in this area, have little commercial importance.

METHODS OF THE DUNVILLE MUSSEL FISHERY.

On my visit to the fishing grounds at Dunnville I found two gangs of men at work on the river above the town; one at a distance of about two miles, and the other some five and one-half miles farther on, near Morgan's island. In the former locality they had a pile of shells which would weigh about five tons. These were fished and shelled in about three and one-half days, by two men and two boys. The men did the fishing, while one boy ran the gasolene launch and the other removed the meat from the shells. The outfit for procuring the clams consists of two scows fastened rigidly together by a plank at each end. The distance between the scows is 4 or 5 feet. The men stand on the stern plank while operating the scoops. The scoop, or dip-net is a dipper-like apparatus with a handle of from 12 to 18 feet in length. The bowl consists of a wire cage about 16 inches in depth, and is attached to a triangular iron frame, 16 inches to a side. Thus the opening of the scoop is triangular and works in the manner of a dredge. To assist in the raking of the beds by this scoop, a number of iron spikes about 3 inches long are fastened to the lower part of the triangular frame, and are set about 3 inches apart. This helps to draw the scoop into the river shown and are set about 3 inches apart. This helps to draw the scoop into the river bed. A line passes from the lower end of the scoop to the forward plank and this is of such a length as to allow the handle to stand vertically against the stern plank. The whole outfit is towed by a gasolene launch. The scows, though varying in size, are about 16 feet long by 3½ feet wide and 14 inches deep. The following diagram may serve to illustrate the fishing outfit in operation:—

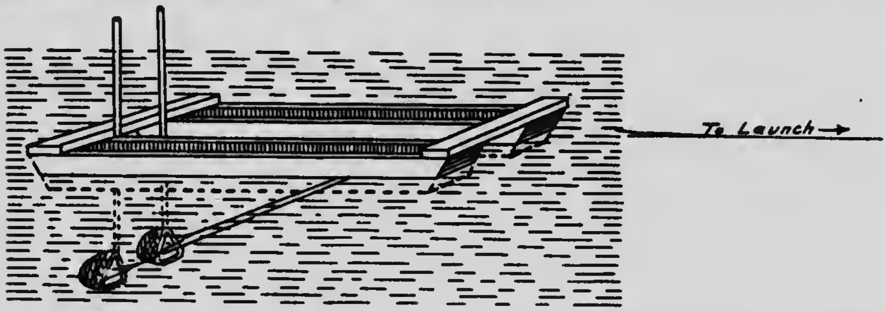

Fig. 1.

In order to remove the mussels from their shells they are subjected to boiling in water. This kills the animal, causes the relaxation of the powerful adductor muscles, which hold the valves together, and permits the easy removal of the muscles from their attachment on the valves. The boiling pans vary in size, but are usually about 6 feet long by 4 feet wide and 8 inches deep.

The bed near Morgan's island is about ½ mile long and 50 feet wide. Here the bottom is gravelly, and although the shells are numerous and of good quality, the number of dead ones is considerably larger than farther down the river, where the bottom is muddy.

Last year the shelling was done below the town at a point a mile north of Port Maitland. Here 265 tons were taken from an area less than ¾ of a mile in length. The bed, I am told, showed no signs of depletion. This year the fishing has been done above the town, and although about 260 tons have been taken, the ground is apparently not as productive as was anticipated.

PEARLS.

A considerable number of pearls and slugs are also found. Some are of very fair size and good quality. In Mr. Clark's opinion, pearling alone would insure a sufficient return for one's labours if followed up. The highest figure yet obtained for a pearl was $75.

RECOMMENDATIONS.

In order to develop to the fullest extent the resources of the river, three main steps are urgent; first, to insure against depletion of the present stock of clams; second, to restock and stock artificially all favourable areas, and third, to improve the river in general by stream regulation. Since the last-mentioned object is so fundamental, I shall deal with it first.

STREAM REGULATION AND SOME OF ITS ADVANTAGES.

Through the progressive removal of the natural physical conditions regulating stream-flow, the floods in the river have for some years been becoming more and more violent and destructive. This increased flood-flow has naturally reduced the volume of low water-flow proportionately. These two conditions, along with the scouring and general damage of river-bed, constitute an increasing menace to mussel life, to fisheries, and to power development along the river.

Some idea of the truth of the above statements may be deduced from a study of the following table of volume of flow at different points. The maximum flow of greatest recent flood is also included. This took place in the spring of 1912.

APPROXIMATE flow in cubic feet per second, period 1914, 1915 and 1916.

Grand River Stations.	Maximum.*	Minimum.*	Mean.	Drainage area in sq. miles.	1912. Estimated Maximum.
Belwood	4,600	3	190	280	10,000
Conestogo	9,300	--	375	550	20,000
Galt	19,000	55	810	1,360	50,000
Glenmorris	23,000	70	900	1,390	.....
Brantford	26,000	100	14,000	2,000	100,000
York	27,000	200	1,550	2,280	.....

* Maximum flows are mean of two gauge heights, taken a.m. and p.m. daily. Minimum flows in some stations consist of leakage from dams.

The danger consequent upon these conditions cannot readily be overestimated. The fact that drainage areas of the Grand River and Great Miami river flowing through Dayton, Ohio, are approximately equal, is sufficient proof. No doubt far-reaching measures for the prevention of dangerous floods will have to be taken in the future. If such measures involve water conservation, the resources of the river will be enormously increased.

In the fall of 1912 the Hydro-electric Power Commission made a reconnaissance survey of the river watershed covering the main stream from Caledonia to the headwaters; also of the larger tributaries from their confluence with the main stream to their headwaters. In this survey, the main object of which was to ascertain what locations, if any, merited examination as sites for storage reservoirs and regulating works, it was found that by the building of nine dams ranging from 30 to 65 feet, storage reservoirs ranging from 450 acres to 3,000 acres in area could be obtained; the aggregate acreage being between ten and eleven thousand. While the above figures are approximations, it is believed to be reasonably certain that the system of storage basins would have an aggregate impounding capacity of not less than five billion cubic feet.[1] It will be evident that the economic advantage accruing from such pools of dependable character cannot be lightly esteemed. In relation to mussel life there would be not only the addition of new flood areas, but also no doubt the improvement of the bed of the streams back of these areas. In these lake-approximations, or river-lakes as they have been called, admirable conditions should be afforded for the particularly valuable shell *L. luteola*. Not only does this shell work up well into buttons but it also lends itself readily to artificial propagation on a commercial basis. Although it is rare to find shells of commercial value in lakes, these river-lakes form a natural habitat for the above mentioned mussel. For example, Lake Peoria, a lake expansion in the Illinois R. forms at present probably the best mussel producing district in the United States. As the young mussels are parasitic on fish in the early stage of their life history, it would of course be necessary to construct effective fish-ways at these dams.

Further, by a study of tables 1 and 2 it will be seen that there are considerable stretches in the river where apparently suitable mussel areas obtain. If mussels are not found here in a survey, the fault will probably be due to flood conditions prohibiting their development in these areas. If such is the case, flow-regulation should overcome the unfavourable environment.

FOOD, A FACTOR OF THE ENVIRONMENT.

In the discussion of favourable environments, due consideration must be given to the food problem. This is doubtless the most important factor in the environment of the mussel, and it is unfortunate that no extensive work has been done along this line. Actual records of stomach contents of fresh-water mussels are rare. Records of analysis show that among the microscopic forms, minute plants, diatomaceæ and other algæ, constitute a part of the food of the mussels. With reference to the food habits, Professor Clark and Dr. Wilson report in part, as follows: "The stomach contents of mussels taken from the main current of the St. Mary's, St. Joseph, and Maumee rivers were rather noteworthy for their paucity of organic material. Through the large mass of muddy matrix filling the stomach were usually scattered a few *Scenedesmus*, various diatoms, and an occasional *Pediastrum* or *Cosmarium*." Dr. Petersen, a Danish ecologist and Director of the Danish Biological Station, has fully demonstrated that the fine dust-like detritus forming a thin top layer of bottom deposits constitutes a large part of the food of the oyster and other mollusks. Dr. Jensen, Petersen's colleague, concluded after investigating the source of the detritus that its origin is primarily from sea plants, broken down until it assumes the fine dust like form. It has been suggested[2] that the "large mass of muddy matrix" referred to by Clark and Wilson was probably the kind of material described by Petersen as "dust-fine detritus." Although large bivalves may not be able to avail themselves of the layer of dust-fine detritus, it is no doubt taken in by water currents. Dr. Jensen also examined the water by centrifuging, and obtained material identical with the top layer of bottom deposits. In Oneida lake the surface of the bottom deposits, in bays and quiet bodies of water, is reported to be of precisely the character described by Dr. Petersen. It would, indeed, be very interesting to establish the relationship between stomach-contents of different species of mussels and the nature of the river bed in which they do, or do not thrive. It would, no doubt, lead to valuable information with regard to the choice and the establishment of new areas for their development. It may be found that the food

[1] Sixth Annual Report, Hydro-Electric Power Commission of Ontario, 1916.

[2] Relation of Mollusks to Fish in Oneida Lake, by Frank Collins Baker, University of Syracuse, N.Y., July, 1916.

supply of the mussels is by no means fully dependent on the free-swimming organisms, and that the favourable localities, discussed above, are largely conducive to the development of the mussel on account of conditions favouring the deposition of the "detritus."

RESTOCKING AND STOCKING.

The restocking of areas where mussels at present exist, and where active fishing is going on, and the stocking of new areas, may be summed up under the head of artificial propagation. As the method pursued in artificial propagation has been described in a general way, we shall now consider its application to the river in question.

Of all mussels so far experimented with, *L. luteola* lends itself most readily to artificial propagation on a commercial basis. It is the species chiefly propagated at present by the United States Government. As time and opportunity prevented my making an extensive survey of Grand River, I cannot state the extent to which this species occurs therein. It is, nevertheless, very generally distributed in Ontario waters, but in order to attain to a size and abundance suitable for commercial value it apparently must have the conditions more or less as described above in "river-lakes." The specimens so far obtained from the river are not of very good quality. This is probably due to unfavourable conditions preventing their optimum development in the areas from which they come. In a commercial appraisal made of some of our shells by Mr. John B. Southall, Shell Expert at the Fairport Station, this particular shell was reported on as follows:[1] "medium size, no discoloration, brittle, third grade[2] and yielding 788, 16—line,[3] gross blanks per ton." In his remarks he further states that they were rather thin and of a steel-coloured nacre and produced blanks that would chip and cleave during the processes of button manufacture.

With regard to this mussel I would suggest a careful examination of the areas lying behind the larger dams with a view to stocking them with the valuable species. Such a survey might include the dams at Dunville, Caledonia, Brantford and Galt on the main river, and also the larger ones on the Speed tributary, where the fall is well utilized, and where clams of good size are said to be found in all such storage basins as hold back water over a considerable area. Behind the dam at Caledonia there is a stretch of practically dead water for twenty miles which might lend itself favourably to the development of this mussel. Here the river bed can be classed as permanent, inasmuch as the usual freshet velocity of the river water above is greatly reduced on reaching this point. At Brantford the old barge canal, described above, containing also Mohawk lake, might prove a very suitable locality for propagation on a small scale. For the purpose of stocking, I would strongly recommend that an attempt be made to introduce the particularly fine *luteolas* of lake Pepin, in the Mississipi, about 30 miles down the river from St. Paul, Minn. In the United States gravid mussels, for purposes of infection, have not been shipped over a much greater distance than 300 miles, but I am informed by the Director of the Fairport Station that they sent a couple of shipments of live mussels from Fairport to New York in the fall of 1916, and that the majority reached their destination in goo[illegible] condition. The distance from lake Pepin to Galt, Ont., would be about 835 miles by[illegible]

Fortunately, this species is not very exclusive in its choice of ho[illegible] [illegible]either is its spawning period of short duration, as is the case with some other commercial mussels. All the Lampsilinæ, in fact, are gravid, more or less, during the whole year

[1] In the report of the appraisal the *luteolas* sent from the Canada Co. Cut and from the Grand River were combined in one report.

[2] In grading the material I sent him, the texture and lustre of the niggerhead (*Q. ebenus*) was taken as the standard.

[3] A line in button measurement is 1/40 of an inch.

but most ripe ones are found from April to July. In my survey in August I found quite a number of gravid *luteolas* but none that on microscopic examination proved to be ripe. This early and extended spawning period would be favourable to successful shipping, before the warm weather comes on. The fish that may serve as carriers belong mainly to the families Centrarchidæ and Percidæ. The species are: *P. sparoides* (speckled bass); *P. annularis* (crappie); *L. pallidus* (blue sunfish); *M. salmoides* (large-mouthed black bass); *M. dolomieu* (small-mouthed black bass); *S. vitreum* (yellow pickerel); *S. Canadense* (sand pickerel); *P. flavescens* (yellow perch) and *R. chrysops* (white bass), all well represented in our waters.

Since the artificial propagation of this mussel is past the experimental stage, I did not consider it advisable to repeat the operation here, on my return from Fairport, particularly as my time was limited and as the localities visited did not appear very favourable. It was kindly suggested at Fairport that gravid mussels be shipped over here for infecting purposes.

Lampsilis recta, though not found plentifully in the Grand river, is a very valuable shell on account of its fine quality. Mr. Southall reported it to be of large size without discoloration, firm and of first grade, making 369, 16—line and 470, 24—line gross blanks per ton. Although the usual run of this species is coloured, those from the Dunnville area seem to be of fine quality. There are, however, some shells which show discoloration. In the fiscal year 1916, 11,288,300 larval mussels of this species were planted at Fairport. The fish which may serve as hosts for artificial propagation are: *L. pallidus* (blue sunfish) and *A. cyanellus* (green sunfish). The former of these species occurs abundantly in some parts of lake Ontario and lake Erie and their tributaries, but the latter has not been reported from Ontario, although it is supposed that it will be found in lake Erie. *P. annularis* (crappie, also called silver bass) has been found naturally infected with this mussel, but it is rare in our waters.[1]

The spawning period of this mussel is similar to that of *Lampsilis luteola* and the river appears to be adapted to this species. The shellers at Dunnville seem to prize this shell above all others.

Lampsilis ventricosa.—This shell is not used very extensively in button manufacture, but it is worked up into novelties. Large shells, however, make buttons of good lustre. Last year 447,000 glochidia were used for infection at Fairport. The species of fish that may serve as hosts in artificial propagation are: *P. annularis*, *L. pallidus*, and *M. salmoides* (large-mouthed black bass). At present it would not appear to be essential to increase the stock of this shell.

The *Quadrula* group is well represented in the Grand, but only two species appear in large quantities—*Q. plicata* and *Q. undulata*. These constitute at present our chief button shells, and the Canadian Pearl Button Company, of Trenton, Ont., which has the sole right to the Dunnville fishery at present, reports that the shells from the Grand compare favourably with those shipped to their plant from the United States. In the commercial appraisal of these two species from the Grand, the report is as follows:—

Species.	Common Name.	Size.	Discolouration.	Texture.	Grade.	No. of gross blanks per ton	
						16-line.	24-line.
Q. plicata[2]	Bluepoint ..	Large ..	None......	Firm.. ...	3rd	142	245
Q. undulata	Three-ridge.	Large ..	None.......	Firm.......	3rd	182	214

[1] Manual of Vertebrates of Ontario, by C. W. Nash, has been consulted for fish distribution in our waters.

[2] The *plicata* from Mud Creek, near Port Franks, were evidently grouped with those of the Grand river, for there is but a single report.

It is noted that they had a very uneven inner surface, causing ... in cutting blanks; the tips of the shells were too thin for buttons. The colour and nacre were not as bright as the usual run of the species found in the Mississippi river; but it nevertheless makes a good button and, with proper care, the material could be worked up with profit. As the Button Company of Trenton works up tons and tons of these shells their statement as to the comparative value of the shells must also receive due consideration.

With regard to the propagation of the former species (*Q. plicata*), Dr. Howard, of Fairport, Iowa, makes the following statement:—

> "Several factors favour the artificial propagation of this species upon a practical scale. It is common and at present one of the most used shells in the button industry. It seems to be a form not narrowly restricted as to hosts, and these are indicated to be among the commonest and most readily obtainable fishes. Although a river form, its habit as a dweller in stiller water and on mud bottom makes it susceptible to propagation or control under conditions readily imitable in artificial lakes or ponds. A continuous water supply is desirable; my observation has been, however, that it will survive rather adverse conditions in this respect. I have collected many live specimens from a slough which had gone dry to the extent that only mud remained. Under these conditions the majority of the pond mussels, *Anodonta corpulenta*, had died. I would cite also the finding of this species accidentally introduced in the parasitic stage into an artificial pond at Fairport, Iowa. The pond had gone dry, and I found a specimen still alive buried in mud barely moist. It is evident, I think, from these observations that the species is hardy, at least as regards some of the more common vicissitudes to which mussels are naturally subjected."[1]

In his experimental work with this species he found that *P. annularis* (crappie), *P. sparoides* (speckled bass), *P. flavescens* (yellow perch), and *L. pallidus* (blue sunfish) were successful carriers. The spawning period is short, being confined chiefly to the month of July. In the last fiscal year 147,000 glochidia of this species were set free in the parasitic stage at Fairport.

At present the safe-guarding of the beds against depletion is more urgent than experimental work in artificial propagation of this species. As experience and equipment are obtained, work on the more difficult *Quadrulas* should no doubt be proceeded with.

I have so far not obtained any data of experimental work done on *Q. undulata*. In general appearance the two forms are similar. In *plicata*, the umbones are more elevated and inflated than in *undulata*.

PROTECTION OF FRESH-WATER MUSSELS.

For the protection of the present mussel beds the following methods may be considered of sufficient importance to merit discussion.[2]

(*a*) A closed season in each year.
(*b*) Restriction as to the methods of fishing.
(*c*) Restriction as to size of mussels retained by fishermen.
(*d*) Closed regions for specified number of years.
(*e*) The imposition of licenses.

[1] Experiments in propagation of Fresh Water Mussels of the Quadrula group. By Dr. A. D. Howard, Bureau of Fisheries, Document No. 801.

[2] See also, Protection of Fresh Water Mussels, by R. E. Coker, Ph.D., Bureau of Fisheries, Document No. 793.

(*a*) The main object to be attained by instituting a closed season for fishing is the protection of the beds during the breeding season. Incidentally, however, a second benefit naturally accompanies the one sought, for by limiting the length of the season, the extent of the fishing will likewise be diminished. Since the chief commercial shells so far shipped are *Quadrula plicata* and *undulata*, and since these species have short periods of gravidity during the summer months, the closed season restriction peculiarly applies to the Grand. But the river also supports other shells of some commercial value which have long breeding seasons, and thus the protection afforded would not be sufficiently wide-reaching. This will be particularly true in case of artificial propagation. Besides, an interruption of fishing operations during a few summer months would seriously interfere with the industry.

(*b*) At present the shells are obtained in one way only, as described above. This method is fortunately not the one against which complaints are generally made. Although it roots up the bed it does not unnecessarily injure the mussels which are too small for commercial purposes, and these should be returned to the water.

(*c*) It is obvious that there is a limit to the size of a shell beneath which it is pure wastefulness to retain it. The fishermen and the button manufacturers lose time in handling the material and the beds are depleted at a much greater rate than they would otherwise be for the same finished product. A limit for every species is, as a rule, impracticable if for no other reason, at least for the fact that the determination of species is sometimes difficult. After a size limit has been decided upon, considerable details will have to be worked out in order to satisfactorily enforce any regulations agreed upon.

(*d*) One of the most immediate protective measures is that of closed areas. This best meet the case of the long breeding species and gives them an opportunity to restock areas, preventing for a term of years the disturbance of gravid clams some of which, when disturbed, discharge the young even though not mature. It also favours the building up of beds by allowing the young clams to establish themselves. The system on which a river or portions of it are to be closed, and the time and duration of areas closed can best be determined by studying field and biological conditions.

(*e*) By the granting of fishing permits as at present on the Grand, no doubt the number of shellers is thereby limited. It is a question, however, just how far the interests of a private person or firm are safeguarded as well as those of the fishing grounds. Although such a fishing permit was granted with a view to stimulating shell prospecting it nevertheless undoubtedly discriminates against other persons or firms. If fishing licenses were granted to resident fishers, thereby eliminating the exploiters or such persons as would not wish to follow up the industry, no doubt good results would be obtained. This would also leave to fishers the opportunity to sell to such firms as paid the best prices.

RIVER AUX SABLES.

In the brief survey of this river for shells I confined my attention chiefly to its lower stretches from which reports of abundance of shells had come in.

The east branch of the river rises a short distance north of Jaffa, in the township of Hibbert, county of Perth. The west branch has its course several miles to the west of this point and the two branches unite near the northern boundary of Stephen township. After a course of about 90 miles the river enters Lake Huron at a point 12 miles, almost due west, from the confluence of the two branches. This U-shaped river is remarkable for its meandering course and for its apparently recent geological history.

Until about 25 years ago the river outlet was not as now, but at a distance of 10 miles further south, near the village of Port Franks. It is an artificial channel one-quarter of a mile in length. Previous to this cut the river made an abrupt turn at Grand Bend when within one-quarter of a mile from the lake, and it flowed almost parallel to the lake shore to the natural outlet, below Port Franks. This deviation of its course was probably due to the sand collecting near its northwesterly banks, forcing the river southwards.

Owing to the frequently occurring floods on the lowlands, the Canada Company, which owns extensive tracks of land in the district, decided to make a cut from the northwestward flowing arm of the river to the southward arm. I shall refer to it as the "Canada Company Cut." It passes through the former lake Burwell and is 3.5 miles in length. Later on, wishing to further improve their lands, the Company put the second cut through at Grand Bend, diverting the river directly into the lake. Although the upper part of the old river channel, between Grand Bend and the lower cut is dry, it still contains a large volume of water. It approximates, in fact, to a narrow lake about 8 miles in length. In places it is a few hundred feet wide and quite deep. The greatest depth at which I took soundings was 17 feet. A fair and apparently continuous current of water flows from it into the main stream at the cut.

Previous to the construction of the artificial channels the river must have been admirably suited to the support of mussel life. Even when the second cut was put in at Grand Bend, and the water let off, I am told by an old resident, Mr. Brenner, that the bed was paved with shells for a considerable distance, many of these being of very large size.

On ascending the river for a few miles from Grand Bend we found large numbers of good-sized clam shells lying on the banks, evidently thrown up in dredging the bed after the cut had been made. In the river we also found quite a number of large mussels of commercial value, the species *Q. undulata* predominating. Other species found were *L. luteola, L. ventricosa,* the large but useless *A. grandis,* and a dead *S. costata.* These mussels were lying about on the bed of the river, in water about a foot deep. With the small amount of water flowing it is difficult to understand how such a quantity of mussels of good size could be maintained. Hand picking here would yield a fair quantity of commercial shells, but since the river is small the supply would soon be exhausted. From Grand Bend we went to Port Franks and crossing the Canada Co. Cut near its western terminus, investigated the water for clams. We found a small bed near the bridge, in shallow water, somewhat protected from the main current. Many of the shells were of large size and also represented quite a variety of species:—*L. recta, L. ventricosa, L. luteola, Q. undulata, Q. rubiginosa;* and *S. costata.* In the commercial appraisal the *luteolas,* sent from this locality, were reported on in conjunction with those from the Grand so that I cannot state precisely what their grade is. We found *L. recta* 6 inches in length and of very fine quality. It was gratifying to find such a collection of shells in an artificial waterway. At Port Franks I was told that the vicinity contained "oceans of shells." As I was not yet acquainted with the river bed, I hoped for good things from it, thinking I might find a suitable area for *L. luteola.*

As stated above, this old channel constitutes a rather long narrow lake from which a small stream of water flows. The bottom of this bed is in many places densely covered with aquatic vegetation, *Chara* predominating. The shores are usually either steep or marshy. Large clams in considerable quantities were found in the shallow water along the shore, where they appear to be somewhat generally distributed. The commonest species is *Q. undulata,* although the Lampsilis group is also represented. I also found one *Q. rubiginosa.* I found it to be practically impossible to determine the extent of the mussel life beyond a short distance from shore, except in very deep parts, and in the upper stretches where quite large barren areas of compact bottom obtain. The small crow-foot bar which I had made for shell prospecting, proved in general absolutely valueless here on account of the dense mat of vegetation covering a large part of the river bed. With a good motor launch and a heavy dredge one might settle the problem, but I do not consider the undertaking worth the trouble or expense. In the deeper parts of the river I was able to use the crow-foot bar but got no shells except dead ones. The river may at one time have contained large quantities of mussels but it seems too stagnant to make good clam beds possible. This condition also would promote the growth of the vegetation now so abundant.

Taking all conditions into consideration this area is of no value for mussel culture. The shells that are there are perhaps only a remnant of a once larger supply and may in time quite disappear. The *L. luteolas* found were fairly large but were badly stained and seemed unhealthy.

In order to make a careful survey of this locality I decided to further investigate the cut and work my way to the east branch of the river to prospect for shells there. The lower end of the cut is quite wide and approximates a small river, but we found no clams with the exception of the bed near the bridge mentioned above. I was able to determine that the upper part of the river's section between the cut and Grand Bend does contain the commercial shell *Q. undulata*. At one place where I went into the water to a depth of four or five feet, I found the bed to consist of fine clay mud quite thickly covered with mussels of this species. They were, however, rather smaller than usual.

This river seems to be peculiar in having a very irregular channel as to width and depth. At places it is shallow and narrow and then again it becomes wide and deep. Shells seem to be quite generally distributed. Even at Ailsa Craig, which must be over 40 miles up the river from the cut, we found the species *Q. undulata*, *L. ventricosa*, *L. luteola* and *Unio gibbosus*. They were not plentiful and of rather small size—too small to be of much value. Good beds of shells may be found on a more thorough investigation. In fact, I am inclined to think that the shells found lying in the shallow places near Grand Bend and in the Canada Company Cut may be washed down from native beds up stream from these points. Conditions in the lower stretches of the river seem to be very favourable to mussel development even with the small flow of water.

I also investigated the river near its mouth at Port Franks, but evidently there are no mussel beds of any importance there. No doubt the great quantities of sand carried down during floods do not permit their development.

It is singular that even small streams in this vicinity support mussels of commercial value. At the mouth of Mud creek, a small stream near Port Franks, I found a number of *Q. undulata* of fairly good size. *Q. rubiginosa* and small *luteolas* were also found here. Shells are reported to be plentiful further up this creek.

In the vicinity of Grand Bend and Port Franks a considerable quantity of shells should be obtainable by hand picking at low water. As the areas are not large, however, the supply would soon be exhausted. Since $20 per ton, delivered at the station, has been offered for them, some enterprising man might find his labours well repaid.

I should advise that the river above the Canada Company Cut be examined with a view to determining its resources in mussel life.

POINT EDWARD.

On my arrival at the bay at Point Edward, near Sarnia, I was again several times assured of the abundance of shells by men about the lumber yards. I obtained a row-boat from the Spanish River Lumber Company, and crossed the North bay (north of the Cleveland lumber tramway) in search of shells. The water here has an average depth of about 3·5 feet and the shells are therefore readily obtained with a dip net or by wading. The sandy bottom is free of weeds with the exception of the margins near the marshy borders. As the water was clear I could readily see the bottom. I found only small shells such as we find in any of our fresh water lakes, for example small worthless *luteolas*. Not having completely satisfied myself I again went over the ground thoroughly the next day in company with Captain Glass of Sarnia, finding very little, howe[illegible]r, of any value whatever. The current flowing through the river here is very strong. It seemed foolish to look so carefully for shells large enough and in sufficient quantity to be of commercial value, but I desired to thoroughly settle the matter. Popular reports concerning shells are generally misleading. This is due to the fact that very few people understand shells from a commercial point of view. With regard to lake Smith, for example, glowing reports of shells were made. One man su[illegible]porting this view was kind enough to get a boat and take me over the ground, but we found only numerous specimens of the common worthless lake clams.

NOTTAWASAGA RIVER.

Mr. Gross, button-manufacturer of Kitchener, Ont., had been informed that large quantities of mussels had been found along the river. He decided to investigate the reports and agreed to my accompanying him. A motor launch was engaged to take us up the river. Several miles up the river we discovered a bed where the mussels were very thick. We needed but to drag the crow-foot bar a short distance when a considerable number of clams would be caught. Shells were also obtained in a similar manner near the mouth of the river, just out from the Riverin hotel. In all, the following species were taken: *L. recta*, *L. ventricosa*, *U. gibbosus*, *S. costata*, and [illegible]*entulus*. In the commercial appraisal the *L. ventricosa* are reported to be small, no discoloration, hard and brittle, fourth grade, and giving 640 16-line gross blanks per ton. Many of the *ventricosa* taken were too small to be of commercial value and had to be thrown back. The shells here are very remarkable for their colour. *Ventricosa* is in fact the only species showing no discoloration. Some of the *recta* are extremely dark purple. Mr. Gross did not consider it worth while to prospect further. Only a small part of the river has thus been surveyed for shells. The prospect here is not at all promising, at any rate not until there is a demand for coloured shells. It would be interesting to determine the cause of discoloration. This is as yet unknown.

The bottom, from which most of the shells came, was gravelly and the water from 5 to 6 feet deep. There is a large flow here and the river should support considerable mussel life.

GENERAL REMARKS.

This investigation was conducted only at selected points on a few of our rivers. The results cannot, therefore, be taken as finally indicative of our mussel resources. The river Thames, for example, draining a large area between the Grand and the Aux Sables, both of which contain commercial shells, has not been touched. It is impossible to know our resources until a more extended survey is made.

A great deal of important information could no doubt be obtained quite economically if further fresh-water mussel investigations were combined with those of the district hydrographers of the Hydro-electric Power Commission of Ontario. They, I believe, cover a great many points along our rivers regularly. In the month of June of last year the staff at Brantford visited the following stations:—

Stations.	*Streams.*
Burford,	Whiteman's Creek,
Onondaga,	Fairchild's Creek,
Brantford,	Grand River,
Canning,	Nith River,
Nicholson,	Nottawasaga River,
Glenmorris,	Grand River,

Stations.	*Streams.*
Galt,	Grand River,
Kimberley,	Beaver River,
Hespeler,	Speed River,
Markdale,	Rocky Saugeen River,
Hornings Mills,	Pine River,
Welland Canal,	Welland River,
Owen Sound,	Sydenham River,
Meaford,	Big Head River,
York,	Grand River,
Severn,	Severn River,
Washago,	Black River,
Port Elgin,	Saugeen River,
Walkerton,	Saugeen River,
Salem,	Irwine,
Belwood, Conestogo and St. Jacobs,	Grand and Conestogo Rivers,
Carnhers,	Speed River,
Kilworth, Fenshaw, Ealing, Kimberley,	Thames, three branches,
Arkona,	Aux Sables River.

In the present year a good many other stations will probably be added. With a car at their disposal the points could be readily reached and often much time saved.

The investigation might also be extended beyond the province of Ontario. The St. John river, N.B., has a large area that may possibly be suitable for mussel culture. Ten miles above Fredericton the Keswick stream enters from the north, and below this point the bed is literally cheked with alluvial islands. At Sugar island, the largest of the group, the river measures 2·5 miles from bank to bank. From Fredericton to Gagetown, a distance of 34 miles, the surrounding land is very low. On the east a mere alluvial flat of great extent separates the waters of the St. John from those of the Jemseg. Some farmers here obtain annually a crop of fish and vgetables.[1] A few of the upper sinuses that branch off to the east from the river might also be suitable for clams. One would not expect to find our larger species there now, but it does not necessarily follow that they would not thrive if introduced. The greatest difficulty would probably be found in procuring the proper species of fish to act as hosts. Here it may be mentioned that in the flood areas of the Mississippi many fish, cut off from the river when the flood subsides, are caught, infected and liberated again. In this way the double purpose of restocking the river with clams and reclaiming the fish is served.

In Manitoba there seems to have been an immigration from the upper waters of the Mississippi region. I am informed that in the *Journal of Conchology* (Leeds, Eng.) IV., pp. 339-346, 1885, there is an interesting account of the Mollusca of Manitoba by R. M. Christy. In a letter received from Dr. Bryant Walker, Detroit, Mich., relative to this article, it is stated that the author (Mr. Christy) lists nineteen species of which six are unidentified. They are: *L. recta, radiata, luteola, borealis,* and *alata. Q. rubiginosa, plicata, lachrymosa,* (and *asperimo*), *undulata* and *heros. Symp. complanata; Stroph. edentula.* Mussels in that region were abundant and especially in the Shell river, which runs into the Assiniboine from the east, about fifty miles above its junction with the Qu'Appelle. Hundreds of dead shells belonging to many species occurred.

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[1] The St. John River. Dr. W. Bailey.

Dr. Walker obtained through the Am. Mus. of Nat. Hist. of N.Y., the following specimens from the Assiniboine: *Lamp. recta, ventricosa, luteola,* and *alata; Sym. complanata; An. grandis* and *Quad. undulata, lachrymosa* and *rubiginosa.*

Many species of commercial mussels are thus represented in our western waters.

Finally, since the maintenance of a mussel supply depends on our fresh-water fish supply, it will be necessary to direct our attention to the greater and more important problem of fish conservation. It is obvious that the two problems go hand in hand, and a station set aside for the latter should be supplemented by a department working in the interests of the former wherever the conditions of the surrounding country demand it. Fish ponds in which the proper species of fish could be reared for the purposes of infection and experiment, might at the same time yield valuable information in the interests of fish-culture. Such information would be of the greatest importance in hastening the day when the farmer would raise his fish as naturally as he raises his poultry. In the near future fresh-water research laboratories, in which our fishery problems are scientifically worked out, will have to be established. But our inland fishery problems can never be satisfactorily solved until the still more basic problem of water conservation is seriously dealt with. Of all the problems relative to national economy none is more likely to engage our serious attention in the future than that of water conservation.