REPORT ON THE STUDY AND APPRAISAL OF MUSSEL RESOURCES IN SELECTED AREAS OF THE UPPER MISSISSIPPI RIVER, 1920-25.*

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I.—INTRODUCTORY.

During the months of August and September, 1925, the U. S. Bureau of Fisheries repeated a study and appraisal of the mussel resources in certain selected areas of the Upper Mississippi River, originally made in July and August, 1920. Both investigations were carried on with reference to legislation on the part of the States of Wisconsin and Minnesota which provided for the closure of certain of these areas for the protection of the fresh water mussels during a period of five years, as well as for areas to remain subject to fishery. The data acquired in 1920 was expected to form a basis for comparing the conditions of that time with those of 1925, after a period of protection.

In 1920, the area studied began at a point about five miles above Red Wing, Minnesota, extending thence through Lake Pepin, and ending nearly 80 miles down stream at La Moille, Minn. In 1925, however, it was arranged that Mr. J. B. Southall, of the Bureau of Fisheries, undertake the bulk of the survey work in Lake Pepin, so as far as the work of the my party was concerned in 1925, the more productive areas of the lake were omitted. The regions studied by Mr. Southall are indicated in the report for 1920 as Areas IV and V. During this investigation, Messrs. R. H. Young, of the Northwestern University Medical School, and Leonard Loeding, of Lake City, Minn., served as assistants.

For a fuller account of the work of 1920 see Final Report on the Study and Appraisal of Mussel Resources in Selected Areas of the Upper Mississippi River. Amer. Mid. Naturalist, Vol. VIII, No. 1, Jan. 1922.

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II.—GENERAL CONDITIONS IN THE AREAS IN 1925.

While in 1920, the river at the time of investigation was in a flood stage of from 2-9 ft., the opposite conditions prevailed in 1925. Government engineers at Fountain City stated that with the exception of a lower stage noted in September, 1923, the stage during which we worked was the lowest since 1864, and varied from 3 ft. above to 3 ft. below zero* during the period between Aug. 15 to Sept. 15. The normal low water stage for the river during August and September is from 2-2½ ft. above zero.

The general effect of this condition was to cause a migration of the mussels toward the channel, which fact had to be taken into account in relocating the stations appraised in 1920. In many cases throughout the region covered by the survey, mussels large and small were observed to be dead and dying as a result of inability to move with the water as it fell. Snags were fully as abundant in the river in 1925 as in 1920. From the clammer's standpoint, the time of the survey in 1925 was not a propitious one. Their contention is that during the normal low water period of August and early September, the mussels burrow in the mud and are not easily taken with the apparatus used by our party, shortly to be described. It is true that some species of mussels burrow in the mud, but such is liable to occur at any season of the year when the substratum does not give sufficient support, and when the mussels are unable to move as the water falls. What may occur to explain the scanty returns secured by clammers in that part of the season is that the clam bed as such is fairly well clammed out by that time, and the remaining shells are so scattered as not to be readily caught under the conditions. Then, when left alone, the beds may gather other shells as they are swept in by the current or migrate from unfavorable conditions elsewhere. At Red Wing, for example, we secured fair hauls of shells from a depth of 2-4 inches of mud. At

* Inspector C. G. Weyl, U. S. Engineers, Fountain City, Wisconsin, furnishes the following information in connection. "The term zero is based on the low water stage of 1864, and the elevation of zero is 644-5 ft. above sea level."

Wabasha, our returns from crow-foot bars were very scanty, yet a young woman had collected a considerable number of shells by hand that same day in the vicinity of our drags. If the clams naturally require a rest at that period of the summer and thus are compelled to go down in the mud, this young woman, as well as our party in the work to be described, would have had dfiiculty in securing returns. Additionally we secured shells at Teepeeota Point through several inches of water weed.

In the report on conditions in 1920 it was indicated that the proportions of mud and sand in the river bottom increase perceptibly in the vicinity of the tributary streams of the region, and it was stated that the Chippewa river was largely responsible for the enormous quantities of sand brought into the areas surveyed by the party below Lake Pepin. Mention was also made of the fact that only through the construction of wing dams, (formerly of stone, but now of stone, brush, or even sand), have the government engineers been able to preserve a navigable channel in the regions surveyed by the party. These dams are designed to catch the sand near midstream, deflecting it toward the shore where it ultimately forms sand bars and islands, but it unfortunately at the same time smothers the valuable clam beds which formerly existed in these regions, with the consequent discouragement of the clamming industry.* While the Engineering Corps is administering what will undoubtedly constitute a cure for the conditions they find, the writer is impelled to point out that coordinated action in reconstructive conservative measures at the present time, may eventually lighten the burden of the separate agencies working upon the various phases of conservation of our natural resources.

The situation and the method of meeting it is described

* According to Inspector C. G. Weyl, U. S. E., Fountain City, Wisconsin, these wing dams are built to a height of 4½ ft. above low water stage, except for 6 miles above Winona, Minn., where they are from 7 to 7½ ft. above. In that portion of the river with which we are concerned, the width of the river from the end of the dams to the opposite shore is 525 ft. Below Winona, however, this width is 625 ft.

from the engineering standpoint in the following letter, dated Oct. 22, 1925, from Major C. F. Williams, U.S.E., District Engineer of the region in which the survey was made:

"Except for the rapids at Rock Island and Keokuk the upper Mississippi River from the Twin Cities to the mouth of the Missouri River is characterized by flat low water slope, gentle current, bed of sand and gravel, and banks from eight to fifteen feet high. The channel consists of alternate pools, ten to twenty feet deep, and shoals which in low water formerly had a depth sometimes as small as one or two feet. The pools occur in the bends while the shoals or bars are in the straight reaches where the channel crosses from one bank to the other, hence their designation as "crossings."

With the completion of the early improvements by the Federal Government in 1877 of the rapids mentioned above, the attention of the engineers was turned to the improvement of the depths over the crossings and since 1878 the scheme now in use has gradually developed.

In a stream with an easily eroded bed such as the Upper Mississippi, the depth is roughly inversely proportional to the width, and on this simple principle is based the scheme of improvement. Back sloughs and secondary channels are closed by low dams of rock and brush, (closing dams), so as to concentrate the entire low water flow in the main channel, and in places of excessive width the main channel is contracted by building dams of similar construction, (wing dams), out from one or both banks. In addition the channel is cleared by snagging and dredging, and banks subject to attack by erosive currents are protected by means of rip rap.

The above improvements were first designed to give a least depth of 4½ feet at low water and later to give 6 feet.

The following table shows the number of wing and closing dams built in the various sections in which you are interested:

OUR AREAS			Total dams completed by the fall of 1920	1925
VII.	(a)	Read's Landing to Minneiska, Minn.	255	257
VIII.	(b)	Minneiska, Minn., to Fountain City, Wis.	130	139
IX.	(c)	Fountain City, Wis., to Winona, Minn.	83	83
X.	(d)	Winona, Minn., to La Moille, Minn.	98	98

As you will notice, very few new dams have been placed in the past five years, nor are many more projected. Our work now consists largely in repairs and extensions to existing dams. Channel dredging of course goes on each year in various localities."

The information in the above letter which has the greatest bearing on the conservation of the mussel resources of this region is that the number of dams has increased in two of the areas surveyed by the party in 1920-1925. These are Area VII—Read's Landings to Minneiska and Area VIII, Minneiska, Minn. to Fountain City, Wis. The possible effects of these improvements upon the mussel beds of those areas will be brought out in the discussion of each of them. In this connection another letter of Major Williams under heading of Sept. 12, 1925, is of interest:

> . . . "You are informed that the works of regulation authorized between Diamond Island and La Moille have not been completed. The length of time necessary for the return of the river to its normal conditions after the construction of works of contraction is a variable depending on numerous conditions, a few of which are stages, conditions of reaches above and below and under improvement, method of improvement, and length of reach under improvement. However two years may be considered on the average. The construction of wing dams is still being carried on below Prescott, Minn. Above Prescott, that work has been suspended indefinitely until the matter of improvement by locks and dams has been settled."

From the second letter it seems evident that two years after the present authorized improvements have been completed, the river bottom may commence to return to conditions under which clams may prosper. No date is indicated as to when the works below Prescott, Minn., will in most probability be completed, and it is difficult to indicate the effect upon the clam beds, if these proposed improvements of the river above Prescott are carried through. Such conditions must necessarily be considered in any plans for the restocking with mussel life of depauperated sections of the river.

III.—STATUS OF THE MUSSEL FISHERIES IN RELATION TO THE PRECEDING.

That stretch of the river about five miles northwest of Red Wing in the vicinity of Diamond Island, and which is known to old-time clammers as the Trenton Bed, was little worked in 1920, but the whole region had been extensively clammed during the past 3-4 years. In 1925, nine rigs were in operation in the Red Wing region. Clammers estimated that 45-50 tons of shells had been produced, selling at $12.50 per ton. The record pearl secured was one of 45 grains. However, the complaint of the clammers was that the region had been extensively polluted by refuse from the St. Paul slaughter houses, rendering clamming operations unattractive. This pollution they observed as early as spring in the year.

Coincident and perhaps correlated with the disappearance of the enormous number of fish formerly seined at the head of Lake Pepin, is the diminution of the mussel resources of the region, Area III. At any rate mussel fishing in this region is considered unprofitable, although mussels are abundant just outside the lake in the river channel. About three and one-half miles from the head of Lake Pepin, we encountered two men and two women picking shells from a depth of about 3½ ft. of water. Although this was in a closed area, they did not have the impression that it was illegal to pick clams by hand. They stated that they could pick 10 bucketfuls per day, which at the rate of 70 bucketfuls to a ton would be worth over $3. One clammer had a 25-grain pearl, another, one of from 45-50 grains. Near Maiden Rock bluff, we also met three clammers, who were operating in the river above Lake Pepin. One reported 15 tons of shells thus far for the season's work, but he had collected only about $10 worth of pearls in two years!

The conditions encountered in the more productive part of Lake Pepin during the summer are best dealt with in the report prepared by J. B. Southall. Our work there was resumed in what will be referred to as Area VI, whose northern boundary is a line drawn between Pepin and King's Coulee. At that time, Aug. 26, we observed a number of rigs lying

idle at Pepin, and observed one rig to put in after a short try for shells. At the foot of Lake Pepin, the low stage of the water permited three clammers to capture mussels with pitchforks. Still another clammer was altruistically removing dead shells with the living ones, on the theory that their presence was harmful to the latter. Nine rigs were observed standing idle at Read's Landing. No pearls were reported to us from this section.

Clammers had been active in the vicinity of Wabasha since 1920, but we saw no rigs. However, the morning we were there as previously noted, a girl picked up seven bucketfuls of commercial shells in that period, but this was exceptional. Above the railroad station at Alma, we observed a pile of about 100 shells, principally niggerheads, pimple backs and pigtoes which had evidently been taken from the water by pitchfork or by hand for the pearls they contained. This was the sole activity in evidence from Read's to Minneiska. So far as our observations go, the few remnants of formerly extensive clam beds at or near Wabasha, Minn., Teepeeota Point, Alma and Fountain City, Wisconsin, and Minneiska, Minn., which we found in 1920, have practically disappeared or are in the process of extinction. The Wabasha bed was clammed out when we studied it this summer, but as it is favorably located, it would probably, if specially protected, regenerate rather rapidly. Dams constructed at Teepeeota Point and the rapidly growing water weed are slowly causing this section of the river to fill in and smother the clams. At Alma, it was found that a government barge laden with stone had sunk in the bed north of the Burlington Station, and that not all this stone had been recovered from the bottom. The clams which may remain in the bed are available only to hand pickers. Further down opposite the center of the town, we found that government engineers had dredged the channel the preceding year, pumping the sand over to the opposite river bank. This utterly destroyed our locality VII-14 of 1920. Exactly the same thing occurred at Fountain City, this summer, while we found that at Minneiska, above Fountain City, additional dams con-

structed in that vicinity, had deposited sand and silt on the remnant of the bed we found there in 1920.

In the report for 1920, it was suggested that the preceding beds, persisting as they had under unfavorable conditions for a number of years, offered fairly suitable conditions for restocking, since the older shells afforded some lodgment for younger ones until they could more readily resist the flow of the current. It is evident however that when such beds are destroyed outright or rendered inaccessible for fishery, that some loss to the mussel resources is occasioned. As first reported in 1920, stream pollution is still extensive at Alma, Fountain City and Minneiska, and if such no longer can effect the local clam beds, it may eventually cause damage to those further down stream, or inhibit the appearance of the older ones through the indestructible nature of the rubbish deposited upon them.

As a general rule, mussels were less numerous in the vicinity of sand bars created by dams in 1925 than in 1920. This of course, may have been the result of the contrasting conditions in the river during the summer and that of 1920. Where, however, sand bars in certain of the sloughs were explored, mussels were found to be quite numerous. In the river sand bars, the following species were most abundant in order: *Fusconaia undata*, *Amblema peruviana*, *Lampsilis ventricosa*, *Lasmigona complanata*, *Obliquaria reflexa*, while in the sloughs they were as follows: *Amblema peruviana*, *Fusconaia undata*, *Lampsilis ventricosa*, *Obovaria olivaria*, *Proptera laevissima*.

In many cases pockets of shells were discovered in the mud and sand accumulating between the dams. Such is represented by our locality VIII-14. At other times they were found in the ponds formed by high water behind the normal shore line. Near Fountain City we met a fish rescue crew from Homer under H. P. Fellgate, which had just removed 2-3,000 game fish under five inches in length from such a pond 175-200 ft. in length, with an average width of from 10-12 ft. With a total of seven people collecting by hand there were removed from this pond in half an hour a total of 374 living

mussels, of which over four-fifths were commercial species of a marketable size. These shells were restored to the river at this point. While their market value may not have justified the efforts of the average clammer, on the other hand the reproductive potentialities of these animals in a region scarce of mussel life is much greater. In 1920, it was recommended that mussels be taken from the sandbars by hand when desirable for commercial purposes, and that when in danger of stranding, these creatures be given the same conserving care as fish receive in the rescue work. Such a recommendation is extended to mussels found trapped in such ponds or anywhere where their life is in danger of curtailment. The two localities stocked with shells in 1920 by the party, which they had removed from the sandbars with the view of rechecking these localities in 1925, were found to be completely covered with sand.

As in 1920, the sloughs of the river below Lake Pepin and above Winona appeared to be richer in mussel life than the main river. Belvedere and Straight Sloughs are still good shell producers, although the latter, as will shortly be described, is in danger of depopulation of its mussel life. West Newton Chute at its upper end is now completely blocked off from the main river by sand pumped in by the engineers and while we found a few shells there, the slough is slowly filling up. The party made one of the best hauls of the trip at the lower end of the slough, (Loc. VII.-22) but here the bottom is principally mud, and it can not be long before the slough becomes inaccessible from the rivers for clammers, and ultimately only the more unprofitable, mud dwelling shells will survive. The low stages of the river prevented the use of crowfoot bars in these sloughs, and all records of them for 1925 are of the party picking by hand.

We entered the Straight Slough overland, from the vicinity of Winona, as the stage in the water was so low that we were unable to enter it with the boat. On the way we observed one clammer picking by hand in a branch of Crooked Slough and saw a pile of about two tons of commercial shells. Due to the low water stage, Crooked Slough was also crossed

by land, and we saw hundreds of dead shells where they had perished *in situ* as a result of the drought. Reports had reached us concerning the extent of the clamming operations during the summer in this region, and while some were obviously exaggerated, it is perfectly true that the low water deprived the mussels of some of their natural protection, and permitted far more of them to be taken than would be the case under ordinary circumstances. As will be more fully discussed later, young children were engaged in the work. Of course such a period of drouth but rarely occurs, but there is suggested immediately a legal limitation to the depth of water from which living clams may be taken under such conditions. Lack of such is conducive to the violation of the protective laws as will be clearly shown.

The party re-explored Straight Slough in a row-boat to the sites of the localities studied in 1920. Four men, and in some cases their families, were reported to be clamming in Straight Slough, which had more dead shells in its water and along its banks and more living young shells than any other section of the Mississippi studied. At Mr. Kline's place there were observed 3 tons of shells collected in two weeks' time from an inlet near his home, five-eighths of a mile long and 30 ft. wide. The pile contained yellow sand shells, three ridges, white heel splitters, bull heads, long johns, pink heel splitters, and spikes. The four children of this family picked by hand on the father's license. The family had collected only a few slugs, and expected to receive only $25 per ton for their shells under the opportunistic methods adopted by the shell buyers. The Klines reported an abundance of shells in Bartlett's Lake nearby. At Mr. McNally's place, a ton of shells had been collected by three children of the family. He reported one pearl selling for $25. In his pile we saw a dead specimen of *Quadrula granifera*, the first seen on the trip, while in the slough we saw our first specimen in 1925 of the bullhead, *Pleurobema aesopus*.

Above our locality IX-22 is located Sandy Creek which at high water connects Crooked Slough and Straight Slough. It was very nearly dry except at its mouth, and at about 50

yards back from the latter the former bottom was thickly covered with dead shells extending back about 100 yards in the channel. These shells gave indication of being buried by the sand or killed by some previous low water stage, rather than being taken and cut open for pearls. They were without exception, have grade shells for commercial purposes, and might have been conserved by rescue work.

As in 1920, we found that portions of Straight Slough and Belvedere Slough appeared to be favorable to the growth of shells as judged by the number of juvenile shells occurring here. With the exception of occasional small piles of shells evidently cut open by pearl hunters, the mussel resources of Belvedere Slough have not attracted clammers. As these sloughs are fed to some extent by local drainage and at places have a fairly rapid current, it is evident that even if they are filling up they will for some years offer a congenial environment to mussels, and may be a convenient source of material for propagation work below Lake Pepin. Additionally they present favorable places for restocking. When it is recalled that they are also the principal spawning grounds of fish from the river, it would seem perfectly clear that special legislation or administrative action in protecting them from exploitation is justified. Such action was taken in the case of Straight Slough during the past year when it was closed to seining by the Game Commissioner of the State of Minnesota. Under the conditions of low water described such an action would be justified for the protection against over-fishing of fresh water mussels.

It is worthy of note that in the vicinity of Winona there exist the most extensive clam beds occurring in the river between that city and Lake Pepin. It is remarkable also that the sand bars of the vicinity yield good returns on picking with the greatest abundance of juvenile shells. Presumably in this region the bottom conditions are favorable toward forming a clam bed, but it is the impression of the writer that further up the river there exist equally good places but with few or no shells. While mussels are thinly scattered in the river above Winona, they are still comparatively plentiful in

the parallel Straight Slough. Possibly the bed at Winona is so favorably located that it has but little trouble in keeping up a fair degree of regeneration, but the presence of many shells, mature and juvenile, on the sand bars of the vicinity suggests that the effects of the current are such that the bed may receive many shells from up stream. Now as the most bountiful and immediate supply of shells is in Straight Slough which opens into the Mississippi about half a mile above Winona, there is a strong probability that many shells find their way into the Mississippi at this point. If experiment shows this to be the case, we have an additional argument for the application of more stringent protective laws to the mussels of the sloughs.

Near Homer, Minn., below Winona, we encountered 3 clammers "frogging it," as they term picking by hand and the best information had was that six or eight clammers had worked the beds in the vicinity of Wniona that summer. Clamming in this region was reported to have increased considerably in the past three years.

Reasons, then, commonly assigned in 1920 within the regions surveyed for the depletion of the mussel resources, and the consequent decline of the clamming industry are still found to hold in 1925, viz.:

1. The smothering of the mussel beds by sand deflected by the dams as already indicated. Additionally, it may be stated that the increased velocity of current thereby insured has the probable effect of sweeping juveniles just dropped from fish, or more mature mussels, long distances down stream, or to lodge them upon sand bars where they may be covered up unless speedily rescued.

2. Destructive fishing methods such as taking very young shells, deliberately clamming out beds and fishing with the shoulder rake are also responsible. Favorable sentiment toward respecting the protective laws is characteristic of the professional clammer, but still a great deal of damage is done by the occasional or less experienced fishermen who in many cases submit immature shells to the buyers. According to the clammers, the latter make the situation worse by accept-

ing them. Under this category there may also be included the cases mentioned where more than one individual clams on a single license, and where conditions of extremely low water permit the clams to be picked in greater numbers than under ordinary circumstances.

3. The growth of formerly extensive clam beds near communities situated along the river has been inhibited by the pernicious practice of dumping rubbish of somewhat indestructible nature in the river at these localities. While State laws are also clear on these points the enforcement of them seems largely a matter of local sentiment. The *hinterland* of the regions involved is still so productive that it seems difficult to arouse the people to the relation of this practice to the conservation of all aquatic resources.

To these may be added a fourth reason due to the lack of a correlating factor between different agencies of the government working for conservation—that of the destruction of clam beds by channel dredging activities. The writer at present finds it impossible to say whether the clams now destroyed by this practice could be conserved by any ready means.

When the preceding data on general conditions in the areas and the status of the mussel fisheries are considered in entirety, it becomes evident that before the mussel resources of these areas can be improved, some practicable basis must be determined from which measures looking forward to their fullest protection and conservation can be inaugurated. A study of this nature then will show when and where this is likely to be obtained by the enaction of protective laws, and when, where, and why such are likely to fail in bringing results as fast as might be anticipated. Such data is also apt to be useful for the future guidance of this branch of conservation activities. Hence the reason for this study and appraisal of mussel resources in certain areas of Wisconsin and Minnesota, the region in which a large percentage of the commercial shells are produced.

IV.—METHODS.

(a.) Description of Outfit for Collection of Shells.

The work was approached from the standpoint of the mussel fisherman, a bar and crowfoot outfit, (john boat), being used to collect the shells. The outfit was towed from place to place by a Government launch. In the areas in and above Lake Pepin, (I-VI. inc,) 100 hooks were attached to each of the 16-ft. bars. Below Lake Pepin, starting at Read's Landing, (areas VII-X inclusive), the river bottom is heavily infested with snags, so the bars were shortened to 10 ft. with a consequent reduction in the number of hooks on each to 75. In the first named areas, the data forming the basis of the conclusions presented, comprises the results of three trials of the same length of drag with the bars, (300 ft.), at each of the localities indicated. In the remaining areas, the number of drags was increased from three to four, to compensate for the reduction in the number of hooks, but otherwise the procedure was the same. Additionally, the john boat had at its bow, a hand windlass bearing three hundred feet of five-eighths inch line, to the free end of which an anchor was attached. In proceeding from one locality to another, the windlass was locked, and the boat towed by a separate piece of rope.

(b). Collecting Mussels for Study and Appraisal.

When it was decided to appraise a particular locality, a starting point was determined by methods shortly to be described, the windlass and the tow-line were released, and the launch going ahead unreeled the 300 ft. of line into the water until it was very nearly taut, when the operator of the launch dropped the anchor at the free end. For the purpose of temporarily anchoring the john-boat while the line was being payed out, one of the bars, usually that one to be placed to the rear, was at favorable opportunity, dropped into the water in such a way that it lay at right angles with the shore, and dragged parallel to it. When it had touched bottom, it was seuured into position by means of props and by knotting its rope around one of the uprights. As soon thereafter as the boat had swung into a favorable position to render less likely

the entangling of the hooks of the bars, the remaining bar was dropped and secured likewise.

After the anchor was dropped and the bars properly spread, one of the two operators in the john boat windlassed the latter by slow and steady turns up to the point where the anchor had been dropped, observing from time to time the relative apparent motion of the shore line to make certain that snagging or fouling of the bars was not causing the john boat to pull the anchor towards it in the meantime. When such was found to be the case, the bars were pulled up, the catch discarded and a new trial made. When the john boat had been properly windlassed up to the anchor, the latter and the bars were pulled up, the mussels taken off the hooks and thrown into a tub. The launch then towed the john boat back to the original starting place, when this procedure was repeated twice again for each locality, the mussels obtained from the 3 trials being counted together. Dead shells obtained were recorded separately. Other biological spceimens obtained through this procedure were sent to various specialists for identification, and the results of their work which is hereby gratefully acknowledged, is comprised in the notes on the various areas. The special dredge carried by the party in 1920 to determine the conditions on the bottom of the river, and for the purpose of securing material for a special study of juvenile mussels was not used in 1925, as there seemed to be no special reason for obtaining additional data of this type.

(c). Determination of Localities.

The course of the river was followed by means of a set of maps of the river published by the Mississippi River Commission and by a copy of the current edition of the light list for the 13th Lighthouse District as in use by navigators on the river in 1920 and 1925. Comparison of these indicated the extent to which the Government Day marks used as land marks in the investigation had changed in position during the past five years. The position of each locality surveyed is indicated on the maps used, which are now in possession of the U. S. Biological Station, Fairport, Iowa. On these maps, the

localities are numbered according to area, and to the order in which they were examined. Thus I-3 on the map indicates Area I and the third locality in it. References to the data to follow should be similarly understood. As previously indicated, only the three best localities in each area are reported upon.

It was not found practicable to draw into the maps these localities on an exact scale. The markings largely indicate the relative position of the locality with regard to the shore line at the time, the more absolute one being obtained by reference to the descriptive material given in connection with the marking on the maps. The more absolute data concerning the position of the locality was obtained by reference to some object or formation along the shore which seemed of a fairly permanent nature, such as the Government Lights or Day Marks or other improvements along the river, ravines, elevation of adjacent hills, clumps of bushes, trestles, etc. The first two types of reference points were not used when anything better could be observed. The light list referred to gives the distance of these marks and lights from more accurately defined points such as bridges, etc. As data furnished by local clammers was sometimes found to be misleading, positions of productive shell beds were frequently determined by a trial drag with a single bar at varying distances from the shore, when, after encouraging results, the three consecutive drags with both bars were attempted. All beds of shells of fair extent which the party encountered are also indicated upon the maps mentioned.

Once the reference point was established, the distance across the water of the starting point of the drag from this was estimated independently by the three members of the party. The average taken of these distances is that one given in the descriptive material of the localities and in case of great variation in estimate, the more probable distance was verified by measurement of other points on the map within sight and by the making of comparisons. A map case of the type used in the U. S. Army provided with compass and transparent water proof cover was found to be a convenient carrier for the maps in the field, and on it the localities could be promptly

located. A spring back aluminum binder was found to be serviceably adaptable for holding the mussel survey sheets used for the recording of data. It should be born in mind, however, that as the larger portion of the work was accomplished under conditions of low water in 1925, it was difficult to accurately estimate the position of the normal shore line, and the distances given are those of the position of the outfit from the nearest land above water at the time.

V.—LIST OF SPECIES COLLECTED.

The following list embraces those species of mussels collected within the areas surveyed.* Besides indicating the common name by which mussels are known to clammers, the older scientific names of Simpson's Descriptive Catalogue of the Naiades are given, and their equivalent in the recent Pilsbry-Ortman-Walker nomenclature, which follows more closely the rules of modern taxonomy so far as they concern the mussels.

* For a complete list of the Naiades of the Upper Mississippi Drainage see Grier, N. M., *Nautilus*, 36.

COMMON NAME	SCIENTIFIC NAME	
Commercial Species	*After Simpson*	*After Pilsbry, Ortmann & Walker*
Niggerhead	Quadrula ebenus	Fusconaia ebena (Lea.)
Niggerhead	Quadrula solida	Pleurobema catillus (Con.)
Hickory Nut	Obovaria ellipsis	Obovaria olivaria (Raf.)
Pimple Back	Quadrula pustulosa	Quadrula pustulosa (Lea.)
Maple Leaf	Quadrula lachrymosa	Quadrula quadrula (Raf.)
Monkey Face	Quadrula metanevra	Quadrula metanevra (Raf.)
Purple Pimple Back	Quadrula tuberculata	Rotundaria granifera (Lea.)
Three Horn Warty Back	Obliquaria reflexa	Obliquaria reflexa (Raf.)
Pig Toe	Quadrula undata	Fusconaia undata (Barnes)
Blue-Point	Quadrula plicata	Amblema peruviana (Lam.)
Three-Ridge	Quadrula undulata	Amblema costata (Raf.)
Wash Board	Quadrula heros	Megalonaias heros (Say.)
Buck Horn	Tritogonia tuberculata	Quadrula verrucosa (Raf.)
Mucket	Lampsilis ligamentina	Actinonais carinata (Barnes)
Higgin's Eye	Lampsilis higginsii	Lampsilis higginsii (Lea.)
Lake Pepin Mucket	Lampsilis luteola	Lampsilis siliquoidea (Barnes)
Butterfly	Plagiola securis	Plagiola lineolata (Raf.)
Deer Toe	Plagiola elegans	Amygdalonais truncata (Raf.)
Pocket Book	Lampsilis ventricosa	Lampsilis ventricosa (Barnes)
Yellow Sand Shell	Lampsilis anodontoides	Lampsilis anodontoides (Lea.)
Slough Sand Shell	Lampsilis fallaciosa	Lampsilis fallaciosa (Smith.)
Black Sand Shell	Lampsilis recta	Eurynia recta (Lam.)

Bull Head	Pleurobema aesopus	Plethobasus cyphyus (Raf.)
(No Common Name)	Lampsilis subrostrata	Eurynia subrostrata (Say.)
White Heel Splitter	Symphynota complanata	Lasmigona complanata (Barnes)
Fluted Shell	Symphynota costata	Lasmigona costata (Raf.)
Pink Heel Splitter	Lampsilis alata	Prostera alata (Say.)
Rock Pocket Book	Arcidens confragosus	Arcidens confragosus (Say.)
Elephant Ear	Unio crassidens	Elliptio niger (Raf.)
Spike	Unio gibbosus	Elliptio dilatatus (Raf.)
Ohio River Pig Toe (?)	Pleurobema pyramidatus	Pleurobema pyramidatum (Lam.)
Elk Toe	Alasmidonta marginata	Alasmidonta marginata (Say.)
Sugar Spoon	Plagiola donaciformis	Amygdalonaias donaciformis (Lea.)

NON-COMMERCIAL SPECIES

Floater	Anodonta grandis	Anodonta grandis (Say.)
Slop Bucket	Anodonta corpulenta	Anodonta corpulenta (Cooper)
Paper Shell	Anodonta imbecillis	Anodonta imbecillis (Say.)
Squaw Foot	Strophitus edentulus	Strophitus edentulus (Say.)
Paper Shell	Lampsilis gracilis	Leptodea fragilis (Raf.)
Paper Shell	Lampsilis laevissima	Proptera laevissima (Lea.)
Snuff Box	Lampsilis parva	Carunculina parva (Barnes.)
(No common name)	Truncilla triquetra	Truncilla triquetra (Raf.)

VI.—RESULTS AND OBSERVATIONS.

These include data compiled upon the absolute and relative abundance of each species of mussel found in the areas appraised, together with such geographical or other information likely to be of use in expediting the rechecking of these results after a period of protection, or which might have a bearing upon propagation experiments. The number of shells of each species collected in each locality is given under the heading of the latter, and the percentage of this in the total catch in the locality is indicated. The average of the three percentages thus obtained for each species in each area is taken to represent the relative abundance of that species in the area. An asterisk indicates that the species was found to be less than 1% in the area and locality involved. A blank space opposite the name of a species indicates that living shells were not collected in either the area or the localities of it.

AREA I.

Boundaries, lower half of Diamond Island, Miss. R. to Red Wing, Minn., at high bridge. Status, open to fishery in 1920, closed in 1925. Length in linear miles 4.2. Physical conditions, 1920, estimated 7-8 ft. high water. Current, about 5 miles per hour. Bottom mostly gravel and sand. Middle sections of area infested with snags. Water at least 5 ft. below normal stage in 1925.

Localities Reported Upon. (Ref. Maps.)

1-1. Starting point of drags Government Day Mark 958-n near center of Diamond Island, 25 ft. from shore on Minnesota side of channel. July 7, 1920. Aug. 19, 1925, bottom covered with decaying organic matter. Drags 5, 15, 25 ft. from the shore.

1-2. Starting point of drags Government Day Mark 958-k, (above island 23), on Wisconsin side of channel, 30 ft. from shore, about one-half mile down stream from the preceding locality, July 7, 1920. Aug. 19, 1925, bottom covered with decaying organic matter. Drags 15, 25, 50 ft. from shore.

1-6. Starting point of drags 300 ft. upstream from Government Day Mark 958-*g* across the mouth of a slough about one mile above Red Wing on the Minnesota side, 50 ft. from the mouth of the slough. July 9, 1920. Aug. 20, 1925, slough largely filled up, bottom muddy, water weeds growing out from the shore. Drags 10, 25, 40 ft. from the shore.

Notes on Area I.

Rotundaria granifera, reported absent from this area in 1920 was not collected by us here in 1925 if it has reappeared, while our northernmost record for *Arcidens confragosus* was obtained near Trenton village.

A marked decline during the past five years was noted in the absolute abundance of mussels in this area,* which is not surprising in view of the fact that the region was extensively clammed during the past few years, and has also been subject to extensive stream pollution. As regards the relative abundance of shells in this area it was observed for commercial species that there was an appreciable increase in the number of pimple backs, pigtoes, blue points, buckhorns, pocketbooks and a decrease in hickory nuts, river muckets, Lake Pepin muckets. This decrease is seen to concern the more valuable shells for button making. Increases among the non-commercial shells were evident in the squaw foot and one of the paper shells *(Proptera lævissima).* From the fact that the clammers discard many of the non-commercial species upon catching, it might be thought that these species would be favored to the extent that they would become dominating species in an extensively clammed area. As a matter of fact decided decreases in their absolute and relative abundance were noted over 1920. According to the calculated data of the table they made up less of the clam bed in 1925 than they did in 1920. Further study may show the extent to which the thin, non-commercial shells through complicated relation-

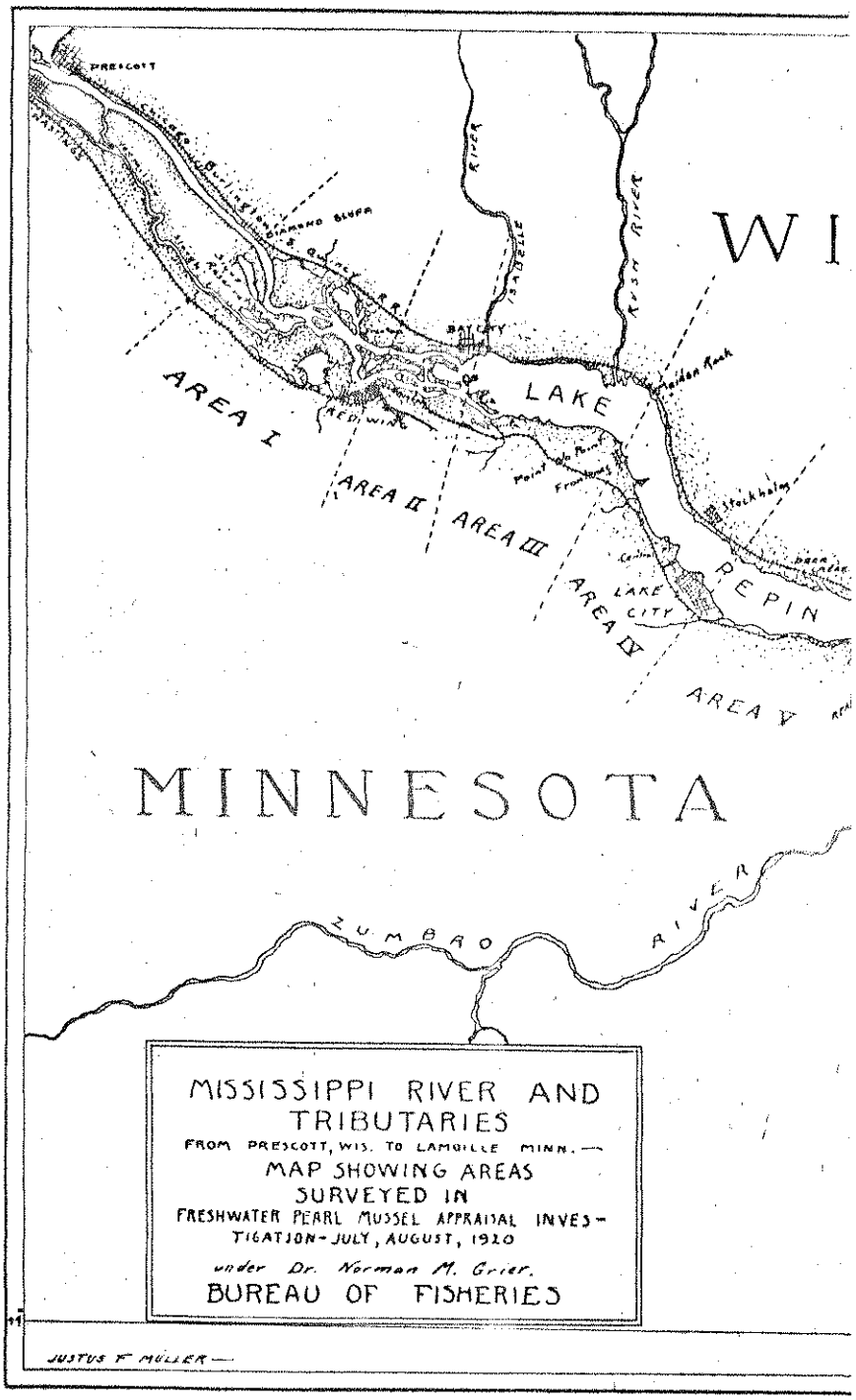
* EDITOR'S NOTE: As it has been found impracticable to reproduce with the manuscript the statistical tables originally accompanying it, those interested further may have access to these tables by applying to Mr. T. K. Chamberlain, Director, U. S. Biological Station, Fairport, Iowa.

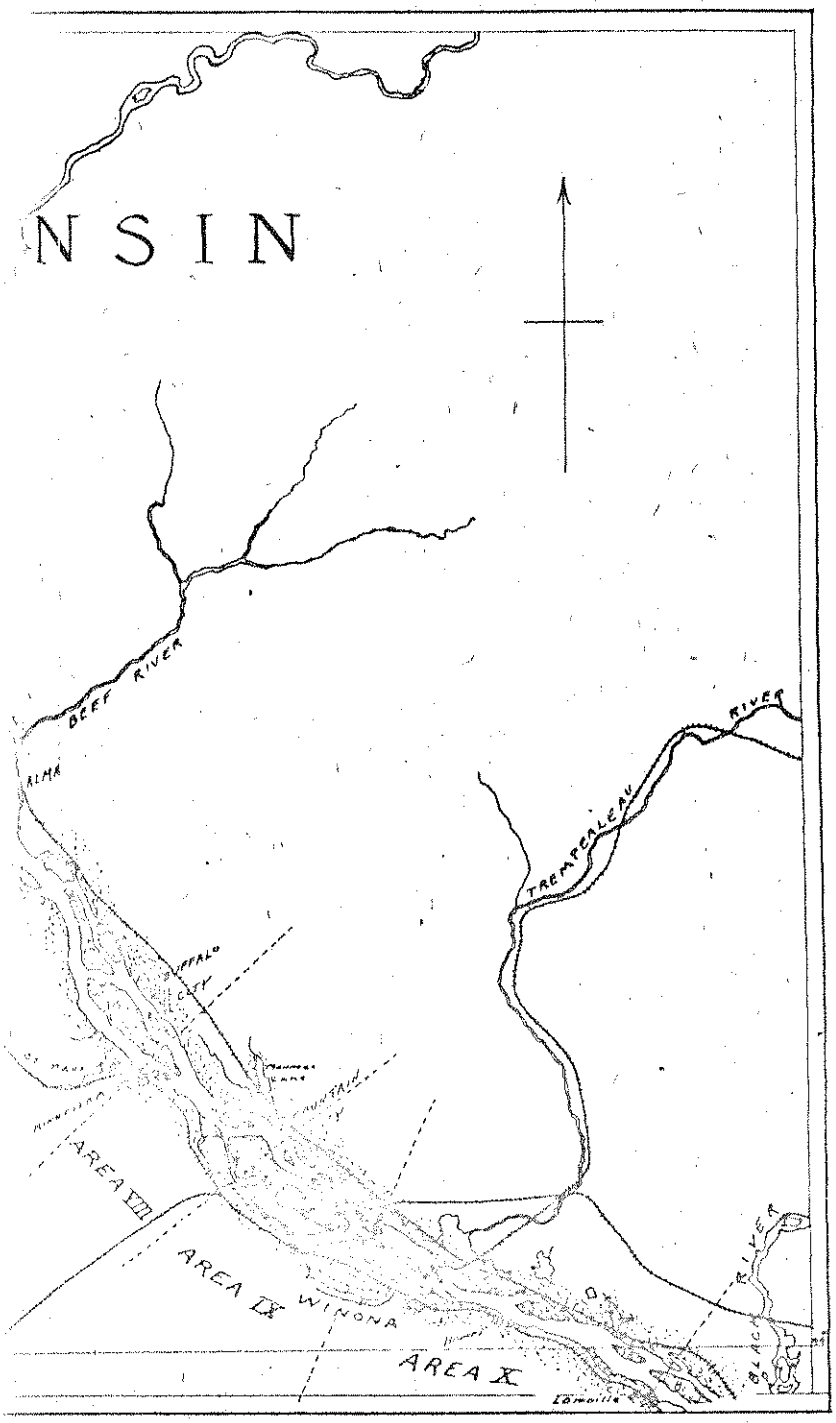
ships of one kind or another are active agents for the welfare of their thicker shelled brethren, beyond merely representing an adaptation enabling them to survive the changing conditions of the river bottom.

In the relative abundance of species represented, the area is distinctly a "pocketbook" area, the pink heel splitters, blue points and pigtoes being next in abundance; in general the thinner type of species seems most highly favored. The writer was impressed by the almost uniform absence of juveniles in this area in 1925, their place in the river bottom society being taken perhaps by the extremely common Sphaeridae which were brought into the boat by the hundreds on the windlass line. The principal species represented was *Sphaerium stamineum* Conrad. Many dead and dying shells were observed along the banks in this area.

Commencing about a mile above Red Wing, water weeds were rather common in this area and included species of *Philotria*, (*Elodea*), *Potamogeton crispus* and *americanus*, *Zannichelia palustris*, *Ruppia occidentalis*, *Ceratophyllum demersum*, and *Vallisneria spiralis*. Leeches collected crawling about on the mussel shells were pronounced by Professor J. Percy Moore of the Zoological Laboratory, University of Pennsylvania, to be *Glossosisphonia complanata*, *Helobdella stagnal's*, and *Erpobdella stagnalis*. Aquatic insects and crustacea similarly collected were determined by Professor J. G. Needham of Cornell University to be the larvae of the damsel flies, *Ischnura verticalis*, *Enallagma* sp. and the orchestid crustacean, *Hyalella Knickerbockeri* Bate.

(To be continued.)


PRESCOTT
DIAMOND BLUFF
RUSH RIVER
LAKE
AREA I
AREA II
AREA III
AREA IV
AREA V
REPIN
LAKE CITY
MINNESOTA
ZUMBRO
RIVER
MISSISSIPPI RIVER AND TRIBUTARIES
FROM PRESCOTT, WIS. TO LAMOILLE MINN.—
MAP SHOWING AREAS SURVEYED IN
FRESHWATER PEARL MUSSEL APPRAISAL INVESTIGATION - JULY, AUGUST, 1920
under Dr. Norman M. Grier.
BUREAU OF FISHERIES
JUSTUS F. MULLER—


NSIN
BEEF RIVER
ALMA
TREMPEALEAU
RIVER
BUFFALO
CITY
AREA VIII
AREA IX
WINONA
AREA X
BLACK
RIVER