XVIII. THE FRESH-WATER MUSSEL FAUNA OF EASTERN OKLAHOMA

F. B. ISELY

Prefatory Note

The accompanying paper was originally prepared by the author for publication by the United States Bureau of Fisheries and accepted by the editorial board for that purpose. However, the war intervened and the program of publication of the Bureau was curtailed, and the paper was not resubmitted. On account of the great local value of the work it was thought desirable to publish it in the present volume of the Proceedings of the Oklahoma Academy of Science. As a considerable amount of time had elapsed since the preparation of the paper, and since mussel nomenclature had undergone a marked development during the intervening years the editorial committee submitted the list of

*The popular name, Coyote, is incorrect when applied to C. frustror Woodhouse, for this animal is no longer recognized by mammalogists as a Coyote. Although it is more closely related to the Old World Jackal than to the true wolf, it is called Woodhouse's Wolf.—E. D. C.

species to Dr. F. C. Baker of the Museum of Natural History of the University of Illinois. The list below gives, in alphabetical order, the synonyms indicated by Dr. Baker for the species mentioned in the body of the paper. These names are also given after the names used by Professor Isely in the Discussion of Species. No changes have been made in the body of the paper.

Lampsilis leptodon—Leptodea leptodon
Lampsilis laevissima—Proptera laevissima
Lampsilis gracilis—Leptodea fragilis (Raf.)
Lampsilis purpurata—Proptera purpurata
Lampsilis corvunculus—Carunculina corvuncla
Lampsilis parva—Carunculina parva
Lampsilis subrostrata—Ligumia subrostrata
Lampsilis recta—Ligumia recta latissima
Lampsilis ligamentina—Actinonaia carinata (Barnes)
Lampsilis hydiana—Lampsilis siliquoidea (Barnes)
Lampsilis capax—Proptera capax
Plagiola securis—Plagiola lineolata Raf.
Plagiola elegans—Truncilla truncata Raf.
Plagiola donaciformis—Truncilla donaciformis
Ptychobranchus phaseolus—Ptychobranchus fasciolare (Raf.)
Quadrula pyramidata—Pleurobema pyramidatum
Quadrula obliqua—Pleurobema cordatum (Rafinesque)
Quadrula undata—Fusconaia undata
Quadrula cerina—Fusconaia cerina
Quadrula solida—Catillus solidum
Quadrula hebetata—Fusconaia hebetata
Quadrula rubiginosa—Fusconaia flava (Rafinesque)
Quadrula pustulata—Quadrula nodluata (Rafinesque)
Quadrula lachrymosa—Quadrula quadrula (Raf.)
Quadrula trapezoides—Plectomerus trapezoides
Quadrula heros—Megalonaia gigantea (Barnes)
Quadrula undulata—Amblema costata (Raf.)
Quadrula perplicata—Amblema perplicata
Quadrula plicata—Amblema peruviana (Lam.)
Strophitus edentulus—Strophitus rugosus Swains
Symphynota complanata—Lasmigona complanata
Symphynota costat—Lasmigona costata
Unio tetralasmus—Uniomerus tetralasmus
Unio gibbosus—Elliptio dilatatus (Raf.)

THE EDITORIAL COMMITTEE,
By A. O. W.

Contents

Introduction

It has been the writer's good fortune to participate in the experimental work and river surveys conducted by the Bureau of Fisheries with regard to the mussel resources. A paper concerning the experimental work has been published (Isely 1914). The present report presents the results of a field survey, principally of the Eastern-Oklahoma portions of the Red and Arkansas drainage systems. The work under the auspices of the Bureau was carried on during the summers of 1910-1912;* previous work was done by the writer in 1908-1909 upon the Chikaskia drainage system, which is a part of the Arkansas system.

The object of the mussel surveys, as set forth in the general instructions of 1910, was: "To secure knowledge and information regarding the abundance, distribution, habits and commercial

*In the 1910 survey the writer was assisted by Owen E. Horne of the University Preparatory School, Tonkawa, Okla., and E. C. Johnston of the University of Kansas; in the 1911 party the assistants were Dwight Isely of Fairmount College and Howard B. Cross of the Preparatory School; in 1912 during a part of the season I was assisted by Merrill Isely of Fairmount College, Wichita, Kansas.

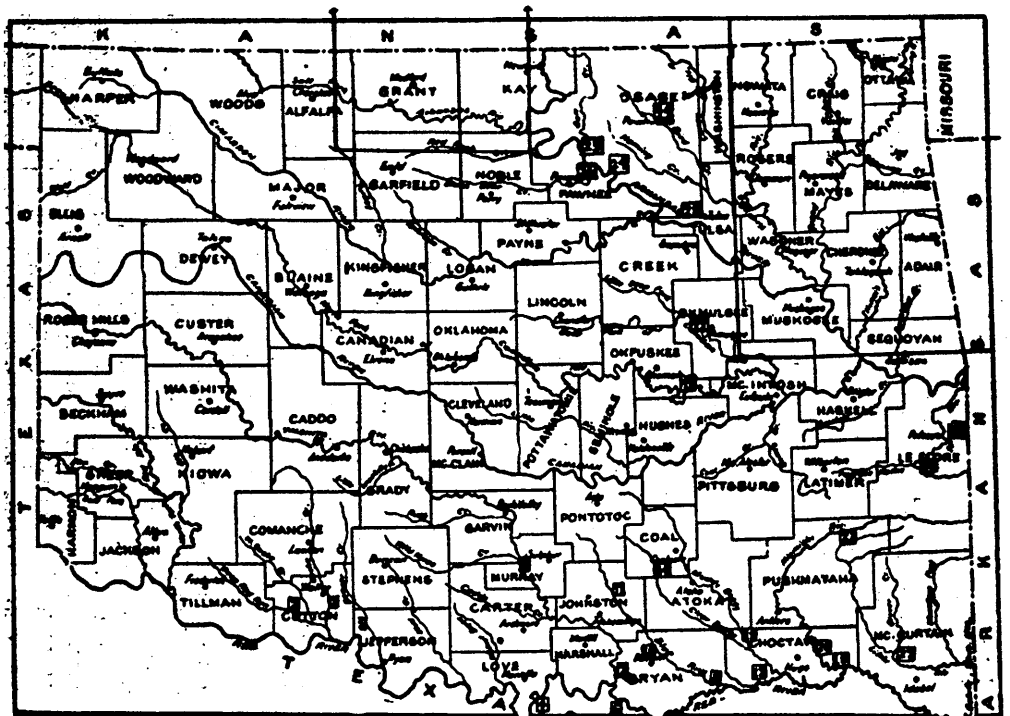
KANSAS
OKLAHOMA
TEXAS
MISSOURI
ARKANSAS
WARPER
WOODS
ALFALFA
GRANT
KAY
OSAGE
WOODWARD
MAJOR
GARFIELD
NOBLE
PAWNEE
ROGERS
MAYES
DELAWARE
CRAIG
OTTAWA
BLAINE
DEWEY
KINGFISHER
LOGAN
PAYNE
CREEK
WAGONER
CHEROKEE
ADAIR
ROGER MILLS
CUSTER
CANADIAN
OKLAHOMA
LINCOLN
OKMULGEE
MUSKOGEE
SEQUOYAH
BECKHAM
WASHITA
CADDO
CLEVELAND
OKFUSKEE
MC. INTOSH
HUGHES
HASKELL
KIOWA
GRADY
PITTSBURG
LATIMER
LE FLORE
COMANCHE
GARVIN
PONTOTOC
COAL
JACKSON
STEPHENS
MURRAY
PUSHMATAHA
TILLMAN
CARTER
JOHNSTON
ATOKA
COTTON
JEFFERSON
LOVE
MARSHALL
BRYAN
CHOCTAW
MC. CURTAIN

Fig. 1

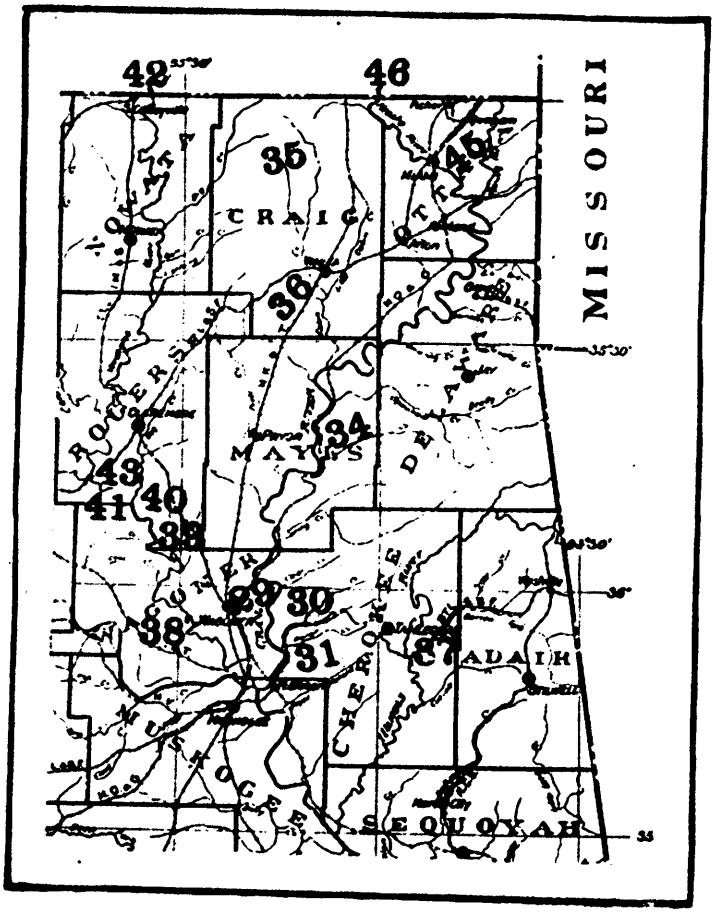
42
46
35
36
34
43
41
40
38
31
37
MISSOURI
CRAIG
MAYES
DELAWARE
CHEROKEE
ADAIR
SEQUOYAH

FIG. 2.

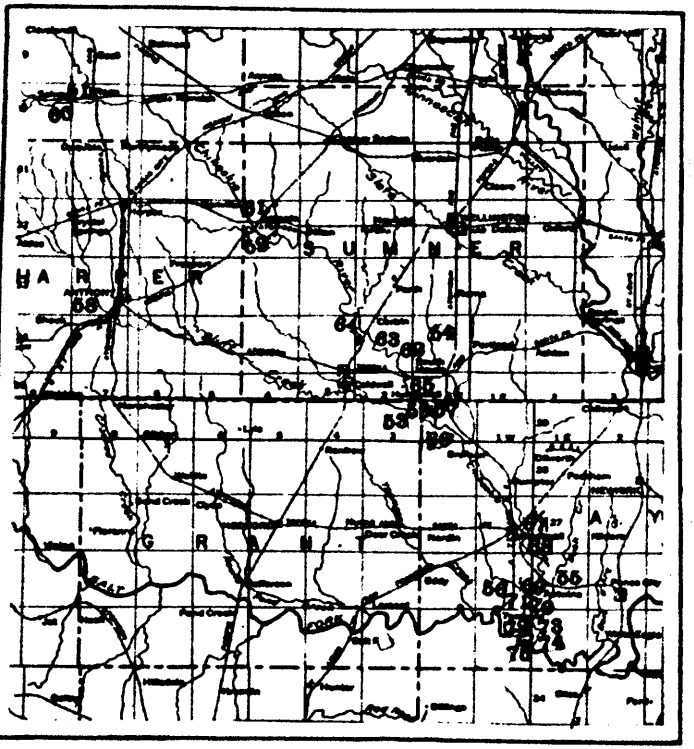

Fig. 3

value of the various species of Unionidae found in the various hydrographic basins." In carrying out these instructions an attempt has been made to emphasize the ecological phases of the general problem, as expressed in bottom conditions, range of species, current, depth of water, water content, temperature, etc.; and I have tried to investigate the relative importance of these factors and their bearing upon the ecology of the Unionidae of this region.

For our 1910 and 1911 trips we followed the usual plan of starting well up the master stream, working down the river, and making side trips up the tributary streams, by boat and by rail. In the case of the Oklahoma surveys, the master streams, the Red and Arkansas rivers, proved to be unproductive as mussel streams, but they served very well as a base for operations upon the tributary streams. The tributary streams proved in most instances to be suited to the activities of the fresh-water mussels. As the region passed thru was sparsely settled in the immediate vicinity of the broad flood-plain valley of the master streams it was necessary to carry a full camping outfit. Our equipment consisted of two light flat-bottomed boats, one serving as a work boat and the other as a luggage boat. With such craft, over a thousand miles of the streams of this region were traversed in the course of our work, besides several hundred miles traveled in making side trips on foot, by team, and by rail to investigate points farther up the small tributary streams.

The area covered by this report embraces the eastern half of the drainage systems of the Red and Arkansas rivers in Oklahoma. A little work was done in a few of the border counties of Texas and Kansas. The region limited by the state lines of Oklahoma is known to the uniologists only from a few scattered references in the literature* of the subject. That the species should close affinities to the mussel fauna of the streams previously studied in Kansas, Texas, and Arkansas was to be expected. However, the newness of the immediate region has added somewhat to the interest in this work. Every drop of water flowing from Oklahoma finds its outlet in the Arkansas and Red rivers. As shown by our map (Fig. 1) this survey covered portions of all of the chief mussel bearing streams in this region. Most of the localities visited are indicated on the map. The Red drains approximately the southern third of the state and the Arkansas the northern two-thirds. It will be apparent to all field workers that an investigation of so extensive a territory

*Especially in the papers of Baker, Ferris, Simpson and Scammon.

by a single party in three summers must of necessity be in the form of a reconnaissance.

As a matter of convenience the observations will be discussed under three divisions: Red River drainage, Arkansas River drainage, and Chikaskia River drainage. The Chikaskia is a part of the Arkansas system and it is treated separately only because the proximity of the writer's residence to this stream during a period of six years made possible a more detailed and extended study of this small river and its tributaries.

Mussel Survey in the Red River Drainage

Starting early in July, 1910, the writer traversed four hundred miles of the Red River, from the mouth of the Wichita River, at Byers, Texas, to the east line of the state of Texas; many side trips were made on the Washita, Blue, Boggy, Kiamichi, and Little Rivers; and on Cache, Frog,† Bois d'Arc,† Saunders,' and Pine† creeks. When possible, the side trips were made by boat; when this was not practicable, as when working on small creeks, the work was undertaken on foot or by team. The trips up the tributary streams, where the work boat was used, were limited to a two or three days run.

†Clay and Lamar Counties, Texas.

By this method it was feasible to examine the master stream thoroughly thruout its course but the work on the tributary streams was necessarily fragmentary. On our return trip by rail to Tonkawa, Okla., after having completed the 1910 field survey on the Red River, we made short stops on the Little River at Garvin, on the Kiamichi at Roby, on Clear Boggy at Boswell, on the Blue at Durant, and on the Washita at Davis. In 1912 a further opportunity was afforded for brief study of the Kiamichi at Tuskahoma, Clear Boggy at Olney, and Blue at Milburn. These stations further up the tributary streams added materially to our list of species and gave interesting data for comparison.

Character of the Streams

The Red River is a typical plains stream belonging to the class of the Platte, the Cimarron, and the Canadian. It has a broad flood plain, and the sand bars spreading from a quarter to a full mile in width. The channel is gorged with shifting sand, and varies from ten to five hundred yards in breath. The volume of the streams is variable and subject to shrinkage. In the upper course, between the mouths of the Wichita and the Washita rivers, the water spreads out until the greatest depth is often not more than two or three inches; deep holes are rare and

far apart. The rate of current is variable and averages, according to our records, a little less than a mile an hour at low water. The main channel often breaks up into a number of small divisions, making navigation even with light boats very difficult; and sometimes in the course of a mile the channel crosses from side to side thru the low flood plain three or four times. These characteristics are especially pronounced above the Washita; below Denison the river is confined to a more definite course, and naturally the depth of the water is greater and the general course of the stream more regular.

The bottom thruout the entire course of the river examined, with rare exceptions,‡ is made up of fine sand; beyond the mouth of the Kiamichi, however, there are a number of good stretches of mud bottom. The river bars are composed of fine sand and at rare intervals a few gravel bars appear in the lower portion. The water is muddy varying from a red to a brownish red color, depending on the region of most recent rainfall in the head-water streams. Analysis of the water shows fair percentages of chlorine and sulphates, and some calcium. It may be stated at the outset that a stream of the character of the Red is not a favorable habitat for fresh-water mussels.

In the tributaries examined, with the exception of the Wichita, and to a certain extent the Washita, conditions are very different from those of the master stream. These tributaries vary greatly among themselves. Not enough time was spent in their study, to enable us to make a detailed characterization. In a general way the environment is much more varied and, as we would expect, a larger and more diversified fauna, not only of mussels but of nearly all aquatic forms of life, is found. The base level portions of the larger northern tributaries are similar; in the lower stretches of these streams the water is from six to twelve feet deep, and the bottom is made up of soft mud, sometimes several feet in depth. The Kiamichi is freer from drift than the other streams, and the bottom mud cover is not so deep. Some further mention of these tributary streams will be made in connection with the descriptions of the various collecting stations.

Collecting Stations and Investigation of Mussels

The point selected for starting the 1910 work was Byers,

‡The unpublished map of the War Department, which I was permitted to examine thru the kindness of Captain A. E. Waldron, shows stony bottom in only thre short stretches from the mouth of the Washita to Fulton, Arkansas.

Texas, on the Wichita River. As one of our boats was delayed in shipment, several days work was done on Cache Creek, a tributary, from the north, of the Red.

STATION 1. CACHE CREEK.—Cache is a clear water stream with course sandy bottom. In the lower portion the banks are steep and the creek is made up of a succession of ponded areas connected by narrow shallow stretches; in extreme drouth the water may entirely cease flowing in these connecting stretches, but this is quite unusual as the volume of spring water is considerable. Most of the typical sandy stream mussels of this region are found in Cache in fairly good numbers thruout the lower twenty-five miles where the collecting was done. A catch taken from northwest of Temple, Cotton Co., indicates the species found: Quadrula forsheyi 35, Quadrula pustulosa 25, Lampsilis gracilis 7, Lampsilis fallaciosa 10, Lampsilis purpurata 1, Lampsilis laevissima 1, Tritogonia tuberculata 4, and Plagiola donaciformis 3. This is a fairly typical ratio of species for Cache altho in deep holes Quadrula forsheyi is more numberous and is clearly the dominant species. Lampsilis fallaciosa is abundant only in its particular environment, i. e., mud banks and side channels. In addition to the above a few specimens of Lampsilis anodontoides, Lampsilis parva, and Plagiola elegans were taken.

STATION 2. WEST CACHE CREEK. This intermittent tributary of the Cache produced a few typical species for a stream of this character: Unio tetralasmus, Lampsilis parva, and Anodonta imbecillis.

The individual mussels are perhaps not numerous enough to make commercial gathering profitable in the Cache Creek district. The sand shell species, however, were represented by the largest and finest specimens found during all our work. Rumors that pearls of some value had been taken from Cache Creek mussels were reported to our party at Temple.

WICHITA RIVER.—This river was examined at Wichita Falls, Tex., and at Byers, Tex. It is a plains stream of considerable size with a stream floor made up of fine shifting sand. No mussels were collected from the Wichita and if they occur they are the light-shelled kinds and very sparingly found. We observed again and again in the course of our work in this region that a stream of the type of the Wichita is poorly suited to the activities of fresh-water mussel.

STATION 3. FROG CREEK. (Clay Co., Texas).—This is a very small creek and enters the Red River at the Frog Creek Ferry. Unio tetralasmus was the only species found.

STATIONS 4-6. RED RIVER.—As already indicated the Red River is poorly adapted to fresh-water mussels. During many days travel down the master stream repeated efforts were made to secure specimens. Altogether there were collected fifty-two specimens of living mussels, representing four species as follows: Lampsilis laevissima 40, L. gracilis 8, L. fallaciosa 2, and Plagiola donaciformis 2. Nearly all of these were secured at three points. The first living specimens were taken about a mile below Horshoe Bend (Station 4, Love Co., Okla.) in small side channels; 12 specimens were collected in a side channel, near Willis (Station 5, Marshall Co.); 30 young specimens all laevissima and doubtless under two years of age, were taken from the margin of a deep hole, at Rock Bluff Ferry (Station 6, Bryan Co.) a few miles above Denison, Texas; two or three times isolated specimens were found. Shells of Anodonta grandis, Quadrula pustulosa, Q. forsheyi, and Lampsilis ventricosa were picked up frequently on the lower one hundred miles of our cruise down the master stream and it seems likely that in certain localities occasional representatives of these species may be found living in the river. It is possible that shells may have been carried into the river, but I think the former by far the safer guess. Singley (1892) reports L. laevissima and L. anodontoides from the Red River (Cook Co.).

Numerous trappers and fishermen interviewed were certain that mussels were never found in the Red River and most of them were very much surprised to learn that we had secured even a few specimens. At Shoals (Choctaw Co.) there is a stony stretch of the river nearly a mile in length. A fisherman told us that he had secured mussels from this stretch in the river, but we were unable to secure them altho it seems likely that L. gracilis and L. laevissima should be found under the rocks in a situation similar to the Shoals stretch. One ferry-man below Horseshoe Bend told us that he had taken mussels in the river before the "great forty foot flood" of 1908. I think it entirely possible that if a series of years should follow one another in succession without extreme floods, that in certain stretches scattering mussels would appear in the Red River.

In view of the extreme scarcity of mussels in the river we were not a little puzzled at the finding of an old "shell heap" called to our attention by a river-man in the southern part of Jefferson county. This shell heap was not far from the river and would seem to indicate that the Red River may in the past have supported a mussel fauna, and if it did the ancient Red

must have been quite different from the river of today. Possibly there is a better explanation, but the shell remains seem to be a typical midden of the aborigines and must have come from a near-by source.

STATION 7. LOWER WASHITA AT WOODVILLE (Marshall).—The Washita is the largest tributary of the Red. It has many of the characteristics of the master stream and in its upper course is the typical sandy river of the plains. Nearly three days, August 3-5, 1910, were spent on the lower Washita working up stream ten miles or more by boat to a point above Mead (Marshall Co.). Above the base level portion of the stream, which extends about two miles, riffles begin to appear and occur frequently. The river is very crooked and the low banks are composed of red clay and shale. The shoals are covered with coarse gravel and in some places stones project out into the stream floor. Scattering specimens of mussels were found in the side channels and upon the low bars. The light-shelled and actively moving species were clearly dominant. Species collected are listed in the Table 1.

STATION 8. WASHITA AT DAVIS (Murray).—On our return trip a small area of the Washita southwest of Davis was examined on September 2. In a mud bank in a slow flowing portion of the stream a small series of species was secured. Among these five juveniles of Plagiola donaciformis were taken. The specimens were very small and attached to pebbles by strong byssus threads (Isely, 1911.)

While a few mussels are found in the Washita, it would on the whole, have to be classed as a poor mussel stream. The Lampsilis species and especially the light-shelled forms may be fairly abundant in certain localities.

STATION 9. LOWER BLUE RIVER (Bryan).—After the Washita the Blue is the next stream of some size that enters the Red from the north. The Washita, like the lower Blue, is full of logs and snags. For the first two miles, as one ascends the Blue, the banks are low and covered with willows, and the stream floor is a deep mud. Farther up, stony stretches and riffles are encountered, the banks become higher and even appear occasionally as sand-stone bluffs forty feet in height. The general width of the stream is 20-30 feet altho over the stony stretches it narrows down and becomes very swift. The abundant species in the lower Blue are Quadrula undulata and Lampsilis purpurata; other species are shown in the table.

STATION 10. BLUE AT DURANT (Bryan).—On Aug-

ust 31, the Blue was examined five miles north of Durant. A stretch of the river of about 200 yards in length was studied. The river at Durant is more typical for the Blue than at Station 9; bottom is made up of gravel and sand, with mud banks in the bends. The water is only a few inches deep over the shoals where it flows swiftly, and in the deepest stretches of this portion of the river is seldom over four feet. In the still deeper water the mussels were sparse in the coarse sandy bottom. In the gravelly stretches where the water flows swiftly, an elongated, brown, and much rayed Quadrula rubiginosa was very abundant. Many of these were quite small averaging from 14 to 20 mm. in length (1-2 to 3-4 of an inch). The older specimens had evidently lived in this situation for some time as the posterior third of the shell was covered with a heavy mat of algal growth, chiefly Cladophora. Q. pustulosa was quite abundant and several specimens of Ptycobranchus clintonese were secured, a good number of Lampsilis ventricosa and Tritogonia tuberculata were taken. In the mud banks Q. undulata was clearly the dominant species. Other species found are listed in the table.

STATION 11. BLUE AT MILBURN (Johnston).—July 19, 1912, another opportunity was afforded to visit the Blue still farther up stream at a point two miles north of Milburn. The Blue at this point is a shallow, clear water, sandy bottomed stream, with good surrent. Mussels were found to be abundant but no extensive beds were seen. Collecting was done up and down the river for about a mile. Mussels were collected from four different types of environment, which may be briefly described and the mussel inhabitants of each of these situations may be shown to advantage for comparison in tabular form.

There are a great many factors that enter into the complex of a mussel environment. Three important physical factors are bottom materials, current, and depth of water. Many other factors, chemical and physiological as well as physical often play an important part in the make up of the environmental complex of fresh-water mussels. Some of these have already been mentioned. Others are, suitable fish hosts, light, oxygen supply, food, carbon dioxide, etc. In the tabular studies, however, I have chosen to make the basis of comparison the factors mentioned above as primary physical factors, for these conditions we are at least partially able to interpret in the field.

Habitat I: sandy bars, shallow flowing water. Habitat II: mud banks in bends of the river, water 2-3 feet deep, very little current. Habitat III: gravel bottom, water 1-3 feet deep, swift

current. Habitat IV: gravel bottom, water 3-5 feet deep, swift current. Species were found in these situations as follows:

Habitats: Species	I	II	III	IV	Tot.
Quadrula undulata	5	23	2	8	38
Quadrula rubiginosa	37	14	11	8	70
Quadrula pustulosa	-	--	2	1	3
Lampsilis gracilis	-	--	1	--	1
Lampsilis hydiana	5	12	1	3	21
Lampsilis purpurata	1	--	--	--	1
Lampsilis ventricosa	2	--	4	5	11
Plagiola donaciformis	-	--	1	--	1
Obliquaria reflexa	1	--	--	--	1
Ptycobranchus clintonense	1	--	--	--	1
Totals	52	49	22	25	148

In regard to activity it may be noted that the mussels of habitat I were moving about, while those in the the other situations were more or less inactive. The aggregate dominance of Quadrula rubiginosa and the relatively large numbers of Q. undulata and Lampsilis hydiana in all habitats are points of interest. That Q. forsheyi should be entirely absent and Q. pustulosa represented by only one example is unusual in a stream of this character. Both species are found at the other stations on the Blue, but neither appeared in the ratios of the Chikaskia and Cache notwithstanding the similarity of these streams to the Blue in respect to current, depth and bottom. While the Blue is described by fishermen as being full of mussels, no mussel beds in the commercial sense were located at the stations visited. Further study of the Blue would be of interest.

BOGGY RIVER.—This stream has a much lower gradient than the Blue or Kiamichi. Boggy was examined at three well separated stations and at all of these points may be characterized as a ponded stream. A number of fishermen told me that this ponded condition was characteristic thruout the lower 100 miles of its course, and that shoals were few and far between. This general sluggish condition extends well up into the tributaries, Clear and Muddy Boggy, and accounts for a mussel fauna, which when carefully analyzed, is seen to be quite different from that of the other major streams of the southern drainage.

STATION 12. LOWER BOGGY AT DAVIS FERRY (Choctaw).—Collecting was first done a short distance above the ferry in still water 3-6 feet deep with a mud-sand bottom. This is a

typical habitat for Lampsilis purpurata and Quadrula undulata and these were the principal species found. At Rock Shoals, a little over a mile above the ferry, we located the largest mussel bed encountered in all of our field work in 1910. This bed was below the shoals, extended down the river for 80 yards and was several yards wide. There were tons of mussels here. Quadrula undulata (the "Blue point") was far more abundant than all other species combined. Tritogonia tuberculata was also found in good numbers. The mussels were large and much eroded indicating that the bed was one of long standing.

Clear Boggy was investigated at two other points, Station 13 at Boswell (Choctaw), and Station 14 at Olney (Coal).

Three creeks flowing into the Red from the Texas side (Bois D'arc, Lamar Co.; Saunders, Lamar Co.; and Big Pine, Lamar Co.) and Slate Shoals Lake were examined for their mussel fauna. The species found are enumerated in table I.

KIAMICHI RIVER.—The last detour by boat of our 1910 cruise was made up the Kiamichi. This is a splendid clear-water stream and the last river in Oklahoma to enter the Red. With Little River, Kiamichi drains the south-east portion of the state. In the upper two-thirds of its course it is a mountain stream, flowing over sand and gravel. Much of this coarse material finds its way into the lower Kiamichi and contributes extensively to the make up of the stream floor.

STATION 19. LOWER KIAMICHI (Choctaw).—We spent two days on the lower Kiamichi working up to a point southwest of Fort Towson. The dead-water stretch of the Kiamichi is less than a mile and a half in length. Stretches of deep water, however, are said to extend up the river for 15 miles. In the back-water stretch in water 6-8 feet deep Lampsilis purpurata was secured in good numbers with our shoulder rake. We had to work up the river about six miles before hand collecting was possible and then we found a stretch that produced a few mussels. It was at this station that we found the first juveniles described in another paper.

STATION 20. THE KIAMICHI AT ROBY (Choctaw, 1910) was of special interest as the abundant species were different from those taken in the other streams. Plagiola elegans and Obliquaria reflexa were found in good numbers; Lampsilis capax was reported from this station and not found again in all of our work.

STATION 21. KIAMICHI AT TUSKAHOMA (Pushmataha).—Two days were spent in studying the Kiamichi at this

point in 1912. The river here is ponded with stretches of shallow water 3-4 feet deep, interrupted frequently by gravelly and rocky shoals where the water flows swiftly. The results from six different habitat studies are shown below. These habitats, altho in different poritions of the stream, may be put into three groups on account of similar conditions, and thus one serves as a check on the other.

Habitats I and IV: side channels and bends of the river with mud bottom, water 2-3 feet deep, no current. Habitats II and V: gravel and sand bottom, water 2-3 feet deep, slow current out of main channel. Habitats III and VI: bottom coarse gravel and rocks, overlying a deeper layer of fine sand, water 1-2 feet deep, current swift.

Habitats:	I & IV		II & V		III & VI		Tot.
Species							
Quadrula undulata	36	19	13	19	1	15	103
Quadrula pustulosa	8	4	4	1	--	3	23
Quadrula undata	14	--	5	1	1	--	21
Tritogonia tuberculata	10	4	8	5	6	4	37
Lampsilis ventricosa	16	4	8	7	4	2	41
Lampsilis ligamentina	5	13	20	9	20	28	87
Lampsilis hydiana	2	1	--	--	--	--	3
Lampsilis purpurata	8	--	--	1	--	--	9
Lampsilis fallaciosa	--	--	--	2	--	--	2
Lampsilis parva	1	--	--	--	--	--	1
Ptycobrachus phaseolus	2	7	15	--	8	26	58
Anodonta grandis	1	--	--	--	--	--	1
Anodonto imbecillis	1	--	1	--	--	--	2
Lampsilis leptodon	--	--	12	1	12	11	36
Strophitus edentulus	--	--	2	--	--	3	5
Obovaria castanea	--	3	3	2	6	6	20
Plagolia elegans	--	--	--	1	6	7	14
Obliquaria reflexa	--	--	--	--	3	--	3
Arkansia wheeleri	--	1	--	--	--	--	1
Totals	104	56	91	49	67	105	472

Half of the Quadrula undulata are found in habitats I and IV; Anodonta grandis, Lampsilis parva, A. imbecillis, L. purpurata, and L. hydiana are not found in large numbers but they appear only in I and IV; L. ligamentina, L. leptodon, Plagiola elegans, and Ptychobranchus phaseolus are largely in III and VI. While a single tabulation of this kind proves nothing it certainly shows tendencies rather clearly. In habitat III and VI many of the

specimens especially L. leptodon was found buried under the coarse gravel in the substratum of fine sand. Arkansis wheeleri Ortman and Walker, a recently discovered species from Arkansas is represented by a single specimen.

LITTLE RIVER.—Joins the Red near Fulton, Arkansas .It has many of the characteristics of the Kiamichi and a similar fauna.

STATION 22. LITTLE RIVER AT GARVIN. (McCurtain).—Only a half a day was spent in the study of Little River at this point. The river here is made up of a succession of long deep holes and shoaly stretches. In slow flowing water 3-5 feet deep a number of interesting specimens were found. The list cludes L. hydiana, L. ligamentina gibba, L. anodontoides, L. parva, L. gracilis, L. castanea, P. elegans, P. donaciformis, Q. reflexa, Q. pustulosa, Q. forsheyi, Q. fragosa, Q. trapezoides, Q. cylindrica, and Q. undulata. This is the only record for Q. trapezoides and the only record for Q. cylindrica in the southern drainage. Just one specimen of Q. cylindrica was found.

In the table given below the general distribution of Red River mussels is well shown and the relative abundance of the several species in different streams, and at different stations is also brought out. This record is based for the most part on actual counts as it was our practise to keep an accurate check on all specimens handled. This method is sometimes exacting but it is the only way to get a fair degree of accuracy as to the relative abundance of species. Besides, in much of the Red River survey the places where mussels are wanting seemed to demand analysis as well as the places where they were abundant.

Discussion of Red River Data

In the study of the distribution and relative abundance of species as shown by the above table and the accounts of the field work at the various stations, some interesting facts appear. We find the following species predominating both as to wide distribution in the various streams and as to the number of individuals at each station: Lampsilis fallaciosa which is found at 16 of the 22 stations recorded; Quadrula* forsheyi and Q. pustulosa occur at 15 stations and usually in good numbers; and Q. undulata is found at 10 stations while at 6 stations it was the dominant species and usually far more numerous in individuals than all other species combined. L. gracilis is found at 15 stations and L. purpurata at 12; these species are nearly always found, but are usually more scattered and not in the compact colonies characteristic of certain of the Quadrulas. In contrast with the species enumerated above 25 out of the 43 species catalogued in the table are reported at not more than 3 stations.

The largest number of species for an individual stream are reported from the Kiamichi, 29 in all; Little River, Boggy (Muddy and Clear Boggy), and Blue have from 17-21 species reported. In Boggy, Cache, and Blue the Quadrulas are by far the most numerous and a different species leads for each stream; Q. forsheyi for Cache, Q. rubiginosa (stations 10 and 11) for Blue, and Q. undulata for Boggy. While every one of the larger streams and many of the smaller have their individualistic mussel faunas, the Kiamichi clearly stands apart from the rest. In the Kiamichi L. ligamentina gibba, L. leptodon, O. castanea, and P. elegans are common to abundant, while these species are scarcely known in the other streams of the southern drainage; more work on Little River, however, would undoubtedly show its mussel fauna to be closely allied to that of the Kiamichi. In Pine Creek, L. fallaciosa and L. hydiana were found in good numbers. Even the Red River has one station (No. 6) where L. laevissima may be recorded as common; this species and L. gracilis are the leading mussels in the Washita in places where mussels are found in this stream. L. laevissima is not found in Boggy, Kiamichi, Little River, and Blue. In the base level stretches of Blue, Boggy, and Kiamichi L purpurata seems to be more abundant than in any other situations. In some half dozen small creeks

*Difficulty in certainly differentiating between L. fallaciosa and L. anodontoides, and between Q. forsheyi and Q. lachrymosa, and also some other species is discussed later in this paper in the consideration of individual species.

TABLE I SHOWING DISTRIBUTION OF FRESH-WATER MUSSELS IN THE RED RIVER DRAINAGE

Mussel species	Streams and stations: Red 4	Red 5	Red 6	Wash. 7	Wash. 8	Blue 9	Blue 10	Blue 11	Boggy 12	Boggy 13	Boggy 14	Kiamichi 19	Kiamichi 20	Kiamichi 21	L.R. 22	Creeks 1	Creeks 2	Creeks 3	Creeks 15	Creeks 16	Creeks 17	Creeks 18	No. of sta's in which species is found
1.Quadrula solida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	r	-	-	-	-	-	-	-	1
2.Quadrula obliqua	-	-	-	-	-	-	-	-	-	-	-	-	r	-	r	-	-	-	-	-	-	-	1
3.Quadrula undata(Pig-toe)	-	-	-	-	-	-	-	-	-	-	-	-	-	c	-	-	-	-	-	-	-	-	1
4.Quadrula rubiginosa	-	-	-	-	-	o	d	d	o	o	o	-	r	-	-	-	-	-	-	-	-	-	7
5.Quadrula pustulosa(Pimple-back)	-	-	s	o	o	f	o	f	f	f	f	f	o	o	o	o	-	-	s	-	-	-	15
6.Quadrula forsheyi	-	-	s	o	o	f	f	-	f	f	o	o	f	o	r	d	-	-	d	-	o	-	15
7.Quadrula fragosa	-	-	-	-	-	-	-	-	r	-	-	-	-	-	r	-	-	-	-	-	-	-	2
8.Quadrula lachrymosa(Maple-leaf)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	r	-	-	-	-	-	-	-	1
9.Tritogonia nobilis	-	-	-	-	-	-	-	-	r	-	-	r	-	-	r	-	-	-	-	-	-	-	3
10.Quadrula cylindrica(Rabbit's-foot)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	r	-	-	-	-	-	-	-	1
11.Quadrula trapezoidea(Bank-climber)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	o	-	-	-	-	-	-	-	1
12.Quadrula heros(Washboard)	-	-	-	-	-	r	-	-	-	r	o	r	-	-	-	-	-	-	-	-	-	-	4
13.Quadrula undulata(Three-ridge)	-	-	-	-	-	d	a	a	d	a	a	f	o	a	f	-	-	-	-	-	-	-	10
14.Quadrula plicata(Bluepoint)	-	-	-	-	-	-	-	-	-	o	-	-	-	-	o	-	-	-	o	-	-	-	3
15.Unio tetralasmus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	f	f	-	-	-	-	o	3
16.Unio gibbosus(Lady-finger)	-	-	-	-	-	-	-	-	-	-	-	-	-	f	-	-	-	-	-	-	-	-	1
17.Symphynota complanata(Mael-splitter)	-	-	-	o	-	s	-	-	o	-	o	-	-	-	-	-	-	-	o	-	-	-	5
18.Arkansia wheeleri	-	-	-	-	-	-	-	-	-	-	-	-	-	r	-	-	-	-	-	-	-	-	1
19.Anodonta corpulenta(Slop-bucket)	-	-	s	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	s	2
20.Anodonta grandis(Floater)	-	-	-	-	-	-	-	-	-	-	-	-	-	r	-	-	-	-	-	-	-	f	2
21.Anodonta imbecillis	-	-	-	-	-	-	-	-	-	-	-	-	f	o	-	f	-	-	-	-	-	s	4
22.Strophitus edentulus(Squaw-foot)	-	-	-	-	-	-	-	-	s	-	-	-	-	f	-	-	-	-	-	-	-	-	2
23.Ptychobranchus clintonensis	-	-	-	-	-	-	o	o	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
24.Ptychobranchus phaseolus(Kidney-shell)	-	-	-	-	-	-	-	-	-	-	-	-	-	o	-	-	-	-	-	-	-	-	1
25.Obliquaria reflexa	-	-	-	s	-	-	-	o	s	-	o	s	f	o	f	-	-	-	-	-	-	-	8
26.Tritogonia tuberculata(Buck-horn)	-	-	-	s	o	o	f	-	o	o	f	-	f	a	-	f	-	-	-	-	-	-	10
27.Plagiola donaciformis	-	r	-	o	o	o	o	o	-	o	-	f	f	-	o	f	-	-	r	-	-	-	12
28.Plagiola elegans	-	-	-	-	-	s	o	-	o	o	-	-	f	o	r	r	-	-	-	-	-	-	8
29.Plagiola securis(Butterfly)	-	-	-	-	-	-	-	-	-	-	-	-	-	o	f	-	-	-	-	-	-	-	3
30.Obovaria castanea	-	-	-	-	-	-	-	-	-	-	-	-	-	o	f	-	-	-	-	-	-	-	2
31.Lampsilis leptodon	-	-	-	-	-	-	-	-	-	-	-	-	-	o	-	-	-	-	-	-	-	-	1
32.Lampsilis laevissima(Paper-shell)	o	f	o	a	o	-	-	-	-	-	-	-	-	-	o	-	-	s	o	o	o	-	10
33.Lampsilis gracilis(Paper-shell)	o	o	-	o	o	f	f	o	f	f	f	f	f	-	f	-	-	o	-	o	-	-	15
34.Lampsilis purpurata(Purply)	-	-	-	-	-	o	o	-	o	o	o	o	f	f	f	-	-	o	-	-	-	-	12
35.Lampsilis parva	-	-	-	-	-	o	s	-	-	-	-	o	-	o	-	-	f	-	-	-	o	-	6
36.Lampsilis subrostrata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	f	f	2
37.Lampsilis fallaciosa(Slough sand-shell)	r	-	-	s	f	o	o	-	o	o	a	f	f	o	s	f	-	-	o	o	a	-	16
38.Lampsilis anodontoides(Sand-shell)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	o	-	-	-	-	-	-	1
39.Lampsilis ligamentina gibba	-	-	-	-	-	-	-	-	-	-	-	-	-	a	c	-	-	-	-	-	-	-	2
40.Lampsilis hydiana	-	-	-	-	-	-	o	o	-	-	f	-	-	o	o	-	-	-	-	-	-	a	-	6
41.Lampsilis capax(Pocket-book)	-	-	-	-	-	-	-	-	-	-	-	-	f	-	-	-	-	-	-	-	-	-	-	1
42.Lampsilis ventricosa(Pocket-book)	-	-	s	s	-	o	-	o	-	-	-	s	-	-	-	-	-	-	-	-	-	-	-	5
43.Lampsilis ventricosa satura	-	-	-	-	-	-	-	-	r	-	-	-	-	a	-	-	-	-	-	-	-	-	-	2
Number of species in each stream		6		12			17			20			29		21	10	3	1	9	2	7	6	

Explanation of Table I

Streams and Collecting Stations

Station 1. Cache Creek.
Station 2. West Cache Creek.
Station 3. Frog Creek.
Station 4, 5, and 6. Red River.
Station 7 and 8. Washita River.
Station 9, 10 and 11. Blue River.
Station 12, 13, and 14. Boggy River.
Station 15. Bois D'arc Creek.
Station 16. Saunders Creek.
Station 17. Big Pine Creek.
Station 18. Slate Shoals Lake.
Station 19, 20 and 21. Kiamichi River.
Station 22. Little River.

Symbols Used in Tabular Summaries

In recording the abundance of mussels I have used the following terms to designate the ratio and the number of mussels taken at a station: dominant, abundant, common, frequent, occasional, rare, shells. In the tabulation these terms have been based upon counts and are given rather arbitrary limits; this method, however, affords a more of less accurate basis for conparison. The significance of these designations may be explained as follows: Dominant (d) is applied to a species that is clearly more numerous than any other at the station in question. Abundant (a) is used when a collector could pick up 15-30 examples of a species in thirty minutes; usually this kind of an estimate is not based upon a single collecting period but on a number of periods and sometimes on the comparative work of two or three collectors. Common (c) indicates that 5-15 specimens were collected in the unit of time (thirty minutes). Frequent (f) implies 2-5 specimens of a species were taken in the unit of time. Occasional (o) implies the finding of single specimens of a species with some regularity when extensive collecting was done; 3-4 specimens a day might be called occasional. Rare (r) is used when a species is rarely taken in the system as a whole; in the Red River drainage Arkansia wheeleri and Quadrula cylindrica are represented by single specimens and are designated as rare; in the Kiamichi after five days work at three different stations only one specimen of Anodonta grandis is found and this is classed as rare for the Kiamichi although it may be exceedingly abundant in a near-by lake. Shells (s) indicate that only weathered or long dead shells are found. These terms are used in all of the summary tables and therefore comparisons between the systems and streams of the north and south drainage may be made.

not mentioned specifically in this paper Unio tetralasmus represents the mussel life and associated with it are scattered specimens of L. parva and A. imbecillis. In lakes and bayous L. laevissima, A. corpulenta, and U. tetralasmus are reported to be the dominant species.

Mineral Content of Water

The saline constitutents of the pond and stream waters have long been considered among the important factors that affect mussel distribution. In many cases unfavorable mineral content is a deciding factor and doubtless the chief inimical condition to be considered in explaining the absence of mussels in certain streams. However, this conclusion has been too often founded on insufficient data and in order to get information on the relative importance of mineral content of water as a factor in the Red River drainage system, analyses were made of the waters from the Red, Washita, Kiamichi, and Blue. The samples were secured, at low water in all the streams and were taken the last week in August in three and September 2, in the Washita. The Red River sample was taken north of Texarkana; Washita at Dougherty (Murray Co.); Kiamichi at Roby; and Blue at Durant.

The work of analysis was done by Mr. Oscar Harder, instructor in Chemistry at the University of Oklahoma. Estimations were made of what are thought to be the essential minerals. All estimations are in milligrams per liter of water.

	1	2	3	4
Chlorine	91.00	46.00	66.00	7.00
Sulphate (SO4) radical	74.30	528.40	9.10	4.50
Calcium (Ca)	84.96	153.60	16.52	65.49
Magnesium (Mg)	4.64	4.30	2.14	10.00
Bicarbonate (HCO3) radical (cal.)	30.90	None	None	104.30
Carbonate (CO3) radical (Cal.)	None	None	None	63.00

Figures above the columns refer to the following: 1—Red River; 2—Washita; 3—Kiamichi and 4—Blue.

As a basis for comparison I give below an analysis of water* taken from the Illinois River, Peoria, Ill.; and from the Kankakee River taken near Kankakee, Ill. These samples were taken in August. Only the minerals estimated in the analysis of water from the Oklahoma streams are here put down.

	Illinois	Kankakee
Chlorine	3.5	20.0
Sulphate (radical SO4)	57.0	28.0
Bicarbonate (radical HCO3)	218.0	166.0

*Water Supply Paper 239, by W. D. Collins, U. S. Geological Survey, 1910.

Calcium (Ca)	54.0	42.0
Magnesium	21.0	20.0

The Illinois and Kankakee are well known as among the best producers of commercial mussels. Blue and Kiamichi of the Oklahoma streams are known to have a fairly abundant mussel fauna and a fair supply of shells at the stations visited by us. The Kiamichi mussels were below average in size and the absence of the bicarbonate may be the important factor. The analysis of the water of the Blue is quite in accord with the Illinois streams and here we have the largest shells. Red River may well be called a mussel desert, altho a few young paper shells were found in three localities. However, it is clear that mineral content of the water is not the only prohibitive factor, for from this standpoint the Red River would rank next to the Blue in the streams here considered. The absence of mussels is clearly due to the shifting sand of the stream floor. In the Washita the mussels were not abundant, according to our standard of abundance, but in certain stretches a good supply of specimens were found, especially of the paper shells; at Davis the bottom conditions seemed fairly favorable for mussel activity; in the Washita the high percentage of calcium sulphate (gypsum) is probably inimical to mussel life. The point of interest seems to center not in the paucity of mussel life in the Washita, but rather in the fact that mussels are even so abundant in the absence of free calcium carbonate and the presence of so high a percentage of sulphates.

Arkansas River Investigation.

As already noted a survey was made during July and August, 1911, of a part of the Oklahoma portion of the Arkansas River drainage system similar to the 1910 Red River survey.

The work on the master stream began at Ponca City and was completed at Ft. Gibson (see map). Portions of the following tributary streams were examined: Chikaskia, Verdigris, Grand, Neosho, Illinois, and North Fork of the Canadian rivers; Salt, Black Bear, Big Cabin, Pryor, Fourteen Mile, Gar, Billy, Deep Fork, and Bird creeks. During July, 1912, further work was done on Bird Creek at Nelagoney; Verdigris at Coffeeville, Kans., Neosho at Chetopa, Kans.; Poteau at Poteau; Gaston Creek at Wister.

The Master Stream and Its Tributaries

The Arkansas belongs to the same type of streams as the Red. The stream floor is made up chiefly of sand (fine and

coarse) and of gravel. However, more frequently in the Arkansas than in the Red, rocky stretches appear, especially below Blackburn. Above Fairfax the water spreads out over the broad stream floor in a thin sheet and often breaks up into a number of small channels. Below the mouth of the Cimarron a more unified and definite channel is marked out for the river. Below Cleveland the banks are generally low and the timber more sparse than along the river in the upper two-thirds of the Osage country.

The tributaries of the Arkansas are of two classes: (1) those that come from the plains region, sand gorged and with low broad valleys, as the Salt Fork of the Arkansas, the Cimarron, and the Canadian; (2) the second class are the clear water streams that flow in from the north as the Verdigris, Neosho-Grand, Illinois, and from the south as the Poteau; the individual characteristics of this second class and some other minor tributaries will be briefly mentioned in connection with the account of the mussel survey of these streams.

Collecting Stations and Investigations of Mussels

STATIONS 23-24. ARKANSAS RIVER.—As in the case of the Red River, mussels are exceedingly sparse in the Arkansas. If, however, the two streams be compared, the Arkansas seems a little more favorable for mussel life than the Red. The number of specimens we actually secured in the Arkansas was small, partly due to the fact that below Cleveland the river was at flood stage and we were not able to collect.

STATION 23. (Osage Co.)—About two miles below the mouth of the Salt Fork extended search was made in the side channels and bays and a few specimens of Lampsilis gracilis and L. laevissima were secured.

STATION 24. BLACKBURN.—About two miles below Blackburn under large rocks, that appeared in the river at this place, several large specimens of the light shelled species were again found. These mussels had undoubtedly lived under these rocks for many years in the identical spot where they were individually located probably having dropped from the host first as it was hiding under these rocks. This inference seems to be substantiated by the fact that in some instances the shells were deformed by having grown between the rocks and by the further fact that only in a sheltered situation could mussels grow to a "good old age" in a stream of the Arkansas type.

SALT FORK.—A bottom of very fine shifting sand makes

the Salt Fork entirely unsuited to mussel habitation. This stream was often examined by the writer in the vicinity of Tonkawa but mussels were never found. The Salt Fork has a number of tributaries that are good mussel bearing streams and the fact that not even a light shelled species could be scraped up from the bars of the Salt Fork is evidence which has been relied upon for the conclusion that, in general, where shells are found, living mussels are not far distant.

STATION 25. SALT CREEK (Osage Co.).—This small creek enter the Arkansas from the north at Fairfax. It is a stony stream and the water is fairly swift over the riffles. It was not possible to work far up the Salt Creek by boat but about three miles of the lower creek were examined. In some of the ponded portions large numbers of Quadrula undulata were found, these specimens are of good size and very thick. A typical Salt Creek habitat for Q. undulata may be described as follows: creek made up of ponded stretches about 200 yards in length, water 2-3 feet deep, bottom material gravel and broken rocks, very little current. In a collection of 200 specimens Q. undulata was found to be nine times as numerous as the combined numbers of six other species. Portions of Salt Creek in the vicinity of Burbank are reported to have a good supply of "shells."

Some of the Salt Creek specimens of Q. undulata were unusually large, measuring 152 mm. (6 inches) and weighing 500 grams. The average length was over 125 mm. The few specimens of Obliquaria reflexa were unusually large measuring 93 by 70 mm. There must be marked differences in chemical content of water, food supply or other factors to account for these marked differences in size of the same species in various streams.

STATION 26. BLACK BEAR CREEK (Pawnee).—About a day's run below Salt Creek, we entered Black Bear which flows into the Arkansas from the south. This creek has its head waters in the Red Beds and as a result the banks are reddish and the water is a dirty reddish brown. The back water stretch has a mud bottom but after the first mile up stream, sand and gravel are the chief bottom constituents. In working up stream to within about two miles west of Skedee (Pawnee Co.) three shoal stretches were passed, at each of which search was made for mussels; altogether the following were found: Q. lachrymosa 5, Q. undulata 4, L. anodontoides 3, L. gracilis 4, L. purpurata 4, S. complanata 1; shells—T. tuberculata, Q. pustulosa, and O. reflexa. Species 9, total living specimens 17.

STATION 27, BLACK BEAR CREEK AT BLACK BEAR (Noble).—On our return to Tonkawa from our 1911 work on the Arkansas River, upper Black Bear was examined by D. Isely and Cross. The work at this station gave further data on the up stream mussel fauna of a small creek. The average width of Black Bear was less than 8 feet. In its deepest places it was about three feet deep. The bottom is a reddish clay mixed with sand. All specimens were taken in shoals immediately above riffles in water about six inches deep. The following list represents the entire catch: Q. lachrymosa 1, L. anodontoides 1, L. Parva 3, S. complanata 1, U. tetralasmus 2. The species not found at the Skedee station are U. tetralasmus and L. parva, typical up stream species.

CIMARRON.—The Cimarron enters the Arkansas from the west at a point where the master stream cuts the southern boundary of Osage county. As the river was at a four foot flood stage, it could not be examined. The Cimarron is noted for its quick-sand and shifting course. The mussel fauna must accordingly be exceedingly sparse.

After passing the Cimarron, flood conditions continued on the Arkansas, and we passed down to the Grand and Verdigris rivers.

STATION 28, TULSA SLOUGH (Tulsa).—A small nameless slough that entered the Arkansas from the south above Tulsa was examined. Over 200 specimens of Lampsilis parva were picked up in a few minutes. The only other species found was U. tetralasmus.

STATION 29, GRAND RIVER (Cherokee and Wagoner).—Several days were spent in working up the Grand River to a point east of Wagoner. The lower Grand is a splendid clear water stream with a swift current. The stream floor is made up chiefly of a very coarse gravel, ranging all the way from the size of hickory nuts to a base ball. Over the riffles and thru the narrow stretches one ascends the Grand in a loaded boat with extreme difficulty. No living mussels were found in the lower Grand even in the side channels. Badly weathered shells were common on the gravel bars and as the river has a very strong current it is thought possible that some shells may have been carried down from farther up stream. Several people told us that, a number of years back, mussels were common in certain areas of the lower Grand, but that in recent years all mussels had died. Of the shells found Q. undulata, Q. heros, and L. ligamentina were the most abundant.

Above the mouth of Spring River in the northern part of the state the Grand is called the Neosho and will be discussed further under that name.

STATION 30, FOURTEENMILE CREEK (Cherokee).—This is a small creek flowing into the Grand from the east, about six miles above Ft. Gibson (on some maps this creek is known as Spring Creek). Fourteenmile is a swift flowing, clear water, spring fed creek. The bottom is filled with very coarse gravel and the stream is too small to ascend by boat farther than a quarter of a mile beyond the mouth. We waded up this stream for a distance of about two miles. Less than a dozen mussels were found in the main channel and numerous small side channels. One large colony, however, was located in a broad side channel about a mile up the creek. The bottom of this side channel was a mixture of mud, gravel, and sand. It appeared to be a cut-off but a fresh water supply was furnished thru the gravel bar that separated it from the main stream.

Quadrula cerina was clearly dominant in this habitat; this species is closely allied to Q. rubiginosa if not a variety of it; accordingly, some of the rubiginosa associates may be expected. After two hours of collecting, a checking up of species gave the following: Q. cerina 85, Q pustulosa 4, Q. lachrymosa 2, Q. Lampsilis recta 6, L. purpurata 8, L. ventricosa 10, L. ligamentina 1, L. luteola 3, L. parva 1, L. gracilis 1, L. subrostrata 4, L. anodontoides 1, L. corvunculus 1, Symphynota complanata 1, Strophitus edentulus 8, Anodonta grandis 13, A. imbecilis 7. Total: species 18, specimens 149. This is an exceedingly peculiar mussel association made up of creek, pond, and small river representatives.

STATION 31, RANGER CREEK (Cherokee).—The mussel fauna of this small tributary of Fourteenmile Creek shows very well the affinities of the species represented at Station 30. In the first place Unio tetralasmus appears here and makes us sure of our grouping. Ranger Creek was examined by Mr. Cross and he reported the following: U. tetralasmus 5, L. subrostrata 4, A. grandis 1, A. imbecilis 1, and L. parva 1.

After finishing the work on Fourteenmile, we worked up the Grand to a point east of Wagoner. On account of flood conditions in the Grand, extreme difficulty of ascent with our outfit, and the paucity of the mussel fauna, it was thought best to transfer our equipment to the Verdigris. The morning after our arrival at the Verdigris, that river reached a high flood stage and continued at high water level for about ten days. Most of this time was spent in studying nearby tributary streams

of the Grand and the Verdigris.

STATION 32, BILLY CREEK (Wagoner).—This is one of the small intermittent streams that flow only during a wet season, altho it has ponded portions that seldom dry up. Billy enters the Verdigis from the north. The same intermittent creek fauna was found for Billy Creek hereinbefore recorded for Ranger Creek: scattering specimens of Unio tetralasmus, Lampislis subrostrata, and Anodonta grandis.

STATION 33, GAR CREEK (Wagoner).—This is a type of stream similar to the one just discussed; it has a little larger volume of water and as a result the ponded portions are deeper and more stable as to their supply. Gar enters the Verdigris from the south. D. Isely, who examined this creek reported the following species: L. subrostrata 5, L. gracilis 1, L. anodontoides 3, A. grandis 10, and a single valve of Symphynota complanata. The absence of U. tetralasmus and the abundance of A. grandis marks a type of mussel association a little in advance of the "tetralasmus" group. The specimens of L. subrostrata from Gar Creek were the largest and thickest shelled representatives of the species found in this region.

STATION 34, PRYOR CREEK (Mayes).—The work on Pryor Creek was done by D. Isely and Cross at a station west of Pryor. A half mile stretch of the creek was examined. Pryor is a tributary of the Grand flowing in a southeasterly direction across Mayes county. High water made collecting difficult, but mussels were found in mud banks and in the bends of the stream. The following is a record of the species found: L. anodontoides 39, L. parva 1, L. purpurata 2, L. luteola 1, S. edentulus 4, T. tuberculata 9, S. complanata 3, Q. pustulosa 5, Q. lachrymosa 7, and Q. undulata 3. A large number of L. anodotoides had recently died and were washed upon the mud bars but no reason was discovered for the death of these mussels.

BIG CABIN CREEK.—This is one of the larger of the creek tributaries of the Grand. It flows thru Craig county and enters the Grand in the northern part of Mayes county. Cabin was examined by the writer at two stations: Welch and Vinita.

STATION 35, BIG CABIN AT WELCH (Craig).—About four miles west of Welch a stretch of creek about a mile in length was examined. A very high flood had just receded; and this gave a most excellent opportunity to study after-flood results upon the mussel fauna of the headwaters of a small stream; however, as the flood water had not entirely run off, a careful investigation of the species inhabiting the deeper water

could not be made. Cabin Creek has a more steady flow of water than Salt, Pryor and Black Bear, on account of a better supply of spring water, and the stream floor is made up of a mud-sand mixture being thus different from that of Fourteen-mile.

At Welch, Cabin seemed to be an ideal L. subrostrata habitat. This light shelled species was found in great numbers in nearly all of the side channels and on many of the bars, where it was actively making its way back into the main channel with the falling of the stream, following the flood. The following species were collected, many of them on the bars, and low bank margins, where they had migrated, and failed to make a safe return to the water; and in other instances where they had been carried out by the strong currents and left stranded: L. subrostrata 61, L. parva 6, L. anodontoides 1, U. tetralasmus 2, A. imbecilla 5, A. grandis 1. Species 6, total specimens 76. Shells of Q. undulata and L. purpurata were also found and these mussels could doubtless have been secured in the deeper holes at a lower stage of the creek.

STATION 36, BIG CABIN AT VINITA (Craig).—The next day August 8, Big Cabin was studied west of Vinita. At this point the creek is considerably larger than at Welch; flood conditions still prevailed. The mussel catch as at Station 35 is represented chiefly by the active light shelled species that had migrated to higher ground on account of high water and were left stranded or had been washed out by the strong currents of the flood water. Anodonta grandis (floater) is as likely to be drifted out by flood currents as any species in our region; on this occasion the bank margin of a rocky shoal were covered with A. grandis specimens, where they had lodged, being brought from a ponded stretch up stream. The following specimens were checked over: A. grandis 66, Lampsilis subrostrata 20, A. imbecillis 4, Symphynota comptanata 6, L. anodontoides 5, L. luteola 4, L. parva 4, Q. lachrymosa 1. Species 8, specimens 110. Here is a fairly diversified fauna with an unusually small representation of Quadrulas. Undoubtedly the heavy shelled species were more numerous than our record indicates. but as noted above conditions did not permit of a thorough examination of the locality.

This is an exceedingly interesting case, clear and clean cut, of one species being succeeded by another as the field worker proceeds down stream. At Welch L. subrostrata was dominant, at Vinita not over twenty miles down stream, cross country. A. grandis had clearly replaced L. subrostrata as the lead-

ing species. At Welch only one specimen of A. grandis was taken.

STATION 37, ILLINOIS AT TAHLEQUAH (Cherokee).—Two days work was put in on the Illinois east of Tahlequah. This is one of the finest clear water streams of Oklahoma but at Tahlequah the Illinois is not much of a mussel stream. The water is clear and flows swiftly over the coarse gravel and clean sand. Hand collecting was the only means available for getting specimens; as a result the deep holes were not investigated. However, I do not believe the deep holes contain many mussels for in a river as swift as the Illinois there would be some shell evidence, along the gravel bars, and over the swift shoals. Not a single drift shell was located. After an extended search along the banks of the river, out of the main current 30 specimens of Lampsilis corvunculus were taken; somewhat nearer the main channel of the stream, a single specimen of Alasmodonta marginata, and two specimens of Quadrula cerina were found. In blind pockets that opened into the river from the down stream side the following specimens were taken: Symphynota complanata 6, L. purpurata 1, L. ventricosa 2, L. parva 6, A. imbecilis 6. A. grandis 2, L. subrostrata 6, and Q. cerina 6. This is rather a queer association of mussels—a mixture of pond and river species. A list of this kind without proper explanations would be altogether misleading and would afford no proper basis for stream characterization based upon its mussel fauna. So definite is the relation of stream conditions and the species of its mussel fauna that an experienced field worker can with considerable accuracy characterize a stream unknown to him if an accurate faunal list with a proper ratio of species is furnished. This is true of many different groups of animals, but in no group, known to the writer, will it work out as readily as for the mussel fauna. The Illinois was the only Oklahoma stream that we investigated that was largely inhabited by river snails the chief kinds being Goniobasis and Campeloma. The latter was found in a number of the other streams in the eastern part of the state but not in the large number characteristic of the Illinois. The list of mussel species of the Illinois is materially increased by a collection sent me from Moodys, Oklahoma by Mr. Thos. S. Hill.*

*Mr. Hill has spent many days collecting on the Illinois and sent me a good collection of species as follows: Q. cerina, L. corvunculus, U. gibosus, L. powellii, L. subrostrata, L. purpurata, L. ventricosa, A. grandis, A. imbecillis, A. marginata, S. costata, T. tuberculata, and L. parva.

VERDIGRIS RIVER FROM WAGONER TO CATOOSA.—The most interesting part of our 1911 work was the examination of the Verdigris from the vicinity of the Mingo Ferry west of Wagoner, up stream to Catoosa, a distance of over 50 miles by the river.

The Verdigris is quite different from the Grand in general characteristics. The shoal stretches are a half mile and more in length and usually far apart; ponded stretches with water from three to fifteen feet deep extend continuously for miles. The river has a very wide course and steep mud banks. When the water supply is good there is a very strong current over the shoaly stretches; at low water, however, the shoals are almost dry, but only in extremely dry years. At ordinary low water the current in the ponded stretches must be rather slow and during dry seasons almost at a standstill. The stream floor is made up in various situations of smooth rock, mud, broken rocks, gravel, and coarse sand.

STATION 38, MINGO FERRY AND VICINITY.—Our first work on the Verdigris was to study the effects of flood waters upon the mussel fauna in a small river. Naturally if flood conditions are going to prove destructive to mussels in a stream like the Verdigris the best place for observation is at the foot of one of these "shoaly stretches" mentioned above. The Mingo Ferry is located at one of these places and a series of gravel bars and flat rock ledges projecting normally above the water about two feet afforded an excellent opportunity for lodgment of mussels carried by the strong currents at the flood period. As noted on several occasions before, the losses to heavy shelled species are slight. For some of the light shelled kinds the loss was considerable. The enumeration given below shows living or recently dead mussels stranded upon the bars and rocks: Lampsilis gracilis 8, Plagiola elegans 38, P. donaciformis 12, Obliquaria reflexa 12, Quadrula pustulosa 12, Q. nobilis 12, Q. pyrimidata 7, Q. undulata 7, Q. heros 2, L. ventricosa 4, L. anodontoides 9, L. purpurata 2. In the light of our later work this list is especially interesting for in half an hour we secured more specimens of the first six species named, at this one point on the Verdigris, than in all the rest of the nine days work. It must not be forgotten that there are at least two important factors to be taken into account in explaining the stranding of mussels at flood times. (1) As I ahve already pointed out some species react positively to the flood influences and have a tendency to seek higher ground and become stranded as the

flood recedes; (2) others on account of light inflated shells are likely to be swept along the stream floor by the strong currents of high water. The apparent paucity of certain species in the river as a whole, while found in good numbers at this station, is to be explained either by the fact that they are widely scattered and not found in the large colony beds of the more abundant species listed below or that in our collecting work we did not locate their distinctive habitats. Further, it may be noted, that while the destruction of species was slight, taking into account the aggregate fauna, at no other place in our cruise up the Verdigris did we find as many stranded specimens as at the Mingo Ferry.

One mile below the Mingo Ferry we located a good sized mussel bed, in fact large enough so that it might be of commercial interest should many beds of this size appear in the river. This bed was about eighty yards in length and six to ten yards wide. On account of the large mussel population we tried to get some little detailed data concerning the conditions of this habitat. The records taken are as follows: temperature over the bed 85° F., current over bed 100 feet in 80 seconds or about three-quarters of a mile an hour, depth of water over bed 3-8 feet, maximum depth of water in channel 15 feet, stream floor made up of a firm mixture of broken shale, gravel, and mud. The mussels were well rooted in this bottom and it was a little difficult to secure them by hand collecting. To get at a rough estimate of the possible aggregate commercial product in a bed of this kind we used the method recommended by Dr. Coker* by making a count of all specimens secured in a 100 square feet.

The results obtained were as follows: Quadrula undula 262, Q. heros 45, Q. rubiginosa 8, Q. pustulosa 1, Q. pyramidata 46, Plagiola securis 16, Lampsilis 1, L. purpurata 1, Tritogonia tuberculata 2, Ptychobranchus phaseolus 1. Most of the foregoing are commercial species and all were medium to large size, altho the average especially for the Q. undulata was quite a little below the average found in a number of other streams in this region. The measurements in mm. and the weight of ten average specimens is given below:

Species	1	2	3	4	5
Quadrula undulata	average	90	75	50	3
Quadrula heros	largest	140	100	55	
	smallest	105	85	35	8

*General directions for Field Parties, 1911.

Quadrula pyrimidata	largest	65	55	40	
	smallest	55	50	40	3
Plagiola securis	largest	90	65	35	
	smallest	60	45	20	4

Figures above columns are used as follows: 1—size; 2—length; 3—height; 4—Thickness, and 5—shell weight of average specimen.

On this basis the aggregate catch on 100 sq. ft. of the four chief species would average 133 pounds. The bed contained 5760 sq. ft. according to figures given above, or about one-eighth of an acre. This would give us 7660.8 pounds of shells or nearly three tons from an area of this kind in the Verdigris. A second count was made on the same bed a short distance above the one just described, giving a ratio of species and aggregate number of specimens quite similar to the count just described.

STATION 39, ONE MILE ABOVE THE MOUTH OF BULL CREEK.—This portion of the Verdigris river was pointed out to us as being especially rich in mussels. In water 2-4 feet deep, with gravel mud bottom, random collecting gave the following ratio of species per hundred: Quadrula metanevra 10, Q. pyramidata 50, Q. undulata 14, Q. heros 3, Q. hebetata 7, Q. pustulosa 5, Q. reflexa 5, Tritogonia tuberculata 3, Ptychobranchus phaseolus 1. Station 39 shows a clear dominance of Q. pyramidata over Q. undulata.

The mussels for the species of which representatives are found in the Verdigris, were nearly all medium to large; in fact, very few small specimens were taken by us in this river.

STATION 40, NORTHWEST OF INOLA ON THE VERDIGRIS (Rogers).—The record of river conditions at this station was as follows: Width of stream 93 feet; current a little over a mile an hour; depth of water over bed 2-4 feet; maximum depth in channel 8 feet; bottom firm mixture of mud and gravel. In a catch of 200 the following species were found: Quadrula pyramidata 128, Q. heros 2, Q. undulata 55, Tritogonia tuberculata 1, Plagiola securis 5, Obliquaria reflexa 1, Ptychobranchus phaseolus 4, Q. rubiginosa 2, Q. metanevra 2. Near the above station in a stream floor made up of broken shale and gravel, water 4-5 a stream floor made up of broken shale and gravel, water 4-5 feet deep the following were taken: Q. undulata 30, Q. pyramidata 8, Q. metanevra 1, and T. tuberculata 1.

In our 1911 work we carried a small 20 hook crowfoot dredge. We had no use for this apparatus until we reached the Verdigris and here on account of rough bottom in the deeper water is was not very successful; however, with this apparatus

we were able to investigate water 12-15 feet deep and almost without exception, a few specimens of the two dominant species —Q. undulata and Q. pryamidata—were brought up with the crowfoot in deep water.

STATION 41, EAST OF CATOOSA (Rogers).—Below the ford at Catoosa a checking up of specimens per 100 sq. ft. was applied to a narrow bed of mussels. The record of the river conditions was as follows: Total width of stream 108 feet, current about a mile an hour, depth over bed 2-4 feet, bottom gravel-sand mixture. The following species were secured: Q. solida 135, Q. undulata 90, Q. heros 10, Q. reflexa 3, Q. metanevra 3, P. securis 3, L. anodontoides 3. Species 7, total specimens 255. The mussels were of fair size with no small specmiens in the lot.

In addition to the species listed under the accounts of the respective stations many random specimens were collected, including: Cypregenia aberti 5, L. subrostrata 1, L. laevissima two shells, Q. cylindrica several shells, Q. lachrymosa 1.

A point of special interest to me in the Verdigris work was the almost absolute absence of mussels under medium sizes; certainly very little recruiting of the mussel fauna of the Verdigris took place in 1911.

STATION 42, VERDIGRIS AT COFFEYVILLE, KANSAS (Montgomery).—July 9, 1912, another opportunity was afforded to study the Verdigris at Coffeyville. A stretch of the river about a half mile west of the Sante Fe bridge north of the town was examined. As time was limited a very extensive study was not possible and the chief interest centers in the fact that three species not taken in our ten days work up the Verdigris in 1911 were added to the faunal list. The specimens were Lampsilis luteola 1, Symphynota complanata 3, Strophitus edentulus 2. These species are more characteristically found in the smaller streams in this region and this fact is emphasized by their up stream appearance in the Verdigris. I should expect these and other small stream species to become more abundant farther up river. Other specimens taken at Coffeyville were: Q. undulata 5, Q. pustulosa 4, Q. heros 4, Q. metanevra 3, Q. cylindrcia 1, Q. pyramidata 12, Q. lachrymosa 4, Q. rubiginosa 1. Q. pustulosa 1, P. elegans 3, O. reflexa 2, L. recta 1, L. ventricosa 8, L. gracilis 8, L. purpurata 6, L. anodontoides 6, and T. tuberculata 3. Altogether 29 species are listed for the Verdigris in this report.

BIRD CREEK.—This creek drains a good portion of the Osage country and enters the Verdigris at Catoosa. It is a

rocky stream similar to Salt Creek. There are deep holes and rocky shoals. Bird Creek was studied at two stations.

STATION 43, BIRD CREEK AT CATOOSA (Rogers).—About a mile stretch of the creek was explored by D. Isely and Cross. Collecting in the deep holes was not possible, but at the shoals a number of shells were secured. Q. undulata was clearly the dominant species.

STATION 44, BIRD CREEK AT NELAGONEY (Osage).—The creek was studied at this station in 1912. In the bends of the creek there are mud banks but sand and gravel are not abundant as bottom material. At a ford a short distance above the M. K. & T. R. R. the creek narrows down to two feet in width; a ponded stretch of deep water is found below the ford. Here were collected: Quadrula undulata, Q. rubiginosa, Q. subrostrata, Lampsilis luteola, Q. tuberculata, Andonta grandis, and L. purpurata. The Q. undulata and Q. rubiginosa specimens are much larger and thicker than representative specimens from the Verdigris.

NEOSHO RIVER.—In Ottawa county at Miami the Neosho was briefly examined in 1911; in 1912 two days were spent on the Neosho near the state line at Chetopa, Kansas. The Neosho-Grand is the only stream in our region that has been commercially used for shell supply in the button industry. A blank factory was put in at Iola in 1912 and others are in operation now. The shells are said to be of fair grade. As already pointed out mussels are virtually absent in the lower Grand; from Miami up the river they are said to be abundant. The Neosho may be described as a clear water stream of good size, with a gravel-sand-mud bottom or pure mixtures of the above materials in the various portions of the stream. The heavy coarse gravel of the lower Grand is not found in the Neosho. This heavy gravel is probably derived from Spring River and the other smaller eastern tributaries of the Grand.

STATION 45, NEOSHO AT MIAMI (Ottawa).—This station was visited Aug. 23, 1911. The water was too high to make work in the stream possible but a couple of shellers had been at work in the Neosho at this point, some months previous to my visit. The shellers had been prospecting for shells to supply a proposed button factory at Miami. The factory project did not materialize but about twenty tons of shells had been collected and gave excellent data as to species and the relative abundance of each kind. The leading kinds represented in the shell heap were: Quadrula undulata, Q. nobilis, Q. rubiginosa,

Q. pyramidata, Q. heros, Q. metanevra, Unio gibossus. I was told by a fisherman at Miami, that a large number of Lampsilis anodontoides, Plagiola securis, and L. ligamentina had been secured but that when the factory project fell thru these species had been sacked up and shipped to a blank factory as they were considered to be of superior value by the mussel fishermen.

STATION 46, NEOSHO AT CHETOPA (Cherokee Co., Kans.),—July 10-12, 1912 the Neosho was again studied at Chetopa. In collecting at this place I attempted to get further data concerning the relative influence of bottom conditions, current, and depth of water upon the distribution of the various species within the stream. This can only be done and give significant data where mussels occur with a fair degree of abundance. To show the results of my findings I give below, as I have in other instances in this paper, a brief characterization of the conditions under which the specimens of the different areas were found. Altogether 442 specimens were checked over in the study at Chetopa. The stretch of the river studied the first day extended for about a half mile above the wagon bridge that crosses over the Neosho at Chetopa.

Habitats: I. In the first bend of the river to the left above the wagon bridge, out of the main current, in water 2 to 3 feet deep, bottom gravel mixed with mud; II. A strip outside I. near the bank, very little current, water 2-3 feet deep, bottom chiefly mud 2-4 inches deep; III. In the same general area, a strip inside of I, nearer the main channel, fair current, water 2-3 feet deep with gravel bottom. After the work on these areas was completed another general area was selected a quarter of a mile above I-III. Habitat IV was located about fifty yards above a sharp bend in the river, the water at the bend being 6-10 feet deep, over area IV 2-3 feet deep, with almost no current, and mud bottom; V. About 100 feet up the river from IV, slow but steady current, water 2 to 3 feet deep, bottom sand-mud mixture; VI. Half way between IV and V with intermediate conditions. The mussel bed along this stretch was very narrow, varying from 3-8 feet, but the mussel population was dense. In all of these habitats the water is about the same depth and the comparison centers around the bottom conditions and the current, but these two factors can not be separated; however, one might say that since current controls distribution of bottom materials, that current is the main factor; and on the other hand, we might conclude that the kinds of materials that

make up the stream floor are the chief considerations. The specifications "strong current," "slight current," etc., are not very instructive, unless used comparatively. When thus used in limited areas in the same stream, the significance is clear enough and the importance of these variations as factors in the distribution of species is recognized by all experienced field students af aquatic life.

The river in the region of habitats IV-VI was about 300 feet wide, but the mussels were restricted to a narrow strip. My observations in this matter were confirmed by Mr. A. Shultz, of Chetopa, a trapper and fisherman who had known the river for a number years in this region. I am not trying to explain at this time the mussel population of a stream, but I do wish to call attention to the need of further study of these facts. Still further up stream, about 200 yards below the Pacific R. R. bridge, another area was examined. Habitats: VII. Water 2-4 feet deep, good current, sand-gravel bottom with some mud; VIII. Water 5-4 feet deep, strong current, bottom broken rocks and gravel.

About a fourth of a mile below the Chetopa road bridge a fourth area was studied on the following day. A rise of about a foot in the river must be taken into account in comparing the current and depth with the areas of the day previous. However, the current is very much stronger in the IX-X habitats. Habitats: IX. Water 2-4 feet deep, swift current, bottom gravel—hazel nut to egg size—and broken rocks; X. A short distance below IX water 2-4 feet deep, very swift current, clean gravel bottom.

Species Habitats:	I	II	III	IV	V	VI	VII	VIII	IX	X	Total
Quadrula undulata	29	15	14	32	62	22	26	12	11	6	229
Quadrula nobilis	15	3	11	2	7	3	10	1	8	1	61
Quadrula pustulosa	22	--	11	1	1	--	9	1	20	6	71
Quadrula rubiinosa	4	5	13	3	10	2	12	--	20	10	79
Quadrula metanevra	5	1	3	--	--	--	1	--	6	3	19
Quadrula pyramidata	4	3	8	1	3	1	12	--	1	3	36
Quadrula cylindrica	1	--	--	--	--	1	--	--	--	--	2
Quadrula heros	--	3	3	6	7	--	3	--	--	1	23
Lampsilis anodontoides	4	11	1	10	5	5	--	--	--	--	36
Lampsilis gracilis	--	1	--	2	1	1	--	--	3	--	8
Lampsilis ventricosa	2	3	--	7	5	3	1	--	--	--	21
Lampsilis ligamentina	--	--	--	3	3	--	3	4	9	10	32
Lampsilis purpurata	--	--	--	2	2	--	--	--	--	--	4
Lampsilis recta	--	--	--	--	--	--	1	1	--	--	2
Tritogonia tuberculata	2	1	6	5	2	4	--	2	4	2	28
Plagiola donaciformis	--	--	--	--	--	--	1	--	--	--	1
Plagolia securis	--	--	--	--	--	--	--	1	1	--	2
Anodonta grandis	--	--	--	--	1	--	--	--	--	--	1
Strophitus edentulus	--	--	--	--	--	1	1	--	--	--	2
Ptycobrano phaseolus	2	--	2	--	--	--	1	--	1	--	6
Unio gibbosa	4	5	2	5	--	1	13	2	7	6	45
Obliquariaus reflexa	1	1	1	--	1	--	--	--	--	--	4
Symphynota complanata	--	--	1	--	--	--	--	--	--	--	1
TOTALS	95	52	76	79	110	44	94	24	90	48	712

Indicators of optimum habitats are not so clearly pointed out in the Neosho study at Chetopa as some other habitat studies we have tabulated. The ten habitat groups may be separated into two chief groups of I-VI and VII-X; the series grades from II and IV at one ent to IX and X at the other. The presence of 21 out of 36 specimens of Lampsilis anodontoides in II and IV show the still-water-mud-bottom association centering around the yellow sand shell; the absence of this species at VII to X is another useful indicator in classification; in this latter grouping L. ligamentina shows 26 out 32 in VI-X habitats. Other suggestions will be followed in the discussion of individual species.

STATION 47, DEEP FORK OF THE CANADIAN AT OKMULGEE (Okmulgee).—The observations at this station were made by Mr. Cross. Below the dam across the creek at Okmulgee he found nine species.

STATION 48, NORTH FORK OF THE CANADIAN AT WEELETKA (Okfuskee).—D. Isely reported for this station. In bends of the stream in deep mud the following were found: Lampsilis gracilis 53, L. laevissima 48, L. anodontoides 4, Obliquaria reflexa 2, Tritogonia tuberculata 1, Plagiola donaciformis 7, Quadrula undulata 1, Q. pustulosa 7, Q. pustulata 2, Q. forsheyi 9. In the very soft mud the light shelled L. laevissima was dominant. This is a very interesting study of dominance of the paper shelled mussels.

POTEAU RIVER.—This river enters the Arkansas from the south near Ft. Smith, Ark., and as already pointed out it differs markedly from the other southern tributaries of the Arkansas. In its upper course it is a mountain stream and with the Kiamichi drains the rough mountainous country south of the Arkansas in eastern Oklahoma and western Arkansas. The lower Poteau is a sluggish, deep, base leveled stream with an occasional shoal.

STATION 49, POTEAU AT POTEAU (Le Flore).—The area selected for study was at a shoaly stretch about 300 yards above the Poteau wagon bridge. The Poteau mussels are quite different from the species in other streams of the Arkansas River area. As in some of my other work definite habitats were studied and counts made of specimens and species.

Habitats: I. Fifty yards below the shoals, water 2-3 feet deep, slow current, bottom broken rocks and gravel, mussels scattering; II. in bend of stream below I. water 2-3 feet deep, no current, mud bottom; III. just a short distance above shoals,

water 1-2 feet deep, slow current, gravel bottom also found under rocks.

Species Habitats	I	II	III	Tot.
Quadrula plicata	17	41	7	65
Quadrula undata	14	9	1	24
Quadrula pustulosa	26	160	6	192
Quadrula heros	1	1	--	2
Quadrula pyramidata	14	19	--	33
Tritogonia tuberculata	7	4	1	12
Plagiola elegans	2	2	--	4
Plagiola securis	--	2	--	2
Lampsilis ligamentina	5	--	2	7
Lampsilis recta	1	1	--	2
Lampsilis anodontoides	--	3	--	3
Lampsilis purpurata	--	13	1	14
Obliquaria reflexa	--	14	--	14
Unio gibbosus	--	--	4	4
Symphyhota complanata	--	2	--	2
TOTALS	87	271	22	380

In the Poteau Quadrula plicata and Q. undata seem to replace Q. undulata and Q. rubiginosa of the other streams. The shells of the plicata are very thick and the furrows shallow. The unusual abundance in comparison with other species, of Q. pustulosa is one of the interesting facts in the study of the Poteau fauna. The habitat differences were not as marked as in some other studies herein reported. The fact that differences existed is best shown in the distribution of L. ligamentina in I and L. purpurata and L. anodontoides in II.

STATION 50, CASTON CREK, AT WISTER (Le Flore). —This small rocky tributary of the Poteau was examined near Wister. Fifteen species were collected. This is rather a formidable list of species for a small creek. It is, however, made up strictly of pond and creek mussels and is enumerated in the table.

In the table given below showing distribution of species in the Arkansas River Drainage the significance of terms as to the relative abundance of species is the same as that used for the Red River fauna. The Chikaskia is shown with the other streams altho a detailed discussion of the Chikaskia system with a special tabular study follows later. The rivers (with their respective collecting stations) are arranged in the order in which they enter the Arkansas as one goes down stream, the

Chikaskia a tributary of the Salt Fork of the Arkansas being an exception to this order. The creeks are arranged in an arbitrary manner with some attempt to arrange them in order of size, altho this not closely followed.

DISCUSSION OF THE ARKANSAS RIVER DATA.

The Neosho and the Verdigris with over two dozen species each are the important mussel streams in the northern drainage. Heavy shelled Quadrulas predominate. Q. undulata leads in the Neosho, representing a third of the catch at Chetopa; Q. undulata and Q. pyramidata are about equal in numbers in the Verdigris; Lampsilis anodontoides is fairly common in favored localities in both streams. As far as one can judge from the lists, the differences express themselves best in the commonness of L. ligamentina and Unio gibbosus in the Neosho. The Illinois has too much gravel to figure as a commercial stream; however some interesting habitats and facts of distribution are found. The Poteau, while not especially rich in its mussel fauna, deserves to be classed in the Neosho-Verdigris group. The sandy master stream, with tributaries of like characteristics, as North Fork of the Canadian and Deep Fork, support in favored habitats the paper shells, L. laevissima and L. gracilis. The various creeks afford quite an extensive range of environments. The stony creeks of the Bird and the Salt Creek type are occupied almost exclusively, as far as the mussel fauna is concerned, by a very heavy shelled variety of Q. undulata. Big Cabin, on the other hand, represents a type of clear water creek, that affords the best conditions for the activities of L. subrostrata, Anodonta grandis, and other members of this association.

As shown by the above table nine different species are clearly dominant at one or another of the 29 stations enumerated. Ten species are found in only one stream and some of these at only one station.

Chikaskia River Drainage.

As already indicated the writer began studying the mussel fauna of the Chikaskia in 1908. This work was continued from time to time, and as a result, a much more thorough study was made of the fauna of the Chikaskia drainage than was possible of the other regions discussed above. On this account the Chikaskia work can be given with more detail, profitably.

The Chikaskia is located in south central Kansas and north central Oklahoma. This stream furnishes an important part of the drainage of Sumner, Harper, and Kingman counties of Kan-

TABLE 2 SHOWING DISTRIBUTION OF FRESH-WATER MUSSELS OF THE ARKANSAS RIVER DRAINAGE. CREEKS ARE LISTED IN GENERAL FROM LARGEST TO SMALLEST.

Mussel species	Streams and Stations: Ark.R. 23	Ark.R. 24	Verdigris 38	Verdigris 40	Verdigris 41	Verdigris 42	Neosho-Grand 29	Neosho-Grand 45	Neosho-Grand 46	I 37	P 49	Chi.R. 62	Chi.R. 74	Creeks: 48	47	43	44	25	50	26	27	30	34	35	36	33	32	31	28	Number of collecting stns where species is found
1.Quadrula pyramidata	-	-	a	d	d	c	-	a	c	-	c	-	-	-	-	c	-	-	-	-	-	-	-	-	-	-	-	-	-	8
2.Quadrula solida	-	-	-	-	-	-	-	-	c	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
3.Quadrula undata(Pig-toe)	-	-	-	-	-	-	-	c	a	-	c	-	a	c	-	c	c	-	-	-	-	-	-	-	-	-	-	-	-	1
4.Quadrula cerina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	d	-	-	-	-	-	-	-	2
5.Quadrula hebetata	-	-	f	f	-	c	-	c	a	-	-	-	c	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
6.Quadrula rubiginosa	-	-	-	-	-	-	-	c	a	-	-	a	c	-	-	c	c	c	-	-	-	-	-	-	-	-	-	-	-	7
7.Quadrula pustulata(Pimple-back)	-	-	-	-	-	r	-	-	a	-	-	-	-	c	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
8.Quadrula pustulosa(Pimple-back)	o	-	o	f	f	o	-	c	a	-	d	a	a	c	f	-	-	f	o	a	-	f	-	-	f	-	-	-	-	17
9.Quadrula forsheyi	-	-	-	-	-	-	-	-	-	-	-	-	-	c	f	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
10.Quadrula fragosa	-	-	-	-	-	-	-	-	r	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
11.Quadrula lachrymosa	-	-	-	-	-	f	-	-	-	-	-	f	a	-	-	c	-	f	-	f	c	c	-	r	c	-	-	-	-	10
12.Tritogonia nobilis	-	-	c	-	-	-	c	c	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
13.Quadrula metanevra(Monkey-face)	-	-	-	c	f	f	c	c	c	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
14.Quadrula cylindrica(Rabbit's foot)	-	-	-	-	r	r	r	r	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
15.Quadrula heros(Washboard)	-	-	a	f	c	f	a	c	c	-	f	-	-	-	-	r	-	-	-	-	-	-	-	-	-	-	-	-	-	9
16.Quadrula undulata(Three-ridge)	-	-	d	a	a	a	a	a	d	-	-	c	a	f	f	a	d	d	r	f	-	-	f	-	f	-	-	-	-	18
17.Quadrula perplicata	-	-	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
18.Quadrula plicata(Blue-Point)	-	-	f	-	-	-	-	-	f	-	-	-	-	-	-	-	f	f	-	-	-	-	-	-	-	-	-	-	-	4
19.Unio tetralasmus	-	-	-	-	-	-	-	-	-	o	-	-	-	-	-	-	-	-	-	-	o	-	r	-	-	-	f	f	o	5
20.Unio gibbosus(Lady-finger)	-	-	-	-	-	-	-	a	a	f	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
21.Alasmidonta marginata(Elk-toe)	-	-	-	-	-	-	-	-	-	o	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
22.Symphynota complanata(Heel-splitter)	-	-	-	-	-	f	-	f	r	f	f	-	o	-	-	-	-	f	o	o	r	r	a	o	f	a	-	-	-	15
23.Symphynota costata(Fluted shell)	-	-	-	-	-	-	-	r	r	f	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
24.Anodonta grandis(Floater)	-	-	-	-	-	-	-	-	r	f	-	o	o	-	-	-	a	-	o	-	-	o	r	d	-	o	f	o	-	12
25.Anodonta imbecillis	-	-	-	-	-	-	-	-	-	f	-	-	-	-	-	-	-	-	-	-	-	f	-	-	-	-	-	f	-	3
26.Strophitus edentulus(Squaw-foot)	-	-	-	-	r	-	r	r	r	-	-	-	-	-	-	-	-	-	o	-	-	f	-	-	f	-	-	-	-	6
27.Ptychobranchus phaseolus(Kidney-shell)	-	-	o	f	o	-	f	f	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
28.Obliquaria reflexa(Three-horned warty-back)	-	-	o	o	f	f	f	o	-	-	o	-	f	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-	-	10
29.Cyprogenia aberti	-	-	r	r	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
30.Tritogonia tuberculata	-	-	f	o	f	-	o	o	r	f	o	-	a	f	o	a	a	f	f	-	-	-	-	o	-	-	-	-	-	16
31.Plagiola donaciformis	r	-	o	-	-	-	-	-	r	-	-	-	o	o	-	a	-	-	-	-	-	-	-	-	-	-	-	-	-	5
32.Plagiola elegans(Deer-toe)	-	-	a	-	-	-	-	-	-	r	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-	-	-	-	5
33.Plagiola securis(Butterfly)	-	-	o	o	f	-	-	r	r	-	o	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
34.Lampsilis laevissima(Paper-shell)	o	f	-	-	r	-	-	f	f	-	-	-	f	d	f	-	-	a	-	f	-	r	r	r	-	r	-	-	-	16
35.Lampsilis gracilis(Paper-shell)	o	r	o	-	-	o	-	f	f	-	o	-	f	d	f	a	-	a	o	f	-	f	r	r	o	-	-	-	-	15
36.Lampsilis purpurata(Purply)	-	r	r	-	-	o	-	-	-	-	o	-	-	-	-	a	-	a	o	f	-	f	-	f	-	-	-	-	-	8
37.Lampsilis corvunculus	-	-	-	-	-	-	-	-	-	a	o	-	-	-	-	-	-	-	-	-	-	f	-	f	-	-	-	-	-	2
38.Lampsilis parva	-	-	-	-	-	-	-	-	-	f	o	-	-	-	-	o	-	f	-	-	-	f	o	f	r	-	-	d	-	11
39.Lampsilis subrostrata	-	-	-	-	r	-	-	-	-	f	o	-	-	-	-	o	-	o	-	-	-	f	-	d	a	f	f	f	-	11
40.Lampsilis recta(Black sand-shell)	r	-	o	-	-	o	-	f	o	-	o	-	-	-	f	-	-	-	-	-	-	f	-	-	-	-	-	-	-	6
41.Lampsilis fallaciosa(Slough sand-shell)	-	-	-	-	-	-	-	-	-	-	-	-	-	f	f	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
42.Lampsilis anodontoides(Yellow sand-shell)	-	-	o	o	o	o	a	o	o	-	f	-	o	-	-	-	-	f	o	f	o	o	r	f	o	f	-	-	-	17
43.Lampsilis ligamentina(Mucket)	-	-	-	-	-	-	a	o	o	-	o	-	-	-	-	-	-	-	-	-	-	r	-	-	-	-	-	-	-	5
44.Lampsilis powelli	-	-	-	-	-	-	-	-	o	o	-	-	-	-	-	a	a	-	-	-	-	f	a	f	o	-	-	-	-	6
45.Lampsilis lutecia(Pat mucket)	-	-	-	-	-	o	-	-	-	-	-	-	-	-	-	a	-	-	-	f	-	-	a	-	-	-	-	-	-	6
46.Lampsilis ventricosa(Pocketbook)	-	-	o	-	-	o	-	f	f	r	o	-	-	-	-	r	-	-	-	f	-	-	o	-	-	-	-	-	-	8
Number of species in each stream	4		28				29			12	17	14		9	7	14	11	12		10	17	9	13	5		3	4	2		

Explanation of Table 2.

Streams and Collecting Stations.

Stations 23 and 24. Arkansas River.
Station 25. Salt Creek.
Stations 26 and 27. Black Bear Creek.
Station 28. Tulsa Slough.
Station 29. Grand.
Station 30. Fourteenmile Creek.
Station 31. Ranger Creek.
Station 32. Billy Creek.
Station 33. Gar Creek.
Station 34. Pryor Creek.
Stations 35 and 36. Big Cabin Creek.
Stations 37. Illinois Creek.
Stations 38, 39, 40, 41 and 42. Verdigris River.
Stations 43 and 44. Bird Creek.
Stations 45 and 46. Neosho River.
Station 47. Deep Fork of the Canadian.
Station 48. North Fork of the Canadian.
Station 49. Poteau.
Station 50. Caston Creek.
Symbols are the same as those used for table 1.

sas, and Kay county in Oklahoma. It also drains small portions of Pratt and Barber counties in Kansas, and Grant county in Oklahoma. The area thus drained is over three thousand five hundred square miles. The master stream is about 125 miles long and has an average fall of eight feet per mile. The 2000 foot contour crosses its head-waters, and the 1000 foot line passes over the stream a few miles above the mouth.

Geology, Geography, and Soils

The Chikaskia is a clear water stream of the small river class. It rises in the high plains of western Kansas, in the southern part of Pratt county. It is here a small prairie draw, fed by the springs of the Tertiary formation. It passes eastward into Kingman county, gradually deepens its channel, and finally, near the eastern side of Kingman county, cuts thru the tertiary upland into the Red Beds. In Sumner county, Kansas, it flows thru the Red Beds, passes into Oklahoma near Caldwell, enters Kay county near the northwest corner, and flows south emptying into the Salt Fork of the Arkansas a few miles southwest of Tonkawa.

The stream flows across three kinds of rocks: first, the Tertiary sands and clays, from which issue the springs of clear water which give the stream its perennial flow; second, the Red Beds in eastern Kingman and western Sumner counties in Kansas; and third, the gray clays and shales of Kay county in Oklahoma. The sand in the river is derived largely from its head waters and its chief tributary Bluff Creek. The purity of the water is the result of the Tertiary springs which issue from the head of the stream.

River Characteristics

In describing the characteristics of the Chikaskia the river may well be divided into upper and lower portions:

UPPER RIVER: The white shifting sands of the upper course derived from the head waters extend down into southern Sumner county. My field notes for May 1, 1909 describe the upper river at the bridge south of Spivey (Kingman) as follows: "The river at this place is 100 feet wide. The bed is of fine white sand, and the water is fairly swift, clear and shallow. There are no places in this part of the stream for a mile in either direction where the water is over three feet deep." At Argonia twenty-five miles farther down stream the river is much the same as at Spivey. A gradual change in conditions is

noticed below Argonia and becomes quite marked three or four miles above Drury.

LOWER RIVER: Below Drury conditions are clearly different from those of the upper river. The water depth is sufficient to afford many favorable holes for fish. The lower course tributaries bring large quantities of mud and silt, and probably add materially to the calcium content. The channel is narrower and deeper and the stream more confined to a definite course, the bottom varies. The current is also more variable in the lower river and it is an important factor in the formation of the various types of habitats. Another important factor is that, more or less permanent stretches free from shifting sand are found.

As regards current and bottom, the following common zones may be named: (1) swift current flowing over bare rocks, gravel, and coarse sand; (2) fairly swift current flowing over coarse sand and sand silt; (3) slow moving water flowing over deep holes, mud banks in bends of stream, and thru side channels; (4) still water covering mud and silt bottom bays; (5) swales beyond margin sand bars, with sand silt bottom and intermittent water supply.

Tributary Streams

BLUFF CREEK: This is the largest of the tributaries, being about 75 miles in length, and flowing into the Chikaskia a few miles below Drury. Bluff Creek has many of the upper-course characteristics of the master stream; the last few miles of the lower part of Bluff is comparable with the Drury portion of the Chikaskia.

SHOOFLY CREEK: This creek is not over 25 miles in length and flows south thru southern Sumner county and northern Kay county where it joins the Chikaskia near Willston. The water supply is fairly abundant and pure. The soil is largely grey, red and blue shales. Mussels are abundant in the ponded areas of the lower Shoofly. These ponded stretches are often 200-300 yards in length, about 35 feet in width, and the water is 3-6 feet deep. The central two-thirds of the bottom is made up of broken shale and gravel, mixed with coarse sand with a silt top covering of one to two inches. The sub-stratum is put down at high floods and the silt cover during minor freshlets. Mud banks are usually found along the sides of these ponded areas.

HEAD WATER SLOUGHS: Typical sloughs were studied on Spring Creek, Grant Co.; Duck Creek near Autwine; Wild Horse Creek near Spivey; Spring Creek, near Anthony; and

upper Shoofly near South Haven. These sloughs may be put into two classes: (1) the pure water slough type, such as we find in Spring Creek, Grant county, where there is a fresh supply of spring water constantly flowing into the sloughs; (2) the stagnant water sloughs, such as we find on Duck Creek, where the sloughs are supplied mainly at flood periods and are subject to shrinkage and in some cases to drying up during drought periods. Between the headwater sloughs of the first type the narrow connecting stretches may afford interesting habitats for certain mussels and are usually populated by large numbers of the various species of Sphaeridae.

Mussel Survey of Chikaskia Drainage

STATION 51, WILD HORSE AND ROSE BUD CREEK AT SPIVEY (Kingman).—From shell evidence, Anodonta grandis and Lampsilis subrostrata are fairly abundant in the sand bottomed sloughs of these creeks.

STATION 52, SAND AND SPRING CREEKS NEAR ARGONIA (Sumner).—The habitats studied in these creeks belong to the fresh-water slough type. The species found were A. grandis and L. subrostrata.

STATION 52, SPRING CREEK IN THE NORTHEAST CORNER OF GRANT COUNTY.—This is a typical fresh-water slough habitat. L. subrostrata and Unio tetralasmus were found to be abundant in pockets near the water line in deep cold sloughs. On the farm where this slough was found the residents considered the meats of the species named here as "good eating as oysters." The meats in these species is not as tough as the river mussels and coming from clean stream they should make desirable food. In the narrow connecting channels L. parva and L. subrostrata were occasionally found.

STATION 54, UPPER SHOOFLY AND BRANCHES OF SHOOFLY NEAR SOUTH HAVEN (Sumner).—These creeks are a little larger than the ones mentioned for stations 51-53. U. tetralasmus was the chief species in the branches. In the largest creek A. grandis and L. parva were found, and a single small sized valve of Quadrula undulata.

STATION 55, DUCK CREEK AT AUTWINE (Kay).—This is a very sluggish creek of the surface water supply type. U. tetralasmus is the dominant species. A. grandis and L. parva are found in fair numbers.

STATION 56, STINK CREEK NEAR TONKAWA (Kay).—A small and sluggish creek, with temporary water supply. Only one species, U. tetralasmus was found.

STATION 57, SHOOFLY CREEK AT WILLSTON (Kay).—Shoofly creek at this point may be compared with favorable stretches of Bird and Salt creeks. In the ponded portions of this creek in the gravel-rock-sand-silt bottom covered with a thin layer of mud, Q. undulata is dominant. Q. pustulosa, Q. lachrymosa, Tritogonia tuberculata, A. imbecilis, L. gracilis, and Symphynota complanata were found. A. grandis is abundant in certain mud-bottomed areas and along the mud banks L. anodontoides is occasionally found.

STATION 58, BLUFF CREEK AT ANTHONY (Harper).—Like the upper Chikaskia, Bluff creek at this point is a shallow shifting stream. Where it was examined for a two mile stretch in 1909, not a trace of a mussel could be found.

STATION 59, BLUFF CREEK IN NORTHEAST GRANT COUNTY.—On lower Bluff Creek Q. pustulosa and Q. lachrymosa were common; the specimens were small showing that they had not lived in this situation long. L. subrostrata was a frequent species and shells of A. grandis and L. purpurata were found.

STATION 60 and 61, CHIKASKIA AT SPIVEY AND ARGONIA.—The upper Chikaskia is poorly suited to mussel activity. It is possible that in a series of favorable seasons, L. subrostrata, L. parva and possibly Q. pustulosa may get a temporary footing in the side channels. At these stations the river was examined for several miles in 1909 and not a trace of a living mussel was found. Two badly weathered valves, one of U. tetralasmus and one of L. anodontoides were found on the sand bars at Argonia.

As stated before the Chikaskia was studied every year since 1908. In 1912 a checking up of the former work was undertaken and the results given below are, for the most part, based on the 1912 work. In 1909 I found that mussels were entirely absent from the Chikaskia at Spivey and Argonia, while at Drury 20 miles down stream the Quadrulas were abundant. I was anxious to locate, if possible, the upper limit of the mussel fauna in the Chikaskia, so I determined to start at Drury and work up stream.

STATION 62, ONE AND ONE-HALF MILES ABOVE DRURY (Sumner).—At this station the water was shallow, the bottom sandy, and the current strong. On the west bank there is a high blue shale bluff which, I show later in this paper, has rather an interesting relation to the mussel beds in this stream. Certain Quadrulas were taken in good numbers at this point, Q.

pustulosa 35, Q. rubiginosa 35, Q. lachrymosa 4, Q. undulata 11, also Lampsilis parva 4, and L. subrostrata 3. The mussels were small, the average size for pustulosa and rubiginosa being about 35 mm. and a good number were taken 12-20 mm. in length. A number of shells were picked up from the bar below the bluff, and on account of the absence of some of these species from other Chikaskia stations they are of special interest: Q rubiginosa 14, Q. undulata 3, Tritogonia tuberculata 1-2 valve, Anodonta grandis 4, L. subrostrata 12, L. parva 11, Unio tetralasmus 1. The record of the last three species is referred to later in this paper.

STATION 63, THREE MILES ABOVE STATION 62.—At this piont the current is slow and the water 2-4 deet deep; 6 examples of Q. pustulosa were secured.

STATION 64, SOUTHWEST OF CORBIN ABOVE THE SANTA FE AND PACIFIC R. R. BRIDGES AND THREE MILES ABOVE STATION 63.—This station marks approximately the line in the surface geology where the sand drift impresses itself not only upon the river bed, but up the contiguous territory. It is in this vicinity that the Red Beds and the Blue Shales meet. The roads and fields on each side of the river become more sandy. The stream floor of the river is more shifting and the bottom more unstable so that the water breaks thru in passign along the channel. In this region, therefore, we are near the upper limit of suitable mussel environments, altho a few scattering specimens are still found. While our survey was not as thorough as we would like to have made it, it seems to me very probable, that in the vicinity of Station 62, we have the first prominent mussel habitat as one descends the Chikaskia.

STATION 65, BELOW DRURY DAM (Sumner).—The river at this station was studied in 1909 and 1912. The results are well shown in the table.

STATION 66, ROCK FALLS NEAR WILLSTON (Kay).—The river was studied at this point in late August 1908, middle June 1910, and July 29, 1912. It was at this point in the Chikaskia that mussels were secured for transplanting to the Shoofly creek in the experimental work (Isely 1914 p. 8). The Rock Falls are natural; the drop is about two feet over a limestone-shale ledge. Below the falls the water is shallow, has a good current, and flows over a coarse sandy bottom. The following species were collected July 29, 1912: Quadrula pustulosa 106, Q. undulata 10, Q. lachrymosa 21, Q. rubiginosa 20, Trito-

gonia tuberculata 2, Lampsilis gracilis 1, L. parva 1.

Most of these mussels were taken from shallow sand bars and narrow channels. Many of the specimens were young, probably not over two or three years old. These late juveniles were especially abundant in the narrow channels with a good current and gravel bottom. The average size of the Q. lachrymosa and the Q. undulata was about 55 mm. (2 1-4 in.), while a good many were as small as 20 mm. Q. pustulosa was considerably smaller than that.

These facts as to size are of very particular interest in connection with our observations of the mussel fauna of the Chikashia for five seasons. In June, 1910, we had special difficulty in securing young specimens to use in the experimental work previously mentioned. At that time only one Q. pustulosa as small as 30 mm. was secured and only a few specimens of Q. lachrymosa and Q. undulata under 60 mm. The average size of the June 14, 1910, specimens was about 75 mm. This questions needs an answer; what was the source of the 55 mm. specimens of Q. undulata and Q. lachrymosa and the 35 mm. specimens of Q. pustulosa found July 29, 1912? It seems clear to me that these juveniles and young mussels had grown to this size since June 14, 1910. These species spawn during June and July, and the parasitic period is only 10-12 days (Howard 1912). Accordingly, many of these small Quadrulas may have dropped from the fish the summer of 1910 and become well advanced juveniles as I actually found them in other parts of the river in June, 1911. July 29, 1912 they were found as 30-55 mm. specimens according to the species. This rate of growth corresponds to what I have experimentally found. These observations also support my suggestion that only in specially favored seasons does natural planting result in the successful starting of a new generation of mussels in large numbers in a stream subject to floods with a bottom that becomes unstable at flood times. My own observations and a study of the weather records show that 1910 was one of these favored seasons in the Chikaskia.

In addition to the work outlined above, a ten mile stretch of the Chikaskia—from about two miles above Antwine to the Antwine Ford southeast of Tonkawa—had been traversed by boat and studied in 1908. As the Chikaskia was of easy access from Tonkawa, Okla., the residence of the writer during this time (1906-1912), the study of the mussel fauna was continued from time to time during this entire period. In 1912 a stretch of the river from Blackwell to the north of the river was again

studied in an effort to find an answer to some of the questions that had arisen concerning the distribution of mussels in this and other streams of this region.

STATION 67, CHIKASKIA AT BLACKWELL (Kay).—From Blackwell down the river about five miles the mussels are not abundant. The river is wide and shallow, the bottom is made up of coarse sand, and the water flows slowly at the average stage of the river. In this area of the river Q. pustulosa and Q. lachrymosa were more numerous than Q. undulata. On account of the clear shallow water, in this part of the Chikaskia, an accurate check on the number of mussels was easily secured.

STATION 68, SCHOOL HOUSE 59 KAY CO.—The first mussel bed of considerable size located on this cruise was found about 200 yards below a shoaly stretch in the river west of the school house of District 59. In a slight bend of the river along a bank six feet high, a well established bed was located. The water was 3-4 feet deep, with a good current; bottom was mud on the side of the bed near the shore and changed to sand toward the main current. The bed was about 100 feet long and 4-8 feet wide. The mussel population was dense. A representative collection taken from the mud and sand areas of the bed checked up as follows:

Species	Mud	Sand	Total
Quadrula undulata	62	40	102
Quadrula lachrymosa	3	16	19
Quadrula pustulosa	5	4	9
Quadrula rubiginosa	1	4	5
Lampsilis gracilis	6	5	11
Lampsilis purpurata	6	1	7
Symphynota complanata	2	1	3
Flagiola donaciformis	0	1	1
Anodonta grandis	1	0	1
Total	89	72	161

Nearly all the specimens were full grown. The Q. undulata measured about 120 mm. (5 3-4 in.), Q. lachrymosa was about the same size, and L. gracilis measured about 140 mm. Of the Quadrulas a very few specimens were small, some as small as 45 mm. in length. Mussels were fairly abundant on the sand bars in this portion of the river and averaged noticeably smaller than those of the established bed. The bed having no juveniles and rather a small ratio of young mussels furnishes one of the lines of evidence that the mussel population of the bed is recruited by

migration from the bars, and that the mussels, once having reached the favorable environment of the bed cease to migrate was well established in our experimental study (1914 pp. 19-21). In all of my field work, however, I have been unable to get evidence that the optimum conditions surrounding a well established mussel bed afford a suitable environment for the beginning of the post parasitic and early juvenile stages of development. These facts tend to support the theory that mussels in small streams and rivers of the Chikaskia type first establish themselves as free living animals in the swifter and better aeriated portions of the stream, such as sand bars, riffles, and swift narrow channels. These situations in many streams are more or less unstable and the mussel that lives to a good old age must ultimately find a well established and permanent portion of the stream.

Often after unusual flood periods, these situations that have been established for years are broken up, and at such time we find old veterans wandering about the stream floor, in their trial and error method of finding a new habitat.

STATION 69, HALF MILE BELOW SANTA FE R. R. BRIDGE NEAR AUTWINE (Kay).—Below a series of shoals another good bed was located. This was similar to 68 both as to conditions and as to species found. The current over this bed was a little over a mile an hour. This bed was studied in 1908 affording some definite information on permanency of mussel habitats in this river. The results are to a great extent a duplication of the findings at Station 68.

STATION 70, BREWERS FARM SOUTHEAST OF AUTWINE (Kay).—This stretch of the Chikaskia was thoroughly studied in 1910 for the distance of a mile in the vicinity of the Brewer Experimental Bed. In 1910 mussels were relatively sparse in this portion of the Chikaskia altho adult mussels transported to this habitat thrive fairly well; further reference will be made to Station 70 later in this paper.

STATION 71, ESCH BED, THREE MILES NORTHWEST OF TONKAWA (Kay).—There are a number of half mile stretches on the Chikaskia where mussels are very plentiful, but they are more numerous on the Esch Beds than on any other I have seen. Above the Esch beds there extends along the west side of the river a high blue shale bank from 20 to 30 feet high and about 200 yards long. The stream floor in this area is made up of solid rock extending from the shale bluff; over this long rocky shoal the water rushes with

At this time I will limit my account of our observations in the vicinity of the Esch Beds to a series of studies made June 27 and July 1, 1912; these studies show facts not only with reference to species and distribution, but, in addition, facts concerning musel bed rejuvenation and the state of mussel life in a coarse sandy bottomed stream.

The river stage had been 12-14 inches above normal during the days of June 25 and June 26; on June 27 the date of the first study here described, it was about 10 inches above normal stage. A study of a section of the river six feet wide and extending clear across the river serves to show how densely populated a portion of the Esch Bed was and at the same time the unusual hazard of this area. The bottom is made up for the most part of course shifting sand, but along the west bank there is a narrow margin where broken rocks and gravel are found. The current of the channel was a little over a mile an hour. The four selected areas may be descirbed as follows: I. First ten feet from west bank; II. Second distance of ten feet from west bank; III. Third section of ten feet from the bank; and IV. The remaining distance of fifty feet to the east side. The current and bottom have already been described The bank on the west side was about twelve feet high and on the east was a low ridge not over three feet high.

Species	I	II*	II†	III*	III†	IV
Quadrula undulata	137	97	13	59	12	4
Quadrula lachrymosa	37	61	9	83	12	7
Quadrula pustulosa	10	8	4	7	11	1
Quadrula rubiginosa	1	4	3	5	--	1
Lampsilis gracilis	2	1	--	--	--	--
Tritogonia tuberculata	4	2	--	--	--	--
Plagiola donaciformis	--	--	--	3	--	--
Total	197	174	29	157	35	13

In regard to size, all of the area I specimens were large. Area II had 29 small, 20-40 mm.; 7 medium 65 mm.; and 167 were classed as large, the Q. lachrymosa and Q. undulata ranging from 100-110 mm. The averages for III were about the same as for II. Area IV specimens were all large size. While much of the Esch area is quite unstable, due to shifting bottom, the narrow channel along the west bank has always been maintained during the five years this stretch has been under observation. This

* indicates large mussels and † indicates small mussels.

channel has always been crowded with mussels, tho it is clearly a hazardous habitat. What is the reason for the large population? I can see only one reason which is that this situation below the longest riffle in the Chikaskia is the most favorable for the critical post parasitic period of mussel development and as a result retains a dense population in spite of the high mortality and the further evidences of instability to be mentioned later.

Three days later, July 1, we again studied this part of the Chikaskia. The river had fallen 6-8 inches and was rapidly approaching the normal stage. A striking change had taken place in the depth of the water in the several parts of the channel and a tremendous shift in stream floor materials. The mussels we had checked over on June 27 had been put back into the river in their respective areas being left in small heaps. A sand bar had drifted into the stretch occupied by Area II and a new channel had formed east of Area III. Many of the mussels were making good their escape from the new drift bar; some, however, had already reacted unfavorably, i. e., pulled in the foot, closed the shell, and toppled over on their sides upon the shallow bar. The outcome was easy to forecast; more sand would accumulate to build up the new bar and with a further slight reduction in the water depth the mussels remaining on the bar would be helplessly stranded and perish. As would be expected, the young mussels were more active than the old ones and for the most part were getting back into the permanent water.

STATION 72, A QUARTER OF A MILE ABOVE THE CHIKASKIA BRIDGE EAST OF TONKAWA.—Another blue shale bluff appears at this stretch. The shoaly area extends well above the bluff and mussels are found in the gravel and in the pockets that have been hollowed out of the rocks. The species are much the same as at other stations on the lower Chikaskia, but the number of Tritogonia tuberculata was far in excess of the usual ratio for that species. Mussels were found in good numbers for over a half mile below the shoaly stretch of Station 72.

STATION 73, HALF MILE BELOW TONKAWA BRIDGE.—This area is pointed out because we have here a ponded stretch of a hundred yards where no mussels can be found altho as we have shown there is a large population immediately above and below this station. The bottom here is a sand-silt mixture and the current very slow.

STATION 7, AGENCY BLUFF.—This station is not over

100 yards below the foot of the stretch described for Station 73. The regulation blue bluff is the signal for another mussel area. The rock bottom that formed the shoaly stretches at 71, 72, Rock Falls, and other areas in the Chikaskia is present, but does not extend clear across the stream channel at this point. A large bed of mussels was found in the sand and gravel bordering the rocky stretch. This bed was unusually well established, and was without doubt one of the oldest beds examined by us in our survey of the Chikaskia. The depth of the water here was below what we have found to be the usual optimum depth in the Chikaski. This was offset, however, by a strong current. The stream floor in the part of the channel where mussels were abundant was made up of coarse gravel, sand, and broken shale. In a lot of 248 shells there were 52 large Tritogonia tuberculata; the other leading species were Quadrula undulata, Q. lachrymosa, Q. pustulosa, and Q. rubiginosa, in the order named.

STATION 75, MOUTH OF THE CHIKASKIA RIVER (Kay).—For a half mile below the Agency Bluff a good number of mussels were found. Farther down stream frequent specimens were taken but beds or abundant mussels on sand bars

Table 3 Showing Distribution of Mussels in the Chikaskia Drainage. Species Arranged, as Nearly as Possible, in Order of Their Appearance in the Drainage System, Working from the Head Waters Downstream. Typical Stations Listed.

Mussel species	Stations: Creeks										Chikaskia River						
	51	52	53	54	55	57	59'	60	61	62	65	66	68	70	71	72	74
1.Unio tetralasmus	–	–	c	c	c	–	–'	–	s	s	–	–	–	–	–	–	–
2.Lampsilis subrostrata	f	f	a	–	–	–	a'	–	–	c	c	–	–	–	–	–	–
3.Lampsilis parva	–	–	c	c	c	–	–'	–	–	c	c	r	–	–	–	–	–
4.Anodonta imbecillis	–	–	–	–	–	r	–'	–	–	–	–	–	–	–	–	–	–
5.Anodonta grandis	f	f	–	c	c	a	a'	–	–	c	a	c	c	c	c	c	
6.Quadrula pustulosa	–	–	–	–	–	c	a'	–	–	a	a	d	c	f	a	a	
7.Quadrula lachrymosa	–	–	–	–	–	c	a'	–	–	f	a	a	a	f	a	a	
8.Quadrula rubiginosa	–	–	–	–	–	c	–'	–	–	a	c	a	c	c	c	c	
9.Quadrula undulata	–	–	–	a	–	d	–'	–	–	c	a	a	d	f	d	a	
10.Lampsilis anodontoides	–	–	–	–	–	c	–'	–	a	a	c	c	c	c	c	c	
11.Lampsilis gracilis	–	–	–	–	–	c	–'	–	–	–	c	f	c	c	f	f	
12.Lampsilis purpurata	–	–	–	–	–	–	a'	–	–	–	–	f	c	c	f	f	
13.Lampsilis laevissima	–	–	–	–	–	–	–'	–	–	–	–	–	–	r	r	–	
14.Fisciola donaciformis	–	–	–	–	–	–	–'	–	–	–	r	–	–	c	f	c	
15.Symphynota complanata	–	–	–	–	–	r	–'	–	–	–	–	r	c	r	c	c	
16.Tritogonia tuberculata	–	–	–	–	–	–	–'	–	–	–	–	c	c	c	c	a	
	2	2	3	4	5	9	5'	0	2	5	10	11	10	12	12	12	

Streams and Collecting Station—51, Wild Horse Creek; 52, Sand Creek; 53, Spring Creek; 54 & 57, Shoofly Creek; 55, Duck Creek; 56, Stink Creek; 58 & 59, Bluff Creek; 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74 & 75, Chikaskia River.

Symbols are the same as in Tables 1 and 2.

were not observed. The Chikaskia flows into the Salt Fork, which is barren of mussels, not a shell of any kind being found to indicate mussels carried from the tributaries.

Discussion of Chikaskia River Data

The up and down stream distribution is better worked out for the Chikaskia drainage than for the other systems tabulated. The Chikaskia results line up well with the data secured for the other streams and give satisfactory link between the creek and river fauna at Station 62. From the standpoint of comparative ratios we find that Quadrula lachrymosa, Q. pustulosa, and Q. rubiginosa hold a higher ratio when checked up with Q. undulata at Drury and Rock Falls than when compared with Q. undulata at the Esch Beds, Agency Bluff and other down stream stations. This fact expresses itself from another standpoint when counts are made of a bed that extends over contiguous sand and mud bottom. Q. undulata shows a strong increase in proportionate numbers over other Chikaskia Quadrulas in the mud bottom counts as compared with the sand bottom areas.

A number of points of general interest in connection with mussel habits and ecology may be briefly discussed to advantage in connection with the Chikaskia data.

HIBERNATION: That mussels react to temperature conditions is well shown in our observation of the Chikaskia fauna. I have already shown (Isely 1914) that growth is decidedly retarded during the winter months. In my winter study I found that mussels entirely disappear from the surface of the stream floor in the shallow water, i. e., water three feet deep and less. I had understood from other field workers that mussels disappear early in November and begin to appear in considerable numbers about the first of April. In the early spring it is common to find cup like depressions in the sand in the shallow water and a mussel track leading from it. These little depressions mark the place where the mussels have come out of their places of hiberation.

SAND-BAR STRANDING: In a number of instances in the earlier pages I have called attention to the reaction of mussels to conditions of high water, also to the resulting destruction growing out of these reactions, and the general effect of flood periods upon the life of the mussel fauna. It is well known that mussel beds are often buried by shifts of bottom materials in stream channels and that by changes of channels they are left to perish without a food supply. It seems to me, however, that a great deal of the loss of mussel life charged to washing, i.

e., carrying and drifting of the animals by the current, is due more to what I here designate as "sand-bar stranding." The agency of washing I have found to be negligible as far as the Chikaskia fauna is concerned.

The only season of notable mussel fatality in the Chikaskia during my five years of observation was in 1908. Thousands of fresh shells were found in August and September upon the islands and sand bars of the river, two to three feet above water level. That these mussels were not carried to this higher ground was proven to my entire satisfaction by studying after flood results of the following year. In May, 1909, the river rose to the exceptionally high stage of 24 feet above low water in less than three days. Three days later the river was nearly back to normal. Extended field work, immediately after this high flood, produced one specimen of Lampsilis gracilis on a bar three feet above low water stage. When facts are known the results are not difficult to explain. The 1908 high water stage, while it did not reach as high as the 1909 flood, was a long period flood and the river was kept bank full for three weeks.

The differences in the effects on the mussel fauna are to be found in the longer duration of the 1908 high water. During the early and high stages of a Chikaskia flood, the quiescent Quadrulas first protective response causes them to retreat into the shell, close up tight, and remain quiet. If the flood is protracted, other forces—perhaps: food, light, oxygen, pressure—become operative, and at least some of the population of the established beds become active and by their chance meandering reach the higher bars and side channels now under water. As the water finally subsides and uncovers these higher positions the Quadrulas react in one of three ways:* (1) The most common reaction, for a Quadrula and several species of other genera, when water is drawn away from around the mussel, either by receding floods or experimentally, is to withdraw the burrowing foot from the substratum, topple over on a side and retreat into the shell. Usually the mussel remains within the shell and is soon dried in the hot sun. (2) A small percentage, however, after a short retirement, come out of the shell and move about in a hit and miss manner, sometimes reaching the water. The track evidence clearly shows that with the Quadrulas direction is a matter of chance; the mussel is just as likely to go away from the water as toward it. Thus about one in four, that respond

*In this matter I have been able to support my field observation by field and laboratory experiments.

after this fashion, should reach the water if the distance is not too great. This reaction differs from that of several of the light shelled and active species, which, as I show in later pages, get back into the water by a definite U-shaped track. (3) A modification of (2) is the behavior that results in burrowing vertically into the sand. This is more likely to be the reaction of the mussels that have migrated into the temporary side channels during high water. In these situations the water goes away more gradually and gives a longer time for the mussel to modify its behavior. Mussels that had burrowed down in this fashion could be located by cup-like depressions. In August 1908 hundred of specimens were thus buried 6-10 inches in the sand and in many cases were found to be still alive. Most of them ultimately perish altho a few may reach the main channel with recurring flood periods. It will thus be seen that, in the Chikaskia and many similar streams, migration during the long periods when the river is above the normal stage, is the direct cause of extensive loss of mussel life.

Commercial Value of Shells

The Oklahoma streams as a whole are not to be classed with the rich shell-producing streams of Arkansas, Iowa, and Illinois; nevertheless, paying quantities of raw material can be secured in some stretches of the rivers here reported upon, and many other shell beds may be found when the region is worked commercially. The actual test as to the value of shells is in their use by the button blank factories. The Neosho shells are being used at the present time by factories at Iola, Kans., and are considered of good grade.

Mr. J. B. Southall, shell expert for the Biological Station at Fairport, examined a small lot of samples from our region and sent me the following tabulation of results:

Table of Shell Values*

Species and locality	Texture	Discoloration	Grade	Gross blanks per ton 16 line	26 line
Quadrula undulata (Three-ridge) Salt Creek--	Firm	10% stained	2	142	236
Quadrula undulata (Three-ridge) Verdigris ---some'at chalky		30% stained	3	190	198
Symphynota complanata (Heel-splitter) Salt Ck.	Firm	None	2	146	139
Symphynota complanata (Heel-splitter) Illinois-	Brittle	None	3	253	206
Tritogonia tuberculata (Buckhorn) Salt Creek--	Brittle	None	3	267	250
Quadrula lachrymosa (Maple-leaf) Salt Creek--	Firm	15% stained	2	186	198
Lampsilis ligamentina (Mucket) Salt Creek----	Firm	None	2	166	285

*Those not acquainted with shell values will find a full explanation in: Mussel Fauna of the Kankakee Basin, by Wilson and Clark, Bureau of Fisheries Document No. 758, p. 39.

Discussion of Species*

In the discussion of the various species attention has been directed to questions of distribution, habits, habitats, and other ecological relations. In the cases where the species is individually abundant and of economic importance the economic phase of the question is considered; species sparingly found are briefly discussed.

1. Quadrula pyramidata (Lea)—Pleurobema pyramidatum.—This species is sometimes classed as "Niggerhead" by the shellers; it is, however, quite different from Q. ebenus. Our Q. pyramidata is lacking somewhat in the height of umbones typical for the species. The species is found in the Verdigris. Neosho, and Poteau. In some of the beds fo the Verdigris as many as 50% of an entire catch belonged to this species. In the Poteau the ratio was about 10% to all others and in the Neosho about 5%. In the matter of bottom distribution in the stream, Q. pyramidata stands between Q. undulata on the one hand and Lampsilis ligamentina on the other. This is well brought out in many of the counts recorded for the Verdigris and the Neosho, where in the mud-sand-gravel-broken shale stream floor mixture, Q. undulata leads toward the mud side, L. ligamentina toward the gravel, and Q. pramidata stands between, associated with Q. metanevra, and often in the Neosho, with Tritogonia nobilis and Q. pustulosa. The shells of this species are heavy, thick, and of good texture. The surface area of the shell is not large but the buttons made from the shells are usually of good quality. The nacre is usually white but occasionally specimens are found in the Verdigris that have a pink nacre. The Poteau shells have a characteristic silky epidermis.

2. Quadrula solida (Lea)—Catillus solidum.—This is a rare species in our region. The specimens from the Neosho are similar to the ones taken from the Mississippi at Fairport. In the southern drainage one specimen is reported for Little River at Garvin.

3. Quadrula obliqua (Lamarck)—Pleurobema cordatum.

*The matter of identification of species has been very carefully checked over. Representative specimens of many of the species and of all doubtful material has been referred to various authorities. Except in the case of a few rare specimens, nearly a complete series of species here enumerated has been seen by the following wll known experts: Bryant Walker, F. C. Baker, A. E. Ortman, H. Walton Clark, L. S. Frierson. Where there is difference of opinion or doubt as to the identification I specifically mention the authority responsible.

(Rafinesque.)—One specimen from the Kiamichi is so identified by Walker and Baker.

4. Quadrula undata (Barnes)—Fusconaia undata.—Pig-toe. —The typical pig-toe as found in the Mississippi is quite different in general appearance from our specimens from the Poteau and the Kiamichi. The species is quite common in the above named streams and was at first doubtfully placed in my field records as one of the variable Q. rubiginosa. Frierson deems Q. undata a more accurate designation. It is interesting to note that Q. rubiginosa is replaced by Q. undata in the limits of our survey, and its distribution within the stream is similar to that of rubiginosa. Our shells are quite small and would not be of high value even for Pig-toe, which hold rather a low rank as a commercial shell.

5. Quadrula cerina (Conrad), Fusconaia cerina.—The species is found in two neighboring streams, Illinois and Fourteenmile Creek. In the latter stream it represented 57% of an entire catch of 149 specimens. This shell looks very much like a typical sandy stream Q. rubiginosa. The shell is lighter and more rounded than the shell of Q. rubiginosa as found in the Chikaskia or Blue; from the evidence of rest rings it appears that the species grows faster than rubiginosa as found in the Chikaskia. In Fourteenmile Creek Q. cerina was found in a side channel in a bottom made up of muck and fine mud. The rest rings are exceptionally distinct and the nacre is warm. The Illinois cerina are similar to those of Fourteenmile, but only a few specimens were taken. Old specimens of Q. cerina are separated from Q. rubiginosa with difficulty.

6. Quadrula hebetata (Conrad), Fusconaia hebetata.—This species is reported only from the Verdigris where it is frequent to common. Representative specimens were examined by Bryant Walker who places them as Q. hebetata. I suggested to Mr. Walker that to me the Verdigris specimens seemed to represent a local race of Q. rubiginosa, Mr. Walker writes: "If you will compare your hebetata with the original figures and description I think you will agree with me that your shells are that species. But whether hebetata is a synonym of rubiginosa is a matter of individual opinion."

7. Quadrula rubiginosa (Lea), Fusconaia flava (Rafinesque). —This is one of the common shells of the Oklahoma region. As I have indicated above the last three named species appear to be very closely related to rubiginosa. It is an exceedingly variable spceies and some careful observers have suggested that rubigi-

nosa has a distinct race for every stream of striking individuality. Typical specimens can be separated clearly enough but intergrades also exist. Some systematists maintain that, if a race in a stream can be differentiated from close allies in other streams, we have here sufficient grounds for considering it a species. Ecological study favors this to the extent that the type habitats in which we find these closely allied species are often different for the various members of the groups. However, it is noted in our study that where hebetata, cerina, etc., are recorded rubiginosa is absent. According to my way of looking at the question, these species appear to have many variations in the various streams and if it were possible to transport hebetata from the Verdigris, cerina from Fourteenmile, and possibly undata from the Kiamichi, all to the Chikaskia, I would expect the next generation all to turn out typical rubiginosa of the Chikaskia. To return to our characterization of Q. rubiginosa, we find it abundant in the Chikaskia, where it reaches large size; it is also recorded from the Neosho and a number of the larger creeks. In Blue, in the southern drainage, it is the dominant mussel at Durant and Milburn stations, where it was found to run as high as 50% of all specimens collected. The sandy stream individuals, as those of the Blue and the Chikaskia, are more elongated and flatter, than the muddy stream mussels of the Boggy. The Boggy examples have a greater inflation of the umbones, are shorter and higher and nearer to Q. hebetata of the Verdigris than rubiginosa of the Chikaskia or Blue. The individuals of Salt and Bird creeks are unusually thick shelled and the posterioventral margin of the shell is markedly extended. Q. rubiginosa is a slow growing species in the Chikaskia and probably wherever found. The glochidia reach maturity in May and June and many reddish gilled specimens may be taken during these months. Like a number of the Quadrula species, (Lefevre and Curtis, 1910), Q. rubiginosa would be difficult to handle in artificial propagation, as disturbed specimens are likely to abort the masses of embryos or mature glochidia.

8. Quadrula pustulata (Lea), Quadrula nodulata (Raf.).—Pimpleback. Only two specimens, one from the Verdigris and one from the North Fork of the Canadian, were taken. It appears to be rare in our region; the specimens taken were characteristic representatives of the species.

9. Quadrula pustulosa (Lea).—Wartyback. According to our field record this is the most widely distributed species found in the Oklahoma region. It is recorded at forty-one stations in

the tables. In the Poteau River at Poteau this species was clearly dominant representing about 50% of all specimens taken. The Poteau pustulosa are singularly small and the height is greater than the length. "Wartyback" is often a meaningless name for this species as in many streams in our area 95% of the specimens are smooth. This is especially the case in the sandy streams. In the Kiamichi the species is nearer to type than in any other streams where collecting was done. The sandy stream specimens have a yellowish brown epidermis while in the gravelly streams the epidermal color is a dark brown. The type of habitat of Q. pustulosa cannot be very clearly defined as its range is wide. With the exception of the Poteau station, a sandy to gravel stream floor will show a larger population of pustulosa per square foot than a mud bottom area in the same stream. As shown by our field records pustulosa was found higher in the Chikaskia than any other Quadrulas; with Q. forsheyi it was fairly common in the lower Washita. The constant associate of pustulosa in our region is Q. lachrymosa-forsheyi. The host fish is not known, but so constant is the association of these species that I have suggested to Dr. A. B. Howard that the host fish of pustulosa, i. e., the catfishes, may be found to carry Q. lachrymosa-forsheyi as well. Q. pustulosa is a slow growing species; as a commercial shell it ranks well above the average in value. As just indicated, Dr. Howard (1912) has recently shown that the Channel Cat (Ictalurus punctatus, Raf.) and other catfishes, serve well as the host fishes for the parasitic stage of pustulosa. This interesting discovery tallies well with the stream distribution of these fishes and of pustulosa.

10. Quadrula forsheyi (Lea).—This species seems to me to be very closely allied to Q. lachrymosa; as we have recorded it, with one exception forsheyi is found in the southern drainage. In Cache Creek it is locally abundant and the most numerous mussel of that creek.

11. Quadrula fragosa (Conrad).—This is a rare species and has been taken only a few times. The best specimens were found in the southern area.

12. Quadrula lachrymosa (Lea), Quadrula quadrula (Raf.).—Mapleleaf. The lachrymosa-forsheyi combination are recorded from thirty-five stations. Q. lachrymosa is second to Q. undulata in numbers in the Chikaskia where it is very abundant in certain areas. As already indicated within the stream its distribution is very much the same as Q. pustulosa; however, there are some notable exceptions as in the Poteau. The Chikaskia,

Black Bear and Salt Creek representatives are thick shelled and large. Lachrymosa is known to be a rapidly growing Quadrula and is considered a good commercial shell. If its fish host can be discovered, and if other difficulties that might individually arise for the species can be solved, it would make one of the best species for artificial progation in this region.

13. Tritogonia nobilis (Conrad).—This species replaces Q. lachrymosa in the Verdigris and Neosho rivers. The shells are rather small but found in good numbers in favored situations.

14. Quadrula cylindrica (Say).—Rabbitsfoot. This is a rare species in the Oklahoma region. One specimen was taken in the Little River. During nearly two weeks work in the Verdigris, only two representatives of this species were taken. Two were collected in the Neosho at Chetopa and several were seen in the shellers pile at Miami.

15. Quadrula metanevra (Rafinesque).—Monkey face. This species was found only in the Verdigris and the Neosho. In these streams it is more likely to be associated in distribution with Q. pyramidata and Lampsilis ligamentina than with any other species. Out of 615 shells collected in the Neosho at Chetopa 19 specimens were Q. metanevra. This species is classed as of medium value as a commercial shell. It is very thick and heavy but deep furrows reduce the area of the cutting surface.

16. Quadrula trapezoides (Lea), Plectomerus trapezoides.—As far as our collecting goes this species belongs only to the Little River fauna; it was found in this stream at Garvin as a common species.

17. Quadrula heros (Say), Megalonaia gigantea (Barnes).—Washboard. This species, sometimes referred to as the heaviest of commercial shells, is found in the larger streams. In general distribution it falls into the Q. undulata association. The largest catch of Q. heros was at the Mingo Ferry on the Verdigris, where 45 good sized specimens were checked up out of a total of 384 specimens examined; this is a little over 10% by count and would be close to 20% by weight. Many of the specimens weighed nearly a pound. Q. heros is undoubtedly a fast growing species and where it thrives should make a fair mussel for commercial propagation. In our specimens the nacre is sometimes stained and this detracts from its value as a button shell.

18. Quadrula undulata (Barnes), Amblema costata (Raf.).—Bluepoint. This species is by far the most abundant fresh-water mussel found in the streams investigated. Among the commercial species according to our records the Q. undulata-plicata-perpli-

cata group makes up more than a third of the mussels checked over during our survey. The heaviest shells and the most thickly populated beds are found in the muddy-bottomed ponded portions of small rocky streams of the Bird, Salt, and Shoofly type. While undulata is sometimes found in very soft mud the optimum bottom seems to be made up of a fine mixture of mud-sand-gravel-broken shale—usually a solid bottom with a soft mud cover as decsribed by Wilson and Clark (1912). In these situations undulata reaches the high ratio of 80-90% of all species taken. Q. undulata, as our data show is found in a wide range of habitats as expressed in bottom conditions, ranging from sandy bars to mud bottomed side channels. In sandy streams where we get a mud-sand bottom ranging from soft mud on the side to pure sand on the channel side, undulata will show a greater number of specimens per square foot on the mud bottomed side, and if compared with Q. pyramidata, Q. lachrymosa, and Q. pustulosa the proportional ratio of the last three species named will show an increase toward the channel or sandy bottomed side. As to depth of water, Q. undulata is found in water from 1-15 feet deep in the Verdigris. As to current this varies in different streams. In the Verdigris a fair current is essential to the development of the largest beds. In some of the creeks, during much of the year, the current is very nearly stationary especially in ponded stretches where Q. undulata is abundant. Thirty-seven of our stations show Q. undulata and at nearly all of these undulata is either abundant or dominant. Cache creek is one of the streams with a fair mussel fauna where undulata was not found, but this is an exception. If the small creeks in the region are ever used for commercial propagation Q. undulata will be as important a species as any we have found. It is a rapid grower and the shells are usually of fair quality. The shells of the Oklahoma rivers are somewhat smaller than specimens from the most favored creeks.

19. Quadrula perplicata (Say), Amblema perplicata.—This species was found only in the Poteau River; here it replaces Q. undulata. The Poteau specimens are rather small but the shells are very thick and the furrows extremely shallow.

20. Quadrula plicata (Say), Amblema peruviana (Lam.).—Three-ridge. The difficulty of separating plicata and undulata is well shown by the fact that the common names are used interchangeably. A number of the specimens that I have sent in for identification have been listed plicata, probably some of the specimens I have listed as undulata should be called plicata, but

if that is the case they run so close together that something more than characters will have to be used to separate them. The difficulty, however, is not mine only (Wilson and Clark, 1912) as my systematic friends have often been unable to agree as to the placing not only of plicata but some other species that seem to intergrade. Dr. Howard has recently found out that plicata glochidia will be carried by cat fishes, crappie, and sun fishes.

21. Unio tetralasmus (Say), Uniomerus tetralasmus.—This is an exceedingly interesting species. It thrives in temporary ponds, "tanks," sloughs, and intermittent creeks. In small sluggish streams where no other mussels are likely to be found U. tetralasmus will probably appear. This species has unusual power to withstand drying as I have shown in another paper (1914, p. 18, note c) and as reported by Simpson (1898 p. 283). I have found animals alive and in perfectly good condition buried deeply in old pond bottoms, so dry on the surface that the ground was being plowed. It is usually difficult to locate geographically the stream where this species is found as the habitat is quite likely to be some nameless pond, railroad cut, or draw. U. tetralasmus is a light shelled species and has probably a most variable rate of growth. I know of no species that shows such a striking variation of rest rings; there is absolutely no regularity as to distance between rings and the number of rings on a young specimen of a given size. I have before me a small collection of shells of this species that average from 50-60 mm. long; on these specimens, nearly of the same size, the well defined rest rings vary from one to eleven in number. This is just what would be expected of a species growing in intermittent ponds subject to all sorts of variations as to water supply, food, oxygen, and other factors of the environment. Under favorable conditions U. tetralasmus is probably a rapidly growing species. The breeding habits and the fish host are not known.

22. Unio gibbosus (Barnes), Elliptio dilatatus (Raf.)—This species is found in only three streams, Neosho, Poteau, and Kiamichi. In the Neosho gibbosus was associated with Lampsilis ligamentina. It was found in the swifter channels and gravel beds where it buried down deep into the stream floor. The nacre was the usual purple in the streams of the Arkansas drainage; in the Kiamichi the gibbosus specimens were white nacred.

23. Alasmidonta marginata (Say).—Only one live specimen of this species was taken by us in this region and this was secured in the main channel of the Illinois at Tahlequah. Mr Hill of

Moodys, Okla., reports this species as frequent in the Illinois where he has collected.

24. Symphynota complanata (Barnes), Lasmigona complanata.—Heel-splitter, Hackle-back. While this species is recorded from 26 stations in our region at none of these places is it abundant. Six specimens is the largest number recorded for a day's catch. The specimens found in the "blind pockets" of the Illinois and the Salk Creek were very large, weighing on an average close to a pound each. S. complanata is more likely to be found in mud banks of large creeks than in any other habitat in our locality. It is sometimes associated with Anodonta grandis, more often with Tritogonia tuberculata and Quadrula undulata. This is a rapidly growing species and well known commercial shell of medium grade.

25. Symphynota costata (Rafinesque), Lasmigona costata.—Squaw-foot, Fluted-shell. Two shells of this species were taken in the shellers pile at Miami. Mr. Hill has sent me some specimens found in the Illinois at Moodys.

26. Arkansia wheeleri (Ortman and Walker).—A single specimen from the Kiamichi at Tuskahoma, is placed in this species by L. S. Frierson. It was collected in a mud bank with Q. undulata and at first was taken for a Quadrula new to our list.

27. Anodonta corpulenta (Cooper).—Slop bucket. The giant Anodontas found in the Bayous along the Red River were named A. corpulenta by Mr. Baker. This species is said to fill the lakes and bayous in the Red River region.

28. Anodonta grandis (Say).—Floater. This species was abundant in the ponded areas of some of the small creeks in the Arkansas system. It is reported from twenty-five stations tabulated for the Arkansas and Chikaskia rivers. Very often it is represented by occasional specimens only. Grandis is sometimes associated with Unio tetralasmus and at other times with Lampsilis subrostrata and L. parva. It is a light shelled species and, as found by Coker, an exceedingly rapid grower.

29. Anodonta imbecilis (Say).—This is a well defined species. The shell is as fragile as that of a young Lampsilis laevissima. Juveniles are very flat, but mature specimens are quite cylindrical; over half of the specimens taken in Fourteenmile creek early in July were gravid, the gills being markedly inflated and pinkish in color. A. imbecillis was found to be hermaphroditic by Ortmann (1911). It is a little bit surprising that such a light shelled species as A. imbecilis should find its way into a swift gravel bottomed stream like the Kiamichi; the adults were found

in the mud banks in the bends of the stream, but the juveniles were taken among the gravel in the swift surrent. A. imbecilis was collected at eight stations, but only 17 specimens were taken altogether. As far as our data goes the habitat preference of this species is not clearly marked; on the one hand, we have Illinois, Kiamichi, and Fourteenmile, clear gravel streams; on the other hand, small nameless creeks as Ranger and West Cache creeks; in the larger streams the adults were taken in mud banks and side channels so the sluggish stream habitat would seem to be favored.

30. Strophitus edentulus (Say), Strophitus rugosus (Swains)—This is not an abundant species in our area. As far as we have data from our field work edentulus belongs to the mussel fauna of the larger creeks. The seventeen specimens taken were from Pryor, Fourteenmile, and Kiamichi at Tuskahoma.

31. Ptychobranchus clintonense (Simpson).—Eight specimens of this species were taken in the Blue at Durant, Sept. 1, 1910. Four of these were gravid and the gills fully inflated. There has been some question as to the identification of these specimens and it is placed as "probably" P. clintonese by Mr. Clark.

32. Ptychobranchus phaseolus (Hildreth), Ptychobranchus fasciolare (Raf.).—This is a frequent to occasional species in the Neosho and Verdigris, it was abundant in the Kiamichi at the Tuskahoma station where 58 specimens were secured and this species was surpassed in numbers only by Quadrula undulata, and Lampsilis ligamentina-gibba. P. phaseolus may be listed with L. ligamentina and Unio gibbosus as an inhabitant of gravely stretches in a swift stream. In these stretches phaseolus burrows into the stream floor to the siphons.

33. Obliquaria reflexa (Rafinesque).—This odd and interesting species is more nearly associated with Ptychobranchus elegans than any other species found in our region. It may be classed as common to frequent in the Poteau, Kiamichi, and Verdigris; this would place it with the river species. It appears altogether at 14 of the stations listed in the tables, but usually as an occasional or frequent species and not as one taken in large numbers. A firm gravel-sand-rock mixture seems to be the best bottom for the activities of reflexa. This species is usually too small to be of any value as a button shell; the average size of specimens taken by us is from 40-50 mm. long; in the Salt Creek at Fairfax three specimens were secured that appear to be giant for O. reflexa and measure 80-90 mm. in length.

34. Cyprogenia aberti (Conrad).—Two live specimens and five shells of this species were taken in the Verdigris in our ten days work on that stream. The specimens taken were found in the main channel in water two to three feet deep, with fair current and sand-gravel bottom.

35. Tritogonia tuberculata (Barnes).—Buck-horn, Pistol-grip. This species was found thruout the region in the larger streams. T. tuberculata, in our collecting, has been occasional or frequent, almost always appearing where persistent collecting was done. Sometimes it has been found in good numbers, but nowhere as abundantly as in the Chikaskia at Tonkawa. At Station 74 in swift shallow water, bottom coarse sand-gravel-broken shale, T. tuberculata was third in abundance of individuals within a species. A count collection showing the four leading species was as follows: Quadrula undulata 77, Q. lachrymosa 68, T. tuberculata 52, Q. pustulosa 32. The specimens of tuberculata taken in the lower Chikaskia were nearly all large and heavy specimens; specimens taken from other streams were much smaller. The species is recorded from 31 stations and is listed as common for the Neosho, Boggy, and Poteau; and abundant for the Kiamichi. As to the environment best suited to tuberculata it is difficult to determine. The sand-gravel bottom, however, is superior to the mud bottomed situations according to our data. This is one of the commercial species of average value.

36. Plagiola donaciformis (Lea), Truncilla donaciformis.—According to our records this species belongs to the sandy stream fauna, altho it is generally found in all of the larger clear water streams. It may be classed as frequent to common in the Chikaskia, Washita, North Fork of the Canadian, and Kiamichi at Roby. P. donaciformis belongs to the few species found in the master streams, Red and Arkansas. The associates of donaciformis are not Lampsilis parva, Plagiola elegans and other small sized species, but rather the paper shells L. gracilis and L. laevissima; on account of this association observed in our field study, the finding of Surber (1912) that the two species P. donaciformis and L. leavissima have a common fish host (Aplodinotus grunniens, Raf., sometimes known as the Drum) is a matter of much interest; further it should be noted that the drum is one of the common fish species where these mussels are found. Dr. Coker has found that this species is a very rapid grower and it is probable that it reaches full maturity in two years' time. As I have already stated this species is too small to be of value as a commercial product.

37. Plagiola elegans (Lea), Truncilla truncata (Raf.).—Deer-toe. This species is more widely found in Oklahoma streams than P. securis, but not as common as the other member of the genus discussed above. P. elegans is an inhabitant of the larger streams and is found in good numbers in the Kiamichi and the Verdigris. Only at three stations was elegans taken in sufficient numbers to be classed as common; at other places occasional would be the best term to apply to its frequency. In the Kiamichi, where the best data was secured regarding the distribution within the stream, elegans was found in the gravel bottomed areas with a strong current. Unlike P. donaciformis, elegans is rare in sandy streams and we find the streams with gravel and broken rocks best suited to its development.

38. Plagiola securis (Lea), Plagiola lineolata (Raf.).—Butterfly. The Plagiolas already discussed are of little value as commercial shells; in P. securis, we have one of the best button shells found. In our region this species is not abundant; it is reported from nine stations and five different streams. The situations in which it is found are similar to those that are suitable for P. elegans and Quedrula reflexa. The Neosho and the Verdigris seem to be the chief streams to support this species.

39. Obovaria castanea (Lea).—This small species was found only in the southern area in Kiamicha and Little River. In the Kiamichi at Tuskahoma it was found associated with Plagiola elegans, Lampsilis leptodon, P. phaseolus, and L. ligamentina gibba. One gravid specimen was taken in the Kiamichi July 16, 1912.

40. Lampsilis leptodon (Rafinesque), Leptodea leptodon.—This light shelled species was found only at one station, at Tuskahoma in the Kiamichi. It is listed by Simpson (1900) "In northern waters south to Tennessee River," Scammon (1906) records it for the Neosho in Kansas. 36 examples of L. leptodon were secured at Tuskahoma; they varied in size from 40-80 mm. in length. Altho a light shelled species it showed a very decided preference for swift water and gravel bottom. As I have pointed out in describing this habitat (p. 14, 11. seq.) the coarse gravel served as an upper layer to a fine sand substratum and it was in this fine sand stratum that leptodon was found; it could be secured only by digging deeply into this layer.

41. Lampsilis laevissima (Lea), Proptera laevissima.—This very light shelled species is absolutely worthless as a commercial mussel. As a representative of the mussel fauna, however, it has habits and relationships that make it a species of very special

interest. In general it has many characteristics and habits in common with L. gracilis, but in our area it is much more restricted in this distribution. In the mussel catch of many of our streams where L. gracilis is common or frequent, laevissima is missing or rare. It is the most rapid burrower of any fresh-water mussel that has come under my observation. In the Washita I have dropped laevissima into the water and in three minutes found them buried to the siphons. In that mussel desert—the Red River—at one station we collected 30 very young to juvenile examples of this species in twenty minutes. Special conditions made the finding of specimens on this occasion easy. The night of August 5, we went into camp a few mile below the mouth of the Washita, at an old ferry site, known as Rock Bluff Ferry. The river was slowly rising and sometime toward morning reached a maximum of two feet above low water stage; at 7 a. m. the river had receded about six inches. The water at this place was quite deep and there was a ledge of rocks extending into the river; in fact, the Rock Ferry habitat was an exceptional one for the Red River. On the wet bank along the water margin I noticed many fresh U-shaped mussel tracks. The evidence clearly indicated that the mussels were moving toward the bank with the rising flood and as the water began to receed had turned back and were now moving toward the channel. Over 30 specimens making their way back toward the channel were collected and many other tracks were noticed where the mussels had already returned to the deeper water, not a single laevissima going in the wrong direction; not a stranded specimen was found. It should be noted that these Bluff Ferry mussels were very young and from growth records found by Coker in the ponds at Fairport Biological station and by observations by Surber (1912) concerning the parasitic and post-parasitic history I should estimate that these 15-30 mm. mussels were 8-9 months old. I have called attention in the earlier pages to a number of species of mussels that respond favorably to the stimulation of receding waters, whereas other respond unfavorably notably the Quadrulas. It is this higher sensitiveness to conditions and the greater activity of the species that makes it possible for L. laevissima to meet with partial success the great hazards of shifting sand in a stream of the Red River class, but the success is rather temporary as the individuals that reach maturity are few and far between. Its great activity is also an important factor coupled with the habit of burrowing deep into the stream floor as a projecting mussel would soon be buried in the drift bar formed from the

edge of its own shell. This same activity must be useful to laevissima in the mud filled bayous where it is often found altho the conditions are markedly different.

L. laevissima was found in the Red, Arkansas, North Fork of the Canadian, Washita, and Red River Bayous, besides occasional examples taken in smaller streams. Unusually large specimens of this mussel were taken under rocks in the Arkansas below Blackburn and also those from some of the Bayous were large measuring 160 mm. long and 105 mm. high. A good many heavily gravid specimens were taken late in August and in September.

42. Lampsilis gracilis (Barnes), Leptodea fragilis (Raf.).—Paper-shell. This species is similar to L. laevissima in many way and is sometimes found associated with it in streams but gracilis is more widely scattered in our region. It is recorded at 38 of the collecting stations. It is not found in the temporary stagnant ponds of the small creeks that may support Unio tetralasmus, Lampsilis subrostrata, L. parva, Anodonta grandis and some others, but in all other situations covered by our work this species is found. At Weeletka, in the North Fork of the Canadian, the high mark for number of individuals for this species was reached, when 53 examples were secured in a short time. All specimens were taken from mud banks in bends of the river, and from a shallow cut-off from the main stream, which flowed around an island. The mud varied in depth from 6-24 inches. Where the total depth of mud and water was between 2-3 feet the mud was very soft and slimy. A larger number of these Weeletka gracilis were found between and under rocks buried in the mud.

In streams with a shifting sandy bottom like the Arkansas, mussels are rarely found. Occasionally, however, a few may be taken in some side channel, and there is another habitat that sometimes will produce a few mussel in streams of this type; if rocky stretches appear as below Blackburn on the Arkansas, and at Rock Bluff Ferry on the Red, a few mussels may be found belonging either to L. gracillis or L. laevissima. Gracilis we have shown to be an exceedingly rapid growing species. It is found gravid in late August and early September and reaches maturity as early as the third year. As an economic button shell it has no value, altho we found slugs and small pearls more frequently in L. gracilis than any other species in our region except the next one discussed.

43. Lampsilis purpurata (Lamarck), Proptera purpurata.—This species is almost as general in its distribution as L. gracilis.

Its most frequent associate is L. anodontoides. The distribution within the stream, however, is often different. The former is quite restricted to the mud banks along the shore; L. purpurata is also found in these situations, but is just as likely to be scattered in the stream. I have never found this species in beds as we find Quadrula undulata, L. ligamentina, and others. In the lower Kiamichi, not over a half mile above the mouth, we found more examples of this species than at any other station. In water 10-12 feet deep, bottom of soft mud, we were able to bring up a good collection of L. purpurata with a shoulder rake, where not a single example of another species could be secured in the deep water. Along the bank by hand collecting L. fallaciosa was taken. This seemed to be an unusually favorable environment for L. pururata; the specimens were large, much inflated, and thin shelled for their size because of their very rapid growth. In other back water stretches of the tributary streams of the Red L. purpurata held a much higher ratio to the total catch than in any other situations where collecting was done. This species has an unusually heavy shell and thruout our region attains a large size. L. purpurata is a great favorite with "pearlers," if we may use this designation for people that destroy mussels with the faint hope of securing a pearl. Especially on lower Blue and lower Boggy did we find a great deal of evidence of this destruction. In the Chikaskia I have found in the examination of two or three scores of shells of this mussel that at least 25% of the old mussels contain "pallial line" slugs and small pearls, sometimes, as many as four or five in a single mantle. The habitat of this species may be characterized as the slow flowing portions of rivers and large creeks, in deep water; it is also a frequenter of mud banks and mud bottomed bays. A good number of gravid specimens were taken in late August and early September; this is one of the species that carry the glochidia thru the winter. On account of its purple nacre it has no value as a button shell, but on account of the liklihood of producing pearls it is worthy of commercial consideration.

44. Lampsilis corvunculus (Lea), Carunculina parva.—This small species was found in only two of our streams. Fourteen-mile and Illinois. Next to L. parva this is the smallest mussel in our region; the epidermis is black and the nacre usually purple. Our specimens were at first identified as L. glans (Lea) but Walker and Baker consider corvunculus as the correct designation, altho this is far out of its previously recorded range. Thirty examples of this species were taken in a firm mud-clay bank in

water 1-2 feet deep, in the Illinois at Tahlequah. In the main river at this station other mussels were exceedingly sparse.

45. Lampsilis parva (Barnes), Corunculina parva.—This is the smallest mussel found in our region; other small species are L. corvunculus, Plagiola donaciformis, P. elegans, Obovaria castanea, and Obliquaria reflexa. As a rule only scattering specimens of parva are found. An interesting exception to this is noted at the Tulsa Slough Station. This small nameless slough that entered the Arkansas from the south above Tulsa was examined shortly after an all night rain. Over 200 specimens of L. parva were picked up in a few minutes by D. Isely and Cross. The mussels were very active and in most cases were making good their return to the water following the receding flood. This was an unusual catch of this small species, resulting from the flood conditions. We started to open the specimens and found so many heavily gravid that we make a check of 100 and found 85 loaded with glochidia. In some the anterior portion of the marsupium was empty. The date was July 20th. It is suggested by Sterki (1898) that L. parva may be hermaphroditic The great preponderance found by us to be gravid tends to confirm Sterki's observations. In the same slough about a dozen specimens of Unio tetralasmus were taken; these were active for tetralasmus and seemed to be strongly stimulated by flood disturbances. Parva is co-extensive with L. subrostrata in distribution and is frequently found associated with Unio tetralasmus, Anodonta imbecillis, and A. grandis. Full grown specimens of this species only one year old have been taken from new ponds at Fairport by Dr. Coker. This interesting fact helps to explain the abundance of mature L. parva in ponds that exist during wet seasons only. Baker (1898), Scammon (1906), and Call (1895) all speak of L. parva as a deep burrower; this may explain in part (as I have pointed out for U. tetralasmus) the ability to live from one season to another even tho the ponds dry up part of the year.

46. Lampsilis subrostrata (Say), Ligumia subrostrata.—As far as our records go this species has a rather well defined distribution. It is a characteristic mussel of clear water creeks, fresh water ponds and sloughs. We also found this mussel in stagnant ponds and creeks but not as frequently or in as good numbers*

*Lefevre and Curtis (1910) have found L. subrostrata and U. tetralasmus in great abundance in artificial ponds in the vicinity of Columbia, Mo.

as in the fresh waters, i. e., those supplied with spring water. Over a hundred specimens were taken in Upper Big Cabin, Gar,

Billy, Pine, and Spring (Grant Co., Okla.) creeks. It was found in the Verdigris, in side pockets in the Illinois and in the Chikaskia above Drury.

L. subrostrata is one of those interesting species that reacts in a marked manner to flood disturbances, working out toward the bank with the rising flood, and turning toward the stream with the receding water. At Station 35 many long U-shaped tracks were found where the mussels had worked out and then turned back; and many specimens were secured in this way by following the tracks they were making in getting back into the main channel. Its activity and perfection of response under the stimulation of flood disturbances is second only to that of L. laevissima among the species that have come under my observation. As I have already indicated this species is often associated with L| parva, U. tetralasmus, and A. grandis; again in other streams it will be found with L. hydiana and L. fallaciosa.

Lefevre and Curtis (1910) have successfully used the sunfishes (Lepomis humilis [Girard] and Lempomis cyanellus [Raf.]) as the host fish of subrostrata; in their artificial infection experiments they have also collected data showing that it is a rapidly growing species in artificial ponds.

47. Lampsilis recta (Lamarck), Ligumia recta latissima.—Black Sand Shell. This species has been taken at a few stations only and altogether not over a dozen specimens were secured. It was found in Fourteen mile, Verdigris, Neosho, and Poteau. At some places in the Neosho, I have been told that L. recta appears in good numbers. The ecology of this species is similar in many ways to that of L. anodontoides. Usually the nacre of L. recta is purple, but nearly all of our examples had the white nacre.

48. Lampsilis fallaciosa (Simpson.—Slough Sand Shell.

49. Lampsilis anodontoides (Lea).—Yellow Sand Shell. While in our tabluation we have tried to keep these species of anodontoides and fallociosa distinct based upon identifications made by authorities we were unable to certainly separate them at all times in our field work. Scammon (1906) suggests that fallaciosa may not be a distinct species. The various systematists that have been good enough to identify my material were divided, Dr. Ortmann, especially, pointing out that fallaciosa could not be separated from anodontoides. Surber (1912) suggests that the glochidia are different, altho the host fishes, as far as he found natural hosts, are the same.

We found L. anodontoides and L. fallaciosa at 42 of our

collecting stations and they are reported for all the streams excepting the very smallest creeks. In spite of this wide range thruout our region there are few species that are more restricted within the streams, where they are found, than the Sand Shells. Occasionally one may find one of these mussels wandering over a shifting sand bar or buried deep in mud-gravel along with L. ligamentina, Q. undulata, and others. At least 90% of the several hundred examples studied in our work were found in one type of habitat; this habitat may be described as a mud bank, in water 2-5 feet deep, generally along the stream margin and out of the main channel. An interesting fact concerning L. anodontoides, which I have observed in other places, was well brought out in our investigation of Clear Boggy at Olney. Of the 29 specimens of L. anodontoides, 24 were found along the mud bank about an inch or two below the water line. Mr. Wood, a fisherman, who had furnished me a boat on this occasion, stated that the river had risen two feet during the last two days; it is inferred then that the anodontoides were following the rise and fall of the river. I have noticed similar behavior in deep holes with mud banks, on the part of L. laevissima, L. hydiana, L. parva, and L. subrostrata. I would except like behavior on the part of A. grandis and other Anodontas, L. gracilis and L. corvunculus, but these have not been directly observed reacting in this prompt manner to changes in depth and current. Station 14 on Clear Boggy and Station 39 on the Verdigris are typical Sand Shell stations. Gravid examples have been taken during July and August and some small specimens, certainly not over three to four years old, with fully developed brood pouches have been seen.

This shell, at its best, is very highly prized commercially, sometimes attaining the value of $60 per ton. Our shells were not of the best quality being a little below size and cylindrical.

50. Lampsilis ligamentina (Lamarck), Actiononaia carinata (Barnes).—Mucket. This is one of the best known and most productive of commercial species. In some Indiana and Iowa streams half of the commercial catch will consist of muckets. It is by no means so abundant in our area, altho found in good numbers in some of the larger streams as the Neosho, Poteau, and Illinois. As I have already suggested the big difference between the mussel fauna of the Neosho and the Verdigris was the absence of L. ligamentina in the latter stream. The habitat in which L. ligamentina was found dominant may be described as stretches of swift water from 1-3 feet deep, flowing over gravel bottom,

Lefevre and Curtis (1910) have shown this to be a rapid growing species. It is one of the species especially being used for the work of artificial propagation.

51. Lampsilis ligamentina gibba (Simpson), Actinonaia carinata gibba.—Most of the examples close to L. ligamentina, found in the Kiamichi and Little River were referred to the variety gibba. They were short and rather truncated posteriorly, otherwise like the typical species. In fact they seemed to be dwarfed specimens like all other of the Kiamichi species, except pustulosa. In habits and distribution they were the same as the regular species. The Kiamichi gibba sometimes has the nacre pink.

52. Lampsilis powellii (Lea).—Mr. Hill reports this species from the Illinois and has sent me a number of specimens. Frierson suggests that Hill's specimens are either powellii or an undescribed species; he also places some of them near L. ligamentina examples of the Neosho as probably powellii.

53. Lampsilis luteola (Lamarck).—Only seventeen examples of this species were taken. With the exception of a shell picked up on the Verdigris all of the specimens have come from creeks and all from the Arkansas River drainage. Fourteenmile, Bird, Big Cabin, Gaston, and Pryor, each supplied a few examples. In habits and distribution this species is associated with L. anodontoides in the streams where it was found in our collecting.

54. Lampsilis hydiana (Lea), Lampsilis siliquoidea (Barnes). —In the southern drainage hydiana replaces luteola. It is very clear cut and easily distinguishable. 48 specimens were secured. In Boggy and Pine this species was found associated with L. fallaciosa. In the Blue at Milburn it was found associated with L. ventricosa. Gravid specimens were taken in July and August.

5. Lampsilis capax (Green), Proptera capax.—Fat Pocketbook. This species may be classed as rare for our region. A few fine examples were taken in the Kiamichi at Roby, but it was not found at any other station. The Roby specimens were clearly capax and of fair size.

56. Lampsilis ventricosa (Barnes).—Pocketbook. This species is common in a number of the streams of the state but nowhere abundant. It has been collected in the Verdigris, Neosho, Illinois, Bird, and Fourteenmile of the northern drainage and in Blue, Boggy, and Kiamichi in the southern. The representatives of the different streams show some interesting differences in rays and color of epidermis. The young of the Neosho have a green-

ish cast with prominent green rays; in the Blue the same sized specimens have a straw colored background and the green rays are very much like those of the Neosho. In the Kiamichi and Poteau the epidermis is olive brown and the rays inconspicuous. The Neosho specimens are of good size while the Poteau and Kiamichi representatives are small or dwarfed. As to bottom preferences ventricosa shows as wide a range of variation as any species I have studied. In the Neosho it is found chiefly in the mud, in the Blue in the sand bottomed areas, and in the Kiamichi in the sand-gravel bottom. This is a rapid growing species as may be made out by well defined winter rest rings. As a commercial shell it ranks high in some localities while in others the quality is inferior.

57. Lampsilis ventricosa satura (Lea).—Some of the brownish rayless specimens of the Poteau and Kiamichi were referred to variety satura by L. S. Frierson.

As I have indicated before the mussel fauna of the Eastern Oklahoma area has been very little studied. While the work of this survey has been fairly extensive many of the streams were touched at only one or two points and a number should be added to our list of 56 species and varieties. In the literature at hand I find the following mentioned that were not seen by us:

1. Lampsilis alata (Say).—From the Neosho in Indian Terri. (Oklahoma) Scammon (1906), Call (1895), also lists this from Ind. Terr. but puts his locality as the Ouachita River which does not reach up into Oklahoma from Arkansas.

2. Truncilla triquetra (Rafinesque). Exact locality not given but listed for Ind. Terr. by Scammon (1906) and Simpson (1900).

3. Pleurobema aesopus (Green). Three examples from the Verdigris River at Coffeyville (Scammon).

4. Pleurobema cicatricosum (Say).—One specimen from the Neosho River near the southern (Kansas) state line (Sammon).

5. Quadrula plena (Lea).—This species is mentioned as being found in Ind. Terr. but as the locality is not given the reference is a little uncertain.

Summary of Mussel Distribution by Types of Habitat

Just what constitutes a suitable environment for the various mussel species and especially the commercial species? This problem has been the foremost question in our field work. It is well to recapitulate the little progress we have made and point out why further work along this line should be encouraged. The

problem of the mussel environment is second to none in the whole field of artificial propagation of fresh water mussels.

The conditions under which mussels thrive are almost as variable as the species. The various factors that enter into a habitat complex are so interwoven, that the relative importance of any one factor is difficult to determine. It is well understood that these conditions are not peculiar to fresh-water mussels (Shelford 1913, p. 22-39), however, there are special difficulties. The intricacy of the work of artificial propagation has been fully appreciated by the various investigators connected with this line of research. We may call attention to: (1) the complex life history; (2) the two sets of environmental essentials for optimum habitats for the early juvenile and later stages; and (3) necessary difficulties in experimental behavior study, especially of the quiescent Quadrulas.

ADULT MUSSELS: In making out these types of habitats, we shall consider chiefly those species that we have taken in large numbers. Our results are based upon recorded observations and not general impression. It is always possible, however, that a species altho found in good numbers is not living in its optimum environment and therefore, observers working in different regions are not always able to agree. Extended observation should reduce these apparent discrepancies to a minimum.

The question of habitat preferences* has not been especially emphasized in our general account altho we have kept this question constantly in mind in our field work. In no group of fresh-water animals, that has come under my observation, is habitat preference so strikingly shown as in the long established beds of our fresh water mussels and in the differences in distribution of the various species.

Habitats: I. Small intermittent creeks, head-water sloughs, and some ponds, without current, water shallow or deep, bottom mud or sand. Upper Shoofly, Duck, Frog, and Tulsa Slough creeks. Unio tetralasmus dominates habits of the above characteristics and we may call the mussel fauna of these situations the U. tetralasmus association. Many times U. tetralasmus is

*The matter of habitat preferences is clearly stated by Shelford (1913). He says: "By observation it has been shown that animals select their habitats. By this we do not mean that the animal reasons, but that selection results from regulatory behavior. The animal usually tries a number of situations as a result of random movements, and stays in the set of conditions in which its physiological processes are least interfered with. . . . The only reason to be assigned for this unequal or local distribution is that they are not in physiological equilibrium in all places."

the only mussel species, in some places Lampsilis, L. parva, and occasionally Anodonta grandis are found.

2a. Small permanent creeks, head water sloughs supplied with spring water, and some† ponds and lakes, with current, bottom, and depth much as above, the important difference between 1 and 2a being a more permanent water supply in the latter. Upper Cabin, Spring (Grant Co.), and Gar creeks. This we have called the L. subrostrata habitat; the species mentioned in 1 will be found and occasional representatives of other species but sobrostrata is dominant.

†Our study of pond mussel fauna was not extended enough to enable us to point out differences; certainly in many instances the differences as far as I was able to make them out are chiefly expressed in the fact that the mussel species are different. This matter needs more study.

2b. Certain stretches of the same stream as 2a and stream similar to these, usually farther down stream. Fourteenmile, lower Cabins, lower Shoofly creeks and Red River bayous. This is the Anodonta grandis association; the species named in 1 and 2a are often found. Lampsilis anodontoides and some others may occur frequently but where grandis is dominant it often runs over 75% of all mussels taken.

3. Mud bottomed creeks with a good water supply, mud banks in bends of rivers in still water; 2-4 feet deep never in ponds. Pine and Pryor creeks; Boggy, Neosho, and Verdigris rivers. The above describes the Lampsilis anodontoides habitat. In many situations it is almost exclusively occupied by L. anodontoides or L. fallaciosa; occasional examples of as many as twenty other species may be taken in this association. In certain localities the most common second species will be L. hydiana, in others Quadrula undulata, and in still others L. purpurata. In other stretches of the same stream, where the anodontoides association occurs, great beds of Quadrulas and other Lampsilis species may occur.

4. Large creeks and small rivers, often designated as stony streams, especially the creeks. Ponded stretches from 100 yards to several miles in length; water cloudy and 3-8 feet in depth; current slow and variable; bottom firm, made up of sand, gravel, broken shale, and silt with a soft mud cover. Stretches in Bird, Salt, and Shoofly creeks; Boggy, Neosho, Blue, Verdigris, and Chikaskia rivers. This describes the Quadrula habitat. In the undulata association the dominant species will represent from 50-90% of the total population; in the rivers usually there is a good proportion of other Quadrula.

5. Streams of about the same size as 4, not stony but sandy;

current slow to strong; water clear and 2-4 feet deep; bottom coarse sand, silt, and gravel. Chikaskia, Blue, Cache, Kiamichi, and Neosho. This is a mixed series of habitats. It is not clear to me why the population is as variable as we find it and it may well be called the Quadrula association with undulata, forsheyi, and rubiginosa dominating in different situations. For example Q. undulata was not found in Cache Creek. At Milburn in the Blue forsheyi and pustulosa were rare. In the Chikaskia undulata was the most abundant but other Quadrulas were found in large numbers. These streams have clear water and usually sandy bottoms.

6. The larger rivers in our area, bottom sand and gravel; water clear and 2-4 feet deep, current strong. Stretches that are usually characterized as shoaly. Neosho, Kiamichi, and Little rivers. This habitat is the home of the Lampsilis ligamentina is absent in the situations outlined in 4-5. Associated with L. ligamentina are the Quadrulas, Unio gibbosa, and others.

7. Rivers of the plains type, with fine and coarse sand, broad channels, and shallow water. Washita and North Fork of Canadian, mussel fauna on the whole sparse; in a few favored stretches large assemblages of mussels are sometimes found. This is a striking characteristic fauna and may be designated as the paper shell association represented by Lampsilis gracilis and L. laevissima and associated with these in smaller numbers Plagiola donaciformis, Quadrula pustulosa, and Q. forsheyi. This is a peculiar association; thru Q. laevissima it shows pond affinities, while L. gracilis and the other representatives have river preferences.

Our data would justify other associations, but the above are the ones most clearly defined. The series from 1-6 is an ascending series from the rivulet to the river; from the single species fauna to the fauna with half a hundred and more representatives as this series leads up to the largest streams in the Mississippi Valley and the master stream itself; 7 stands rather apart and represents a condition that does not line up very will in the series.

The tabulation below is interesting as it rather fairly emphasizes the individuality of the associations outlined above. The symbols have the same significance as was applied in the other tables.

*Closely allied species included, for example L. anodontoides-fallaciosus and others discussed earlier in the paper. The fact that the grouping under habitat 7 does not line up in the series as well as the other groups is emphasized by the tabulation. 5 also has some irregularities and suggests that sandy bottom material is the basis for these differences.

Species	Habitat numbers							
	1	2a	2b	3	4	5	6	7
1 Unio tetralasmus	d	e	c	-	-	-	-	-
2 Lampsilis subrostrata	c	d	c	c	-	-	-	-
3 Lampsilis parva	f	e	c	r	-	-	-	-
4 Anodonta grandis	c	f	d	e	c	r	-	-
5 Lampsilis anodontoides *	-	c	c	d	f	r	-	-
6 Lampsilis ovata	-	c	c	c	f	r	-	-
7 Lampsilis purpurata	-	-	e	e	f	r	-	-
8 Quadrula undulata	-	-	-	c	d	a	a	-
9 Quadrula pyramidata	-	-	-	-	c	a	c	-
10 Quadrula lachrymosa *	-	-	-	-	c	a	c	c
11 Quadrula pustulosa	-	-	-	-	c	a	c	c
12 Quadrula rubiginosa *	-	-	-	-	f	a	c	-
13 Tritogonia tuberculata	-	-	-	-	c	c	c	-
14 Lampsilis ligamentina	-	-	-	-	-	-	d	-
15 Unio gibbosa	-	-	-	-	-	-	c	-
16 Pleurobranchus phaseolus	-	-	-	-	-	-	c	-
17 Plagiola elegans	-	-	-	-	-	-	c	-
18 Lampsilis gracilis	-	-	-	-	-	c	c	d
19 Lampsilis laevissima	-	-	c**	-	-	r	-	d
20 Plagiola donaciformis	-	-	-	-	-	e	-	c

JUVENILE MUSSELS: In 1911, a brief paper by the writer, was devoted to the ecology of juveniles; considerable additional data has been secured, especially from our work in the Chikaskia. Most of these observations have been with reference to the juveniles of the Quadrulas. The observations have been quite fully discussed in the consideration of the Rock Falls and Esch Bed stations (p. 57 and 61) and also in another paper (1914). The fact that I wish to reemphasize here is that the optimum adult habitat is often unfavorable for early juvenile activity. A strong line of evidence in support of this position, altho negative in its character, centers around the fact that juveniles are absent from well established beds of habitats 3, 4, 5, and 7 of the adult mussels. So important has this matter of juvenile preference habitat seemed to me that in all of our field work during five summers we have ever been on the alert for

*Closely allied species included, for example L. anodontoides fallaciosus and others discussed earlier in the paper. The fact that the grouping under habitat 7 does not line up in the series as well as the other groups is emphasized by the tabulation. 5 also has some irregularities and suggests that sandy bottom material is the basis for these differences.

**Some lakes, never creeks.

facts concerning the early post parasitic history of mussels. In the well established beds in the Neosho, Verdigris, Chikaskia, and Bird we found little information concerning juveniles. The ligamentina association as outlined under Habitat 6 is an exception as in this group the adults and juveniles are found together in the same stream environment.

We have secured no data concerning pond juveniles, except that previously we found (1911) juvenile of Lampsilis parva and Anodonta imbecillis similar to Habitat 6. There can be no doubt that pond species start in quiet stretches, but even ponds and lakes have their restricted localities for mussel activity as reported by Headlee (1906). As far as our data goes we are able to name two habitats for the early juveniles of our region.

1. In the streams described for Habitat 5 above. On gravelly and sandy bars, in water 1-2 feet deep, with a good current, we have taken several hundred juveniles, from 12-18 mm. long, and probably about ten months old. All of the Chikaskia Quadrulas: undulata, lachrymosa, pustulosa, and rubiginosa were thus distributed. In the Blue a large number of juveniles of Q. rubiginosa were taken. These were the chief sources of large numbers of specimens but many random examples in outer streams support the general conclusions arrived at concerning these species.

2. This juvenile habitat is essentially the same as Habitat 6. The juveniles, however, are restricted to this environment, according to our observation, while the adults of several of the species are largely found in other situations tho this is the optimum environment for them. Here too, we find Lampsilis anodontoides, L. gracilis, L. hydiana, Plagiola donaciformis, that are not found in these situations as adults; on the other hand L. ligamentina, Ptychobranchus, Unio gibbosa, and L. leptodon find this the preference habitat for the mature forms.

Bibliography

This list contains only those papers, which have been quoted in the text.

Baker, F. C. 1898.The Mullusca of the Chicago area. Pelecypoda. Bulletin. Chicago Academy of Science, 3, Part I.

1909. Mollusks from Kansas and Oklahoma. Nautilus. V. 23, 91-94.

Call, R. E. 1885. Contributions to the knowledge of the freshwater mollusks of Kansas. Bulletin of the Washburn College Laboratory of Natural History. V. I, 115-124.

1895. A study of the Unionidae of Arkansas, etc. Transactions of the Academy of Science of St. Louis. V. 8: 1-65.

Ferriss, Jas. H. 1906. Mollusks of Oklahoma. Nautilus. V. 20: 16-17.

Headlee, T. J. 1906. Ecological notes on the mussels of Winona, Pike, and Center Lakes, etc. Biological Bulletin. V. II: 305-318.

Howard, A. D. 1912. Catfish as a host of fresh-water mussels. Transactions of the American Fisheries Society. p. 1-5.

Isely, F. B. 1911. Preliminary note on the ecology of the early juvenile life of the Unionidae. Biological Bulletin, V. 20:77-80.

1914. Experimental study of the growth and migration of fresh-water mussels. Bureau of Fisheries document, No. 792.

Lefevre, G., and Curtis, W. C. 1910. Studies of the reproduction and artificial propagation of fresh-water mussels. Bulletin of the Bureau of Fisheries, V. 30: 105-201.

Ortmann, A. E. 1911. A monograph of the Najades of Pennsylvania. Memoirs of the Carneigie Museum, 4: 279-347.

Scammon, R. E. 1906. The Unionidae of Kansas. Part I. Kansas University Science Bulletin. 3: 279-373.

Shelford, V. F. 1913. Animal communities in temperate America, etc. Bulletin 5, Geographical Society of Chicago.

Simpson, C. T. 1898. Pearly fresh-water mussels of the United States, etc. Bulletin of the Bureau of Fisheries, 18: 279-288.

1900. Synopsis of the Naiades, or pearly fresh-water mussels. Proceedings of the United States National Museum, 22: 501-1044.

Singley, J. A. 1892. Texas Mollusca. Geological survey of Texas. Fourth annual report, p. 299-343.

Sterki, V. 1898. Some observations on the genital organs of the Unionidae with reference to classification. Nautilus 12: 103-113.

Surber, T. 1912. Notes on the natural hosts of fresh-water mussels. Bulletin of the Bureau of Fisheries, 32: 101-115.

Wilson, C. B. and Clark, H. W. 1912a. The mussel fauna of the Maumee River. Bureau of Fisheries Document, No. 757.

1912b. The mussel fauna of the Kankakee Basin, Bureau of Fisheries Document, No. 758.

Figure 1. Outline map of Oklahoma with collection stations in the Red River Drainage and parts of the Arkansas Drainage. The areas covered by maps in Figures 2 and 3 are indicated by heavy lines.

Figure 2. Map showing collection stations on the Grand, Verdigris and their tributaries.

Figure 3. Map showing collection stations in the Chikaskia Drainage in Northern Oklahoma and Southern Kansas.