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The Fresh-Water Mussel Industry of the Lower Tennessee River: Ecology & Future

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Grace,

Randall

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THE FRESH-WATER MUSSEL INDUSTRY OF THE LOWER TENNESSEE RIVER: ECOLOGY AND FUTURE

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THE FRESH-WATER MUSSEL INDUSTRY OF
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ECOLOGY AND FUTURE

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Directed by: Drs. Albert J. Petersen, James L. Davis, and Claude E. Pickard

Department of Geography Western Kentucky University

The fresh-water mussel industry of the Tennessee River is nearing an end. Overharvesting, habitat alterations, and pollution are the major contributors to the depletion of the mussel resource, upon which the shell industry is based. A history of unconcern by shell harvesters and weak conservation enforcement by governmental agencies, has left the major waterways of the United States nearly void of commercial clams. The lower Tennessee River presently supplies the mussel industry with nearly all the important species of mollusks. If this industry is to be maintained in the United States, ways to preserve and propagate the mussel population must be sought. A number of recommendations have been submitted in this work that could aid in the protection of the mussel fauna. Limitations on harvesting methods, more stringent enforcement of existing laws, and extended research on propagation possibilities are suggested as aids in the preservation of this valuable natural resource.

CHAPTER I

INTRODUCTION

For centuries, the Tennessee River has provided a wealth of resources for those who have lived along its banks. One of the least known, yet most constantly extracted resources is the fresh-water mussel,[1] which has been harvested to the point of near extinction.

The harvesting of the Tennessee River mussel began when it was first utilized by Woodland Tribes that settled along the river bank. The Indian valued the mussel primarily as a food source, and he was not selective in his choice of species to be eaten, as is evident by the large variety of shell remains that have been located in middens near many of the rivers of the United States. It was not until the late Nineteenth Century that man became selective in his choice of mussels to be utilized.

When the shells of various species of these aquatic animals were found to be good material for the making of buttons, the full exploitation of the fresh-water mussel began. The button industry grew with such rapidity that in less than two decades, it was observed that the quick

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[1] The terms clam, mollusk, or naiad may be substituted for mussel at various points throughout this research.

depletion of this resource could soon leave the rivers of the United States depleted of commercially valuable naiads. While the fresh-water mussel industry was only four to five years old, the United States Fish Commission undertook investigations, in 1897, dealing with the natural history of the mussel, shell and pearl fisheries, and the button industry (Coker, 1914: 7).

Carlander (1954: 40) states that during the period of the pearl button industry, there existed "the same 'feast or famine' philosophy which has characterized other industries in the United States which have depended upon the use of natural resources--for example, lumbering, mining, and other fisheries such as whaling, sturgeon, and salmon." While the button industry provided a colorful and beneficial chapter to American industry, it has also aided in the destruction of an intriguing and complex animal. This is not to say, however, that man's utilization of the mussel is the only element in this destruction, for habitat alterations and pollution have also contributed to the disappearance of some species.

In the early days of the button industry, one writer (Woolley, 1914: 115) observed that, "people, by the thousands, flocked to the Mississippi River to harvest clams." The majority of the fishermen were part-time farmers, looking for supplementary incomes. Today, the situation is somewhat similar, with most of the fishermen of mussels supplementing their regular incomes by clamming during the

summer months. This way of life, however, may soon come to an abrupt end.

Only the lower Tennessee River continues to provide a clam resource large enough to support major shell harvesting interests. If the remaining clam resource is eliminated from the Tennessee, it will send approximately 200 people elsewhere to seek employment (Grace, 1972: 50).

Today, with loud voices calling for the preservation of what remains of the earth's natural environment, more concern and research should be directed toward the conservation and propagation of the fresh-water mussel. Ways should also be sought to preserve the shell harvesting industry from demise at its own hands.

Purpose of Study

The purpose of this study is to describe the causes of the decline of the fresh-water mussel fauna of the lower Tennessee River and propose methods of safeguarding the remaining resource. An evaluation of the needs of the mussel industry will be made to determine ways in which both the naiad resource and the industry will benefit.

Utilization of the mussel will be traced from prehistoric times through the present day, with the results being a rapid depletion of this once abundant aquatic animal. Harvesting methods will be examined to show their damaging effects on the mussel population. Personal observations will be noted concerning the most recent methods

of collecting shells.

The changing habitat of the fresh-water mussel will be reviewed. Natural water-flow alterations, in the form of dams, and pollution will be cited as possible causes of the depletion of many mussel species. Data provided by governmental agencies and personal field observations will be evaluated, while the changing ecosystem of the fresh-water mollusk will be examined.

Study Area

While most of the rivers and streams of the United States support, or have supported, some species of fresh-water mussels, the lower Tennessee River (Figure 1) will provide the study area for this thesis. As Isom (1969: 409 and 412) noted, when reporting on the varying ages and physiography of the reservoirs, "each reservoir unit should be considered an independent ecological unit," as variations in the bottom habitat are clearly evident.

The selection of this study area is fourfold. First, the Tennessee River supports the largest remaining population of commercial[2] shell fauna. Second, the lower Tennessee continues to support the major large-scale mussel harvesting interest in the United States. Third, the Tennessee Valley

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[2] "Commercial," as referring to the fresh-water mussel will be used for those shells valued by mussel fishermen. A list of commercial shells and their scientific names appear in APPENDIX A.

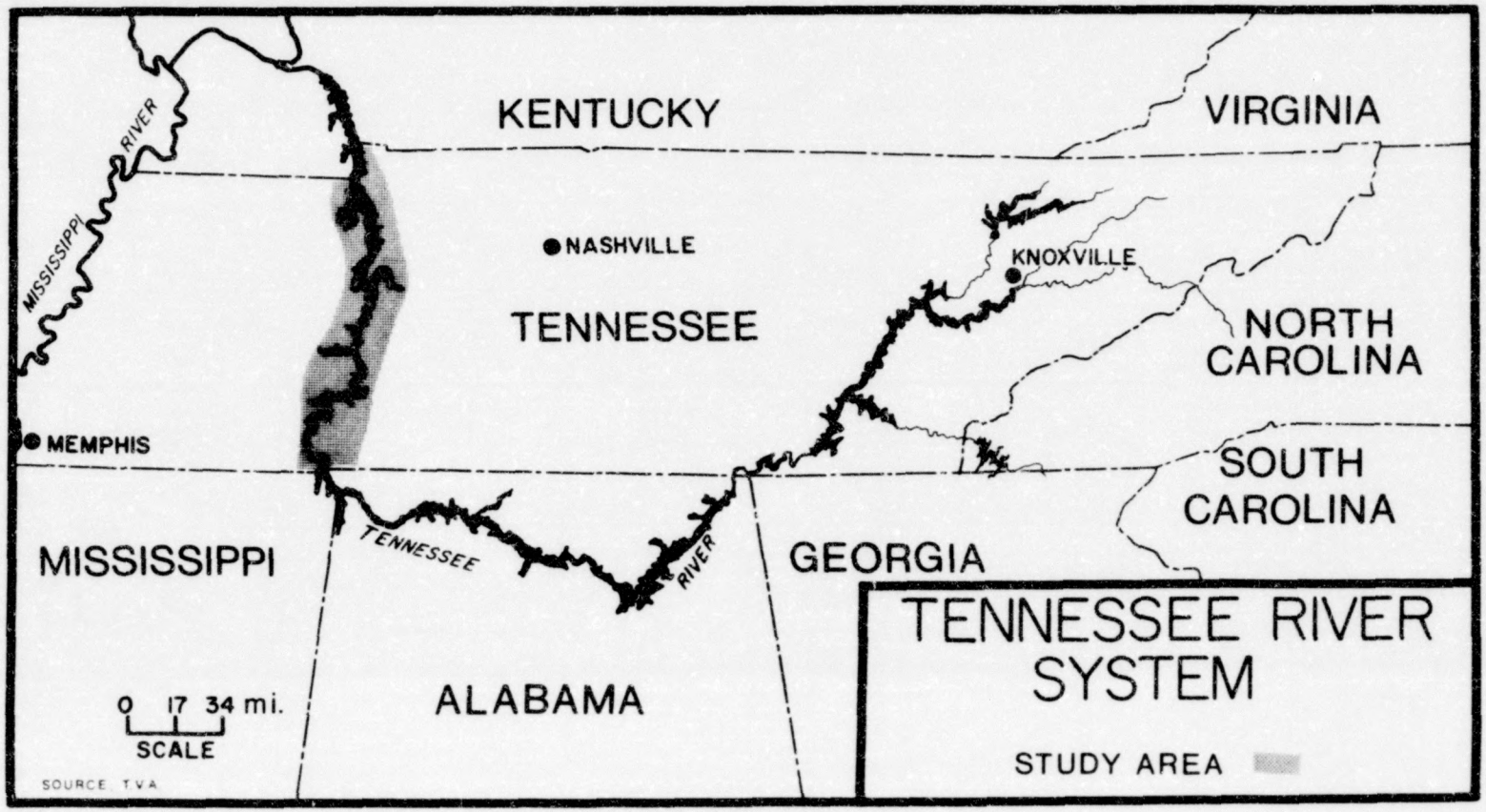
KENTUCKY
VIRGINIA
MISSISSIPPI RIVER
NASHVILLE
KNOXVILLE
TENNESSEE
NORTH CAROLINA
MEMPHIS
SOUTH CAROLINA
MISSISSIPPI
TENNESSEE RIVER
GEORGIA
ALABAMA
0 17 34 mi.
SCALE
SOURCE: T.V.A.
TENNESSEE RIVER SYSTEM
STUDY AREA

FIGURE 1

Authority is involved in research, not only concerning the preservation of the mussel, but also in the preservation of the shell industry. Finally, the lower Tennessee River was chosen as the study area because of the direct experiences of this writer as a diver for fresh-water mussels.

CHAPTER II

UTILIZATION OF THE FRESH-WATER MUSSEL

The Early Uses of the Fresh-Water Mussel

The North American Indian harvested mussels for various purposes, however, the major utilization of the mollusk was for a source of nourishment. Stansbery (1966: 42) noted that Archaic Man (6000-1500 B.C.) was a hunting and gathering people, who settled near the mussel rich riffles of large streams (Figure 2). While the fresh-water clam was most important as a food staple, Archaic Man modified certain shells for use as spoons and dippers. This early exploitation of the mussel was quite extensive, as is evident by numerous shell middens that may be observed along the major rivers of the central portion of the United States.

Matteson (1960: 117-120) observed that the shell midden not only gives a description of the Indian life style, but it also provides some insight into the types of mussels that existed in the rivers of North America. The anthropologist Kneberg, (1960: 190-198) used the middens along the Tennessee River to describe the prehistoric settlement in the area. It was found by Kneberg that the various cultures utilized the naiads in different ways.

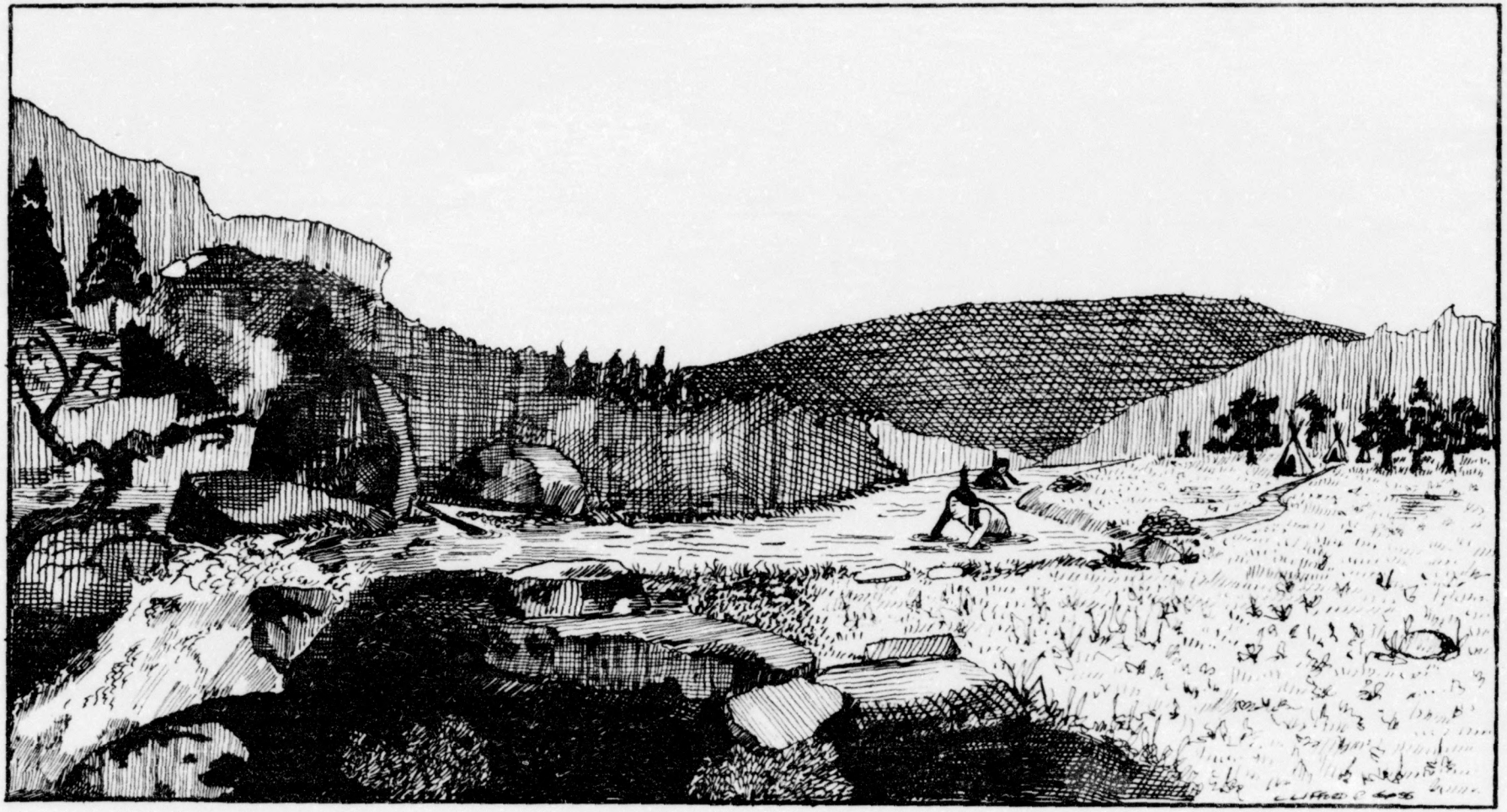

FIGURE 2: The North American Indian generally settled near the mussel rich riffles of the larger streams. These people harvested the naiad by hand, as shown in this illustration.

The Eva people were non-agrarian people who utilized the mussel as a food source, and they fashioned awls, fish-hooks, needles, and ornaments from the shells. Small Anculosa shells were strung as beads and undoubtedly used as barter for pottery.

Stansbery (1966: 42) describes two more notable uses of the naiad shell as being the formation of the shell hoe by the Cole Complex (800 A.D. - 1200-1300 A.D.). A second noteworthy use was the crushing of shells into a powder, which was used for the tempering of pottery. This was first done by the Fort Ancient people (1200-1300 A.D. - 1650 A.D.). As a result of the utilization by the Indians, the depletion of the mussel fauna of the Tennessee River was quite extensive. This depletion is evident from the large shell middens (up to 15 acres each) that are noted along the course of the Tennessee River. While many enormous middens have been destroyed by impoundment waters, a number of the refuse dumps remain along the west bank of the river (Figures 3 and 4). From examinations of these middens, it is obvious that these people were not selective in their extraction of shells from the Tennessee River. Not until the European settlers came into the valley did selective harvesting of shells begin.

Little is actually known of the earliest use of the fresh-water mussel by the European immigrants who settled along the river. Reuben G. Twaites noted the eating of mussels by some settlers along the lower section of the

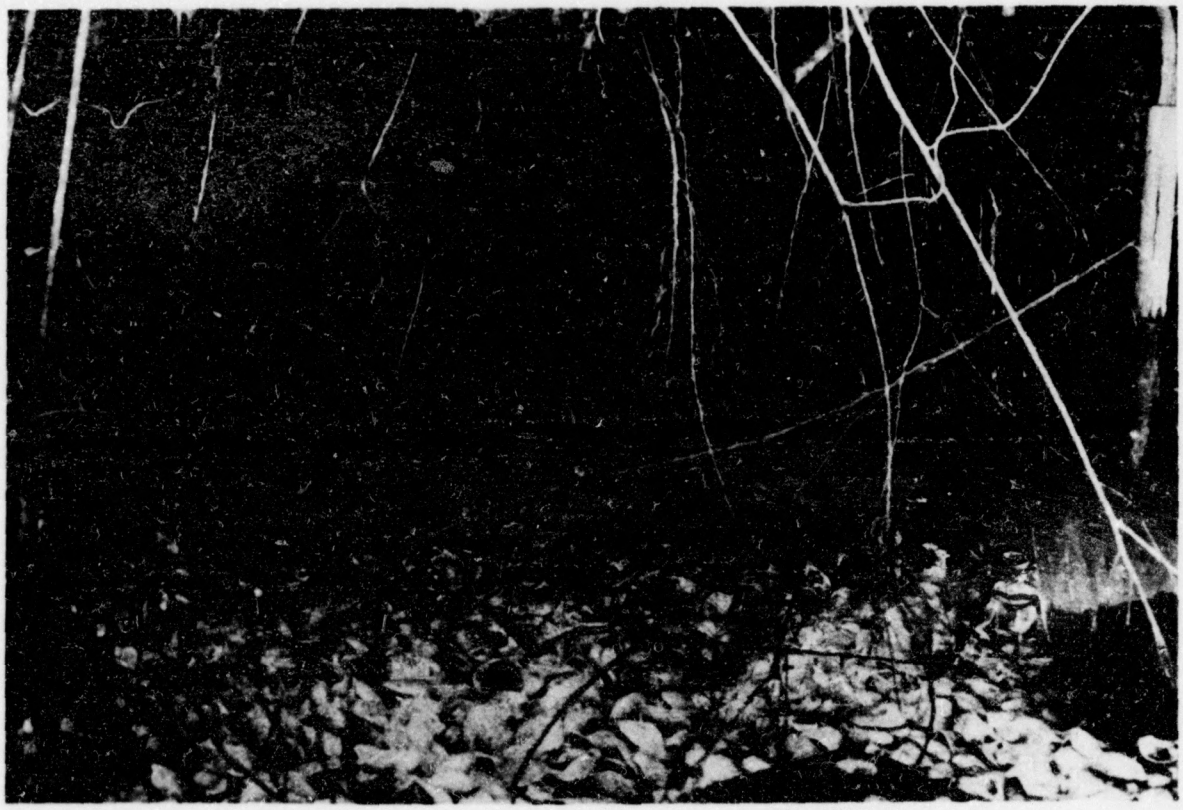

FIGURE 3: A portion of a shell midden located on the west bank of the Tennessee River in Decatur County, Tennessee.

Tennessee, in his Early Western Travels: 1748 to 1846. As to the amount of consumption, it is generally conceded that it was a rare exception, since fresh-water mussels are not included in the Anglo-Saxon food inventory. In an interview with Dr. Samuel G. Brinton, a surgeon with the Army of the Cumberland during the Civil War, Rau (1873: 385) learned that soldiers had been observed eating mussels from the Tennessee River. As stated by Brinton, the soldiers found the clams "a change" from their regular rations.

While the utilization of the naiad shells by the early

DARK DOCUMENTS

"May Not Film Well."

FIGURE 4: The above portion of a shell midden is located in Decatur County, Tennessee. River sediments cover this midden where a large variety of mussel species were found.

settlers is not commonly noted, it may be assumed that the shells were used for needles and some household utensils. These home uses of the mussel shells are not thought to have been extensive, but by the Nineteenth Century, some small industries for the production of buttons were established in the Ohio River and Mississippi River valleys.

The Pearl Button Industry

Until the early part of the Nineteenth Century, the mussel fauna resource remained unnoticed by the Anglo American settlers. The first known commercial use of the shell was about 1802. At this time, Coker (1921: 64) noted that a small cuff button manufacturing operation was located on the Ohio River. Little is recorded concerning this operation, and industries such as this were rare since wood, metals, horn, and marine shells were the most common sources of button material. Buttons of wood and brass had been used since 1750, horn was introduced around 1812, and the marine shells were first formed into buttons around 1855, in the United States. These materials had a tendency to rust, break, or warp.

About 1872, a man in Peoria, Illinois conceived the possibility of using the fresh-water mussel shell for the manufacturing of pearl buttons. Consequently, a quantity of shells from the Illinois River were sent to Germany for processing. It is not known, however, if the European

button cutters experimented with the North American shells.[3] Coker (1921: 65) states that the experimentation with the American shells in European countries was limited, since these industries were accustomed to working with marine shells. The cutting machinery used in Europe was built to manufacture buttons from the harder ocean shells, and aside from hardness, there are distinct differences in the qualities of the two shell types.

With the exception of a short-lived industry established in Knoxville, Tennessee (1883), twenty years passed before shell buttons were manufactured in the United States. The commercial plant that was located in Knoxville, fashioned buttons and novelties from the Tennessee River mussel shell. Unfortunately, this endeavor only existed for a short time. Because of a lack of suitable shell cutting machinery, the factory closed in less than twelve months (Coker, 1921: 64).

The utilization of fresh-water mussel shells remained dormant until 1891, when J.F. Boepple came to the United States from Germany. In his homeland, Boepple had been a button worker and had the opportunity to examine a sample of the American naiads. He believed that this shell material was, potentially, excellent for the manufacture of buttons (Woolley, 1914: 113).

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[3] Many European countries had established button industries at this time. Marine shells, however, were the material used for buttons.

After arriving in the United States, Boepple went to the Midwest in search of the river that had been the origin of the shells he had examined in Germany. He knew the shells had come from an area near Chicago, Illinois, and he examined various rivers in the Mississippi River Basin. In the Mississippi, near Muscatine, Iowa, Boepple found a large quantity of mollusks immediately available, and it was here that he established a small button factory.

As with any new venture, the button factory was less than successful in the beginning. Boepple was a traditional button cutter, and even with the development of more practical cutting machinery, he held to the use of the European style lathes (Woolley, 1914: 116-119). Other individuals became involved in the industry and by 1895, several factories were established, primarily along the Mississippi River.

By 1898, the industry had grown to about fifty factories in more than a dozen cities along the Mississippi. According to Carlander (1954: 40), it was because of the large clam population in the river near Muscatine that the industry grew rapidly, and soon Muscatine was known as the undisputed pearl button capital of the United States.

Kiddier (1959) reported that in 1897, over three-hundred persons were harvesting mussels in the eight miles of river between Clinton and Burlington, Iowa, and by the following year, over one-hundred clammers were working from Muscatine alone. As the number of harvesters grew, the clam resource showed signs of being overharvested.

The mass wasting of the mussel resource was caused by two factors--harvesting methods and ineffective controls on the button manufacturers.

Shell Harvesting and Button Manufacturing Waste

As in the case of many industries that survive on a natural resource, shell harvesters and button manufacturers did little to protect themselves against the loss of the fresh-water mussel resource. The overwhelming abundance of the naiads in the upper Mississippi River lured thousands of people to the river for a quick economic gain.

Mass wasting of the mussel fauna was noted almost immediately after the introduction of the button industry. Baker (1903: 104) observed piles of discarded shells along the banks of the Mississippi "for a distance of a quarter of a mile." Most of the wasted shells Baker noted were non-commercial clams, but the wasting was not restricted to these accidentally harvested species. Many valuable species were also lost (Smith, 1899: 300). Young clams were caught and retained. However, because of their size, they generally were discarded by the fishermen. The methods used to obtain mussels also led to the distruction of the animal.

In the early days of commercial shell harvesting, hand picking (simialr to Indian collecting) was the common form of gathering clams. This was limited to the riffle areas of the streams and rivers. With increasing demands for shells from the button industry, the mussel shell populations in

deeper water was sought. Longhandled tongs and rakes (Figures 5 and 6) were utilized to lift the clams from their beds. Generally, all commercially valuable shells were retained and little concern was noted for undersized mollusks, and as Coker (1921: 63) noted, the taking of undersized mussels was the major problem when dealing with the resource depletion. It was also stated by Coker that experiments showed that 35 to 40 percent of the young mussels would die after being harvested and returned to the river bottom. The replacement of these undersized young naiads would, potentially, leave 60 percent for a continued natural growth. However, it was not generally the practice of the fishermen to return the small shells.

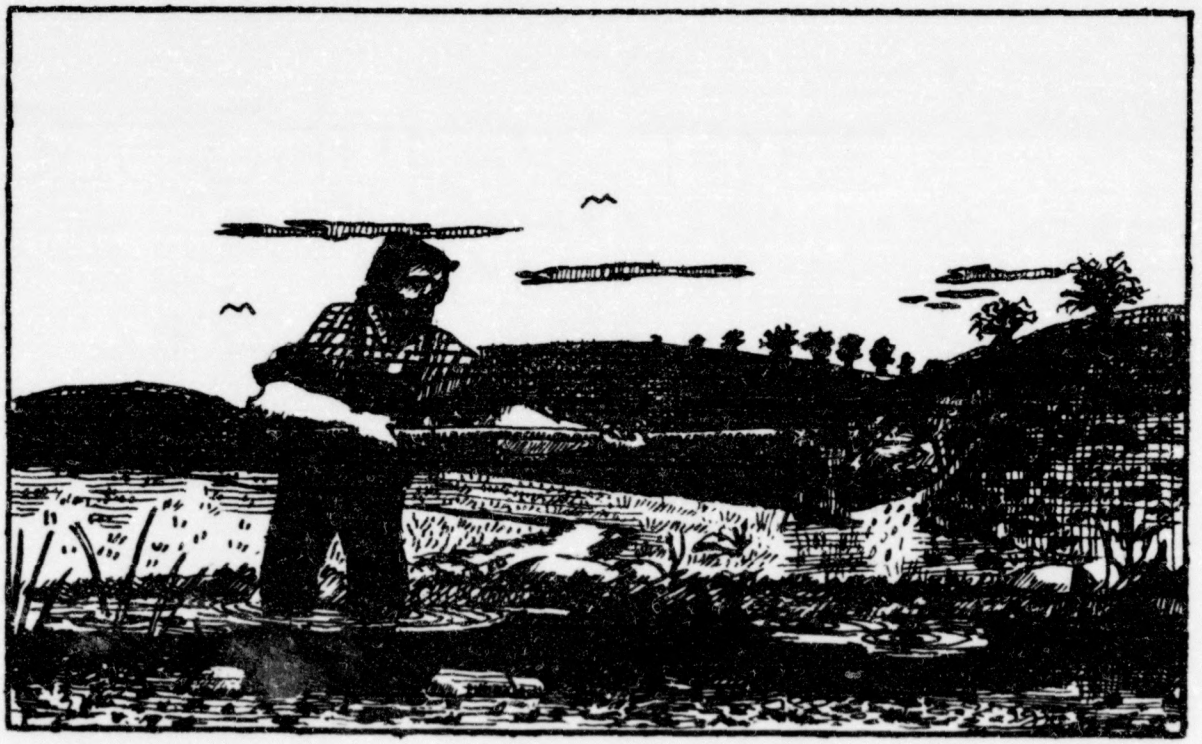

FIGURE 5: Raking for shells was common practice in the riffles and shallows of the smaller streams in the Mississippi River Basin.

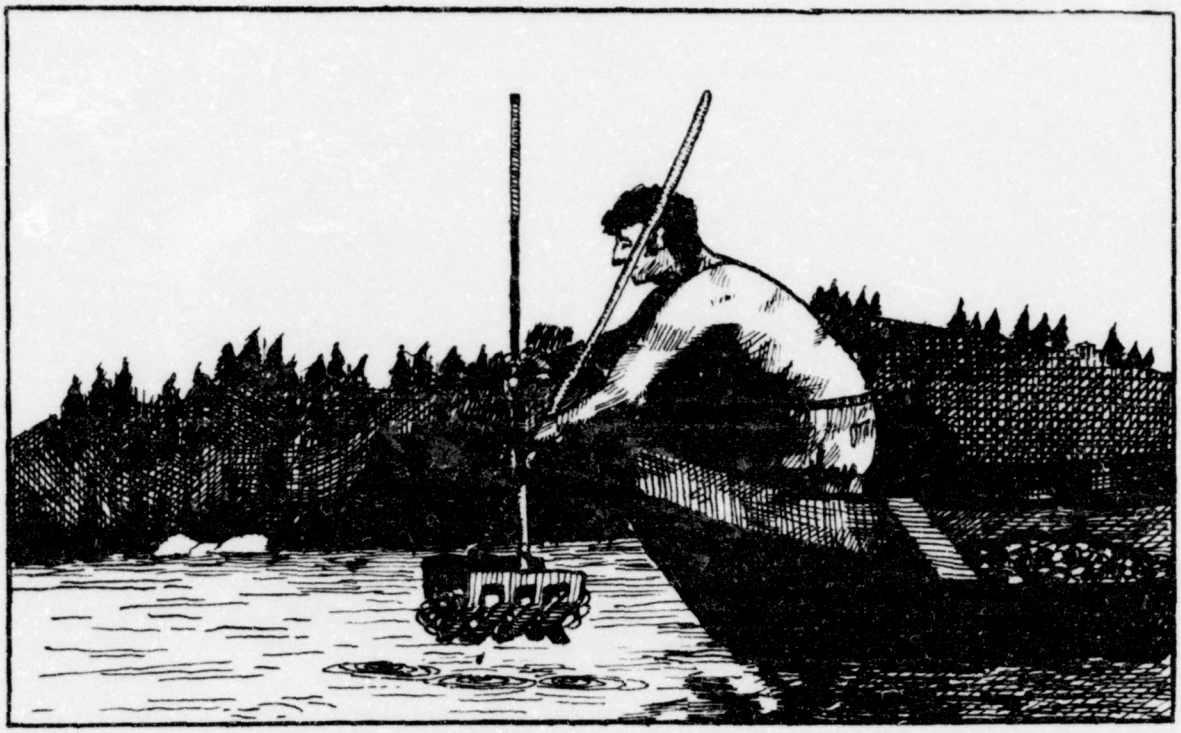

FIGURE 6: The use of longhandled tongs was one of the earliest methods used for collecting shells. This was most often done in shallow waters.

Even if the undersized naiads were to be returned to the river bed, the invention of the "brail"[4] aided further in the depletion process (Figure 7). The "brail" was developed in 1897, and its use grew rapidly when it was found to be a very efficient and less laborious method of collecting mussels. "Brails" consisted of eight to ten foot boards or iron bars, to which were attached hundreds of four prong wire hooks (Figure 8). As the dredge was lowered to the river bed and pulled along, the hooks became lodged between the open valves of the naiads (Figure 9). When the fisher-

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[4] The "brail" was earlier referred to as the crowfoot dredge.

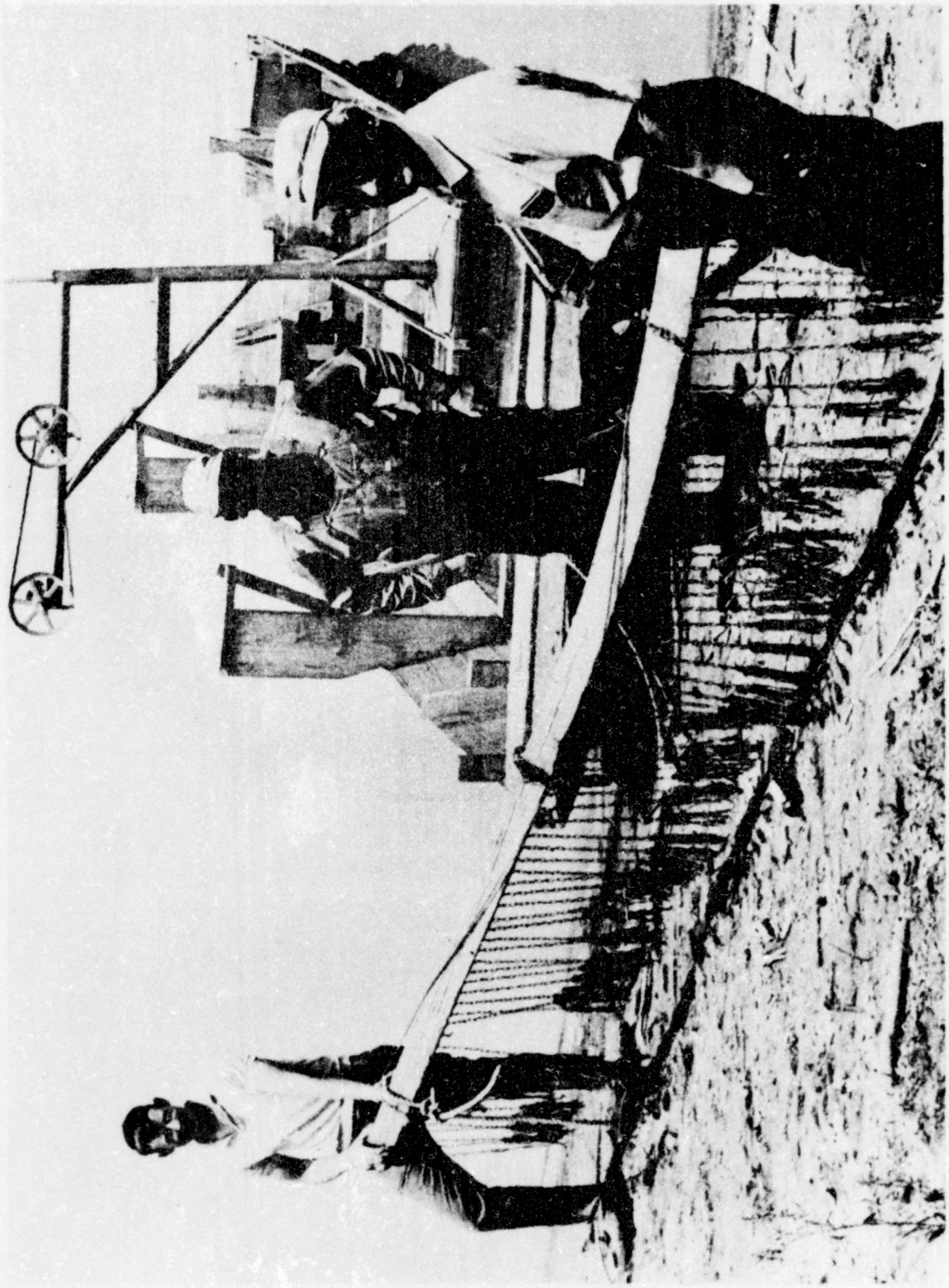

FIGURE 7: This "brail" rig is typical of the type used on the upper Mississippi River during the early part of the Twentieth Century. This particular outfit worked the Ohio River until recently.

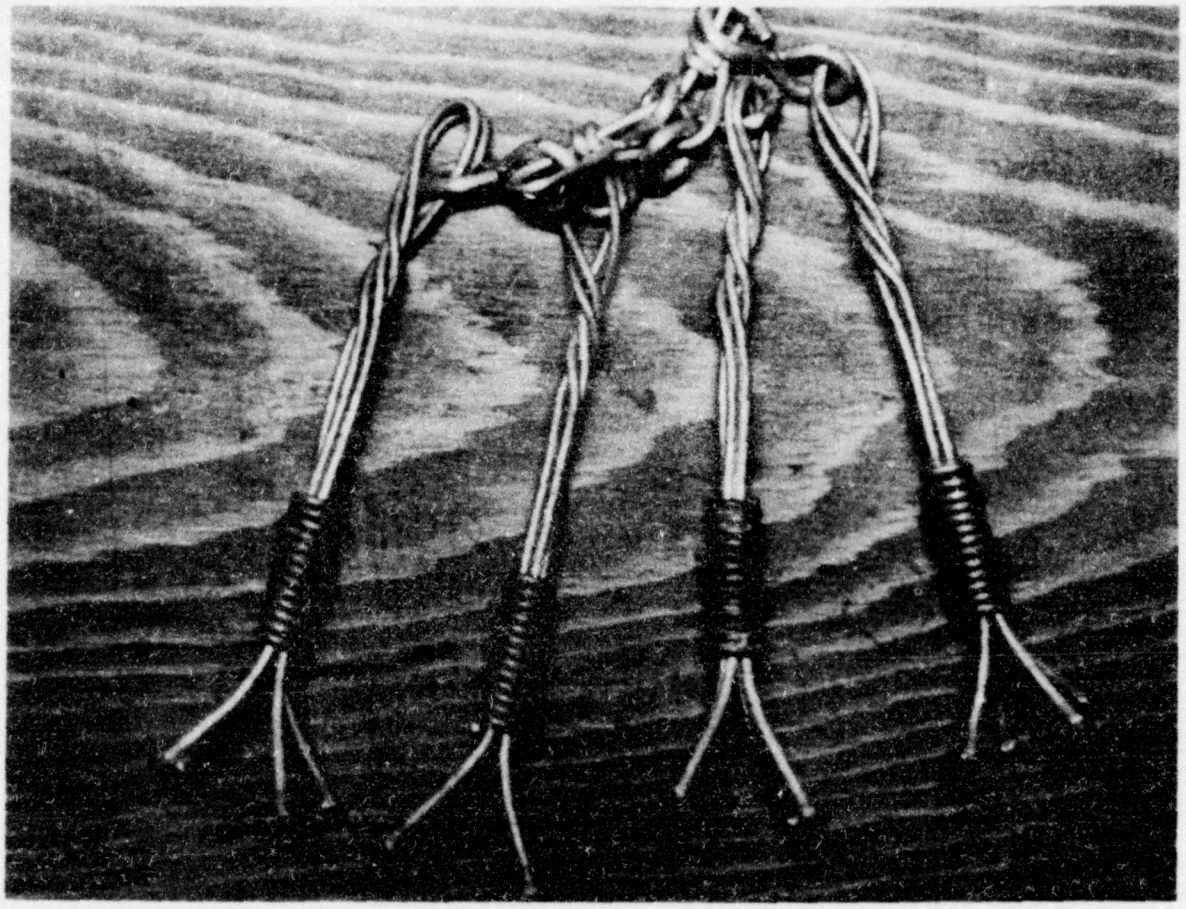

FIGURE 8: Wire "brail" hooks similar to this were used as early as 1897. The prongs of the hooks would become lodged in the valve openings of the live mussels.

man reached the end of the mussel bed, he would raise the "brail" and retrieve the mussels. This harvesting method was extremely effective and Smith (1899: 295) in 1899, observed sixty marketable mussels being caught on thirty-nine "brail" hooks. He continued by stating that on a good mussel bed, a man could easily harvest eight hundred to a thousand pounds of "niggerheads" (Fusconaia ebenus) in a day.

While the "brail" was an effective device for harvesting clams, it was also a factor in the interruption of the

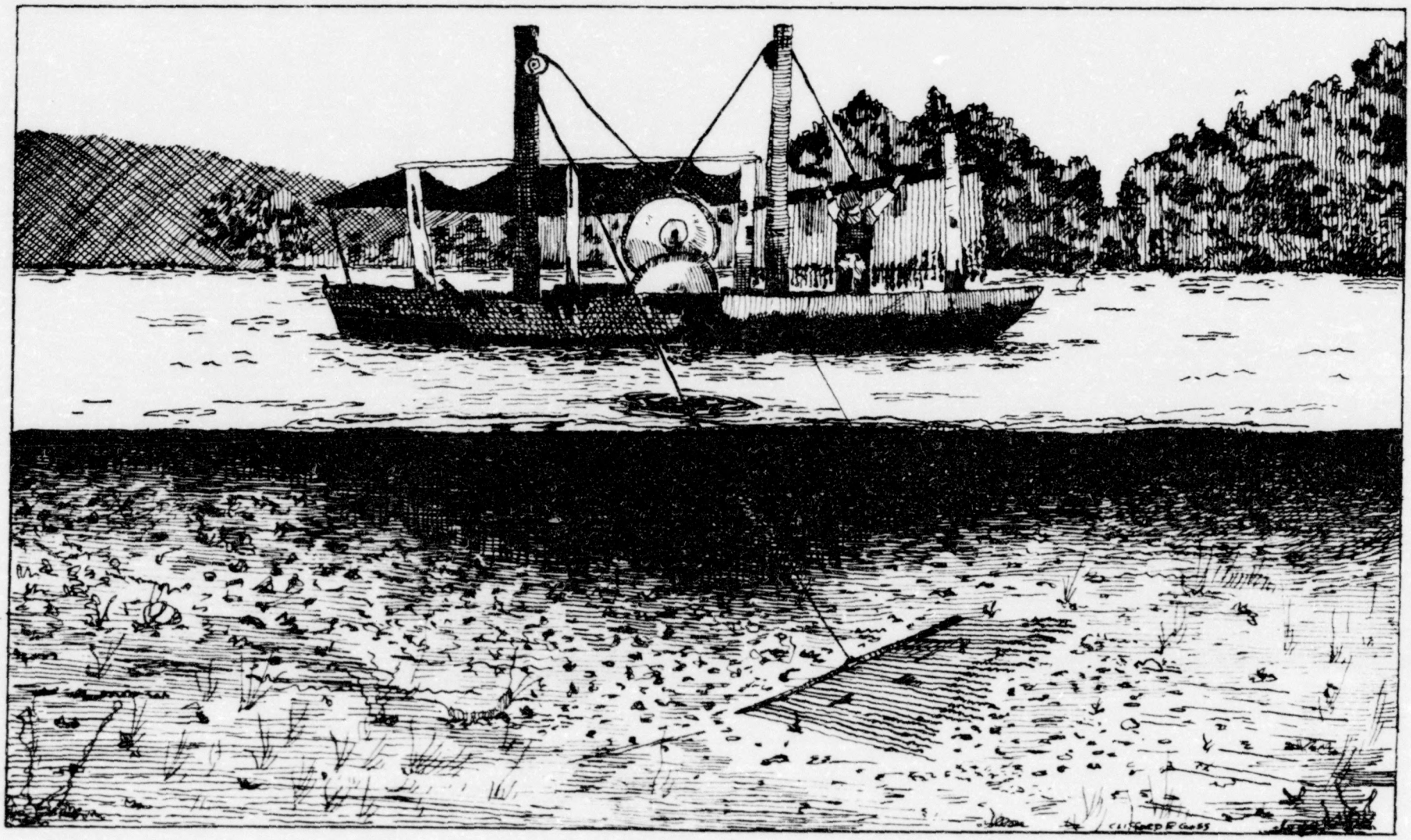

FIGURE 9: The operation of the "brail" dredge. The hooks become lodged in the open valves of the mussels and then are lifted to the boat.

natural reproduction of mussel beds. Coker (1922: 82) observed that often the slightest disturbance could easily interfere with the natural growth of the mussel. In light of this, the overharvesting of naiads was not the only source of the depletion of the resource. The constant dragging of the "brail" across the bed of the mussels would not only disturb the growth of the naiad population, but would also remove mussels during the breeding season.

In the early years of the button industry, clamming was not the only factor in the depletion of the mussel resource. Button manufacturers found the demand for pearl buttons to be great and consequently, little care was taken in the production of buttons, to eliminate wasting of shell material.

With the swift acceptance of the fresh-water mussel as the most suitable material for making buttons,[5] the industry was slow to change its manufacturing methods, to insure the most suitable and complete utilization of each shell. Coker (1921: 82) noted that during the early years of the industry, the most wasteful use of the shells prevailed. Skilled button cutters were rare and the result was that two or three button blanks (Figure 10) were cut from shells that had the potential to produce two or three times that number. It was also noted that only five to eight percent of the

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[5] The table in APPENDIX B will give some indication of the acceptance of the fresh-water mussel shell as the predominant button making material.

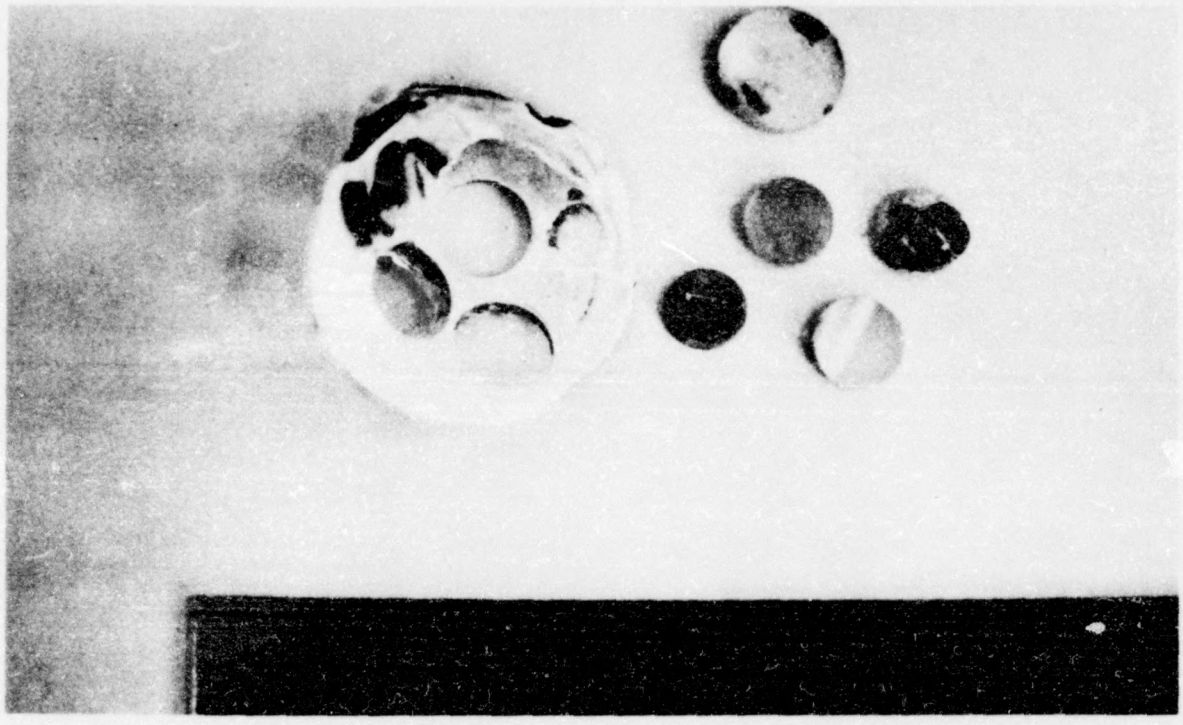

FIGURE 10: Button blanks such as these were cut from the shells, and often a great deal of waste resulted. The large amount of valuable shell material remaining in the shell above could have been utilized if proper cutting methods had been used.

original gross weight of the mussel entered into the button product. For example, only seven percent of the very valuable "niggerhead" shell was utilized, leaving 93 percent to total waste (Coker, 1921: 86). A break down of utilization as opposed to waste may be noted from Table 1.

Another startling by-product of the clam that was wasted was the meat of the naiads. Only slight utilization of this potential food has ever been noted during the early part of the Twentieth Century. The meat of the fresh-water mussel contains approximately 44 percent protein. Not only would the meat have been an excellent source of human food, but

TABLE1
LOSSES IN SHELLS OF CERTAIN
SPECIES DURING MANUFACTURE OF BUTTONS*

Waste or by-product	Lake Pepin Mucket	Nigger-head
	Percent	Percent
Discarded shell.....	60.8	73.6
Dust in sawing blanks.....	16.9	8.8
Dust in grinding and finishing buttons.....	12.9	10.8
Total waste or by-product...	90.6	93.2
Weight of buttons.....	9.4	6.8
Total.....	100.0	100.0

* This data is the result of tests made by J.B. Southall, and related by R.E. Coker (1921: 86).

they would have been superior sources of nourishment for animals.

This mass wasting of the fresh-water mussel continued both in the harvesting and button manufacturing. Consequently, the button industry began to reach out to other rivers in the Mississippi Basin for its shell supply, as the resource in the Mississippi River was unable to meet the demands of the industry. As the tributaries of the Mississippi became non-productive, rivers outside the Mississippi drainage system were explored. One of these rivers that became important to the pearl button industry was the Tennessee River.

Shell Harvesting and Utilization of the Mussel on the Tennessee River

During the early part of the Twentieth Century, while the upper Mississippi River was supplying the majority of the mussel shells for the button industry, the shell fauna of the Tennessee River was virtually neglected. For years, the Mississippi mussel was felt to be the only shell adequate for the production of quality mother-of-pearl buttons. This, however, is not to say that the mussel of the Tennessee River was not utilized.

There was a great deal of mass wasting of the Tennessee Valley mussel population. The majority of this waste resulted from fresh-water pearl hunting. The fresh-water mussel produces a pearl or slug, which was highly valued on the jewelry market. Mussels from the Tennessee Basin--particularly from the headwaters in East Tennessee--were extracted and searched for pearls. Boepple and Coker (1912: 3-13) noted that tons of valuable shells were discarded along the banks of the Clinch, Holston, and Powell rivers.[6] The search for pearls in this area was more important than the shipping of the shells to be fashioned into buttons.

Boepple and Coker suggested that this valuable resource be processed and shipped to the button market, but this was not done to any extent. Coker (1921: 40) later noted that

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[6] The Clinch, Holston, and Powell rivers are the main headwater streams that form the Tennessee River.

the Clinch only provided minor supplies of shells and the Holston and Powell rivers were not mentioned.

While the Mississippi River supplied three-fourths of the material used by the button industry in 1914, the Tennessee ranked last in the United States in harvesting of mussels (Coker, 1921: 39-40). Isom (1969: 398) reports that in 1914, 650 tons of shells were extracted from the Tennessee River, with production increasing yearly until 1936. At that time, the Tennessee Valley Authority completed the first of its mainstream dam projects at Elgin, Alabama. Most of the mussel fishermen felt the impoundment of the river would eliminate most of the suitable shell fauna habitat. Consequently, harvesting stopped until 1945, when exploratory shell harvesting in Wheeler Reservoir produced large collections of commercial shells. In 1947, the Tennessee produced 10,610 tons of commercially valuable shells (T.V.A., 1970: n.p.).

The supply of shells continued to increase for a number of years and the Tennessee River shells made up the largest portion of shell button material. Button industry demands for shells soon declined with the introduction of plastics and other materials. The decline was short-lived because in the mid-1950's, a lucrative export market was developed with Japanese demands for fresh-water mussel shells (Isom, 1969: 398).

The Japanese developed a process by which pearl producing oysters could produce cultured pearls in a shorter period

of time by inserting fresh-water mussel shell "seeds"[7] into the oyster. The natural nacre would be veneered around the "seed" and form the pearl (Time, 1959: 198). Isom (1969: 398) states that the resulting cultured pearls from this process are the basis for an $85-million-a-year business for the Japanese.

With the Japanese market as a stimulus, the shell harvest from the Tennessee River increased until the early 1960's, when it became evident that the demand had surpassed the productive abiltiy of the normal "brail" collecting methods of harvest. Consequently, the introduction of the SCUBA diver (Figure 11) aided greatly in the further depletion of the Tennessee River mussel resource. Divers have a distinct advantage over the "brail" fisherman. Working from the same type boats, the diver is able to locate mussels more rapidly. Dredge fishermen must pass over an area four or five times before determining whether fishing the particular location will be profitable. This exploration may involve one full days work. The diver, however, can lower a collecting barrel to the river bottom, descend to the bottom, and in a matter of minutes, he can determine the potential of that section of river.

Often, divers will harvest from beds of shells that had previously been dredged by "brail." The crowfoot dredge was very effective, but large quantities of calms

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[7] "Seeds" is the term used for the rounded pieces of fresh-water shells that form the nucleus of cultured pearls.

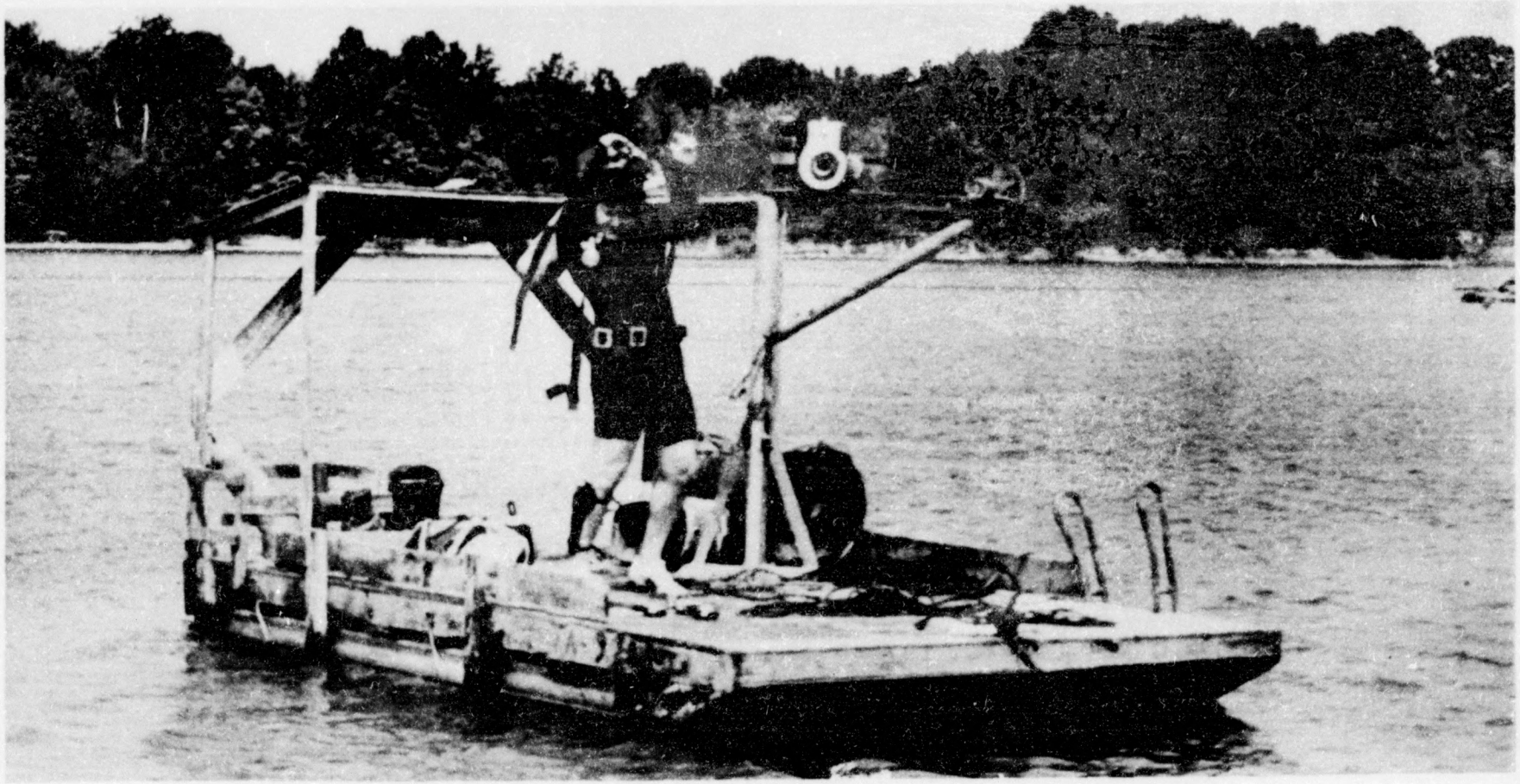

FIGURE 11: The SCUBA diver first appeared on the Tennessee River in the mid-1960's. Divers replaced "brail" harvesting when the shell population was depleted to the point that dragging became unprofitable. Since the introduction of the divers, the mussel resource of the Tennessee has almost disappeared.

were not extracted by this method. Consequently, divers will harvest these "abandoned" shell beds, taking all remaining commercial species. Working in groups of up to ten boats, divers can clear a productive mussel bed in a matter of days.

Overharvesting--similar to that in the upper Mississippi River in the early 1900's--of the fresh-water mussel in the Tennessee, has left the United States on the verge of having no commercially valuable shell resource. Overharvesting alone has not been the single cause of the decline of the naiad population. Pollution and habitat alterations (in the form of dams) undoubtedly have attributed to the decrease in the shell fauna. Isom (1969: 397-422) and a T.V.A. report (1966: 6-7) notes the causes of the mussel decline as being the three above mentioned sources of depletion, but there are other possible causes that have yet to be researched thoroughly.

CHAPTER III

FACTORS IN THE DECLINE OF THE FRESH-WATER MUSSEL OF THE TENNESSEE RIVER

Commercial fresh-water mussels that inhabit the Tennessee River are being eliminated at a greater rate than can be compensated for by natural reproduction. Various factors have jointly led to the depletion of the naiad resource. Harvesting methods--particularly overharvesting by SCUBA divers--and the lack of governmental control on shell collecting have been the major contributors to the decline of the clam resource. Mainstream dams on the Tennessee have altered the habitat in which the mussel once thrived. Pollution is another factor that has intruded upon the habitat of the mollusk. Combined, these factors may soon eliminate the remaining commercial mussels and mussel fisheries activities from the lower Tennessee River. Preservation of this natural resource is possible if proper control and research of the mussel is adopted. This author has concluded this chapter with a number of recommendations that could eventually preserve the remaining clams, and possibly increase the entire naiad assemblage.

Overharvesting

The methods of collecting fresh-water mussels in the Tennessee River have been the same as those employed on the upper Mississippi River. Tongs and rakes were used in the shoal areas, and the "brail" has been used extensively along the 580 mile river. The constant harvesting of the clam beds has reduced the density of commercial-size mussels 23 times faster than they can be replaced by young mussels (T.V.A., 1966: 1). This depletion rate was escalated in 1962, with the introduction of SCUBA divers.

Divers were first placed on the river for the purpose of retrieving "dead" shells that were laying waste, and could not be extracted from the river by the "brail" operation. However, divers soon found more live naiads than dead (Lawrence, 1969: 18). Thus, the depletion rate grew, and today the commercial clam resource of the Tennessee River is in great jeopardy.

Until 1962 though, there was evidence that a decline in the shell population was occurring. According to Isom (1969: 408) commercial production declined 50 percent between 1960 and 1962. By 1964, the yield was down another 64 percent (Table 2). This decline continued through the years, even though more mussel boats were licensed and operated on the Tennessee River. With increased demands from the Japanese market, the price paid per ton increased. Isom (1969: 408) noted that from 1954 to 1963, the average price for shells increased from $42 to $147 per ton. The number of clamming

TABLE 2
ANNUAL SHELL HARVEST, TENNESSEE RIVER 1945-1967

Year	Number of boats (approx.)	Total shells (tons)	Total value* $
1945	143	3,720	148,660
1946	149	9,875	373,781
1947	186	10,610	410,540
1948	210	11,663	502,229
1949	200	7,570	265,000
1950	228	10,500	315,000
1951	256	10,241	409,640
1952	256	8,124	365,580
1953	261	10,890	600,518
1954	280	11,220	472,975
1955	298	11,463	504,252
1956	280	6,603	390,583
1957	317	7,376	556,026
1958	294	4,802	288,120
1959	519	5,606	389,616
1960	861	10,380	1,267,875
1961	926	7,039	882,397
1962	802	4,716**	666,548
1963	678	5,800***	852,911
1964	398	2,112	294,385
1965	233	2,418	346,121
1966	268	2,734	577,161
1967	366	2.361	428,561

Source: Isom, 1969: 401.

*Based on river bank prices.
**Divers collected 235 tons.
***Divers collected 212 tons, dredge boats 97 tons.

boats increased three times and at one point, over 1000 persons were engaged in harvesting. At its peak in 1966, the American mussel industry represented an 8.75 million dollar business (Lawrence, 1969: 18).

The major part of the industry is centered on the lower Tennessee River (Figure 12), from Pickwick Dam to the Kentucky

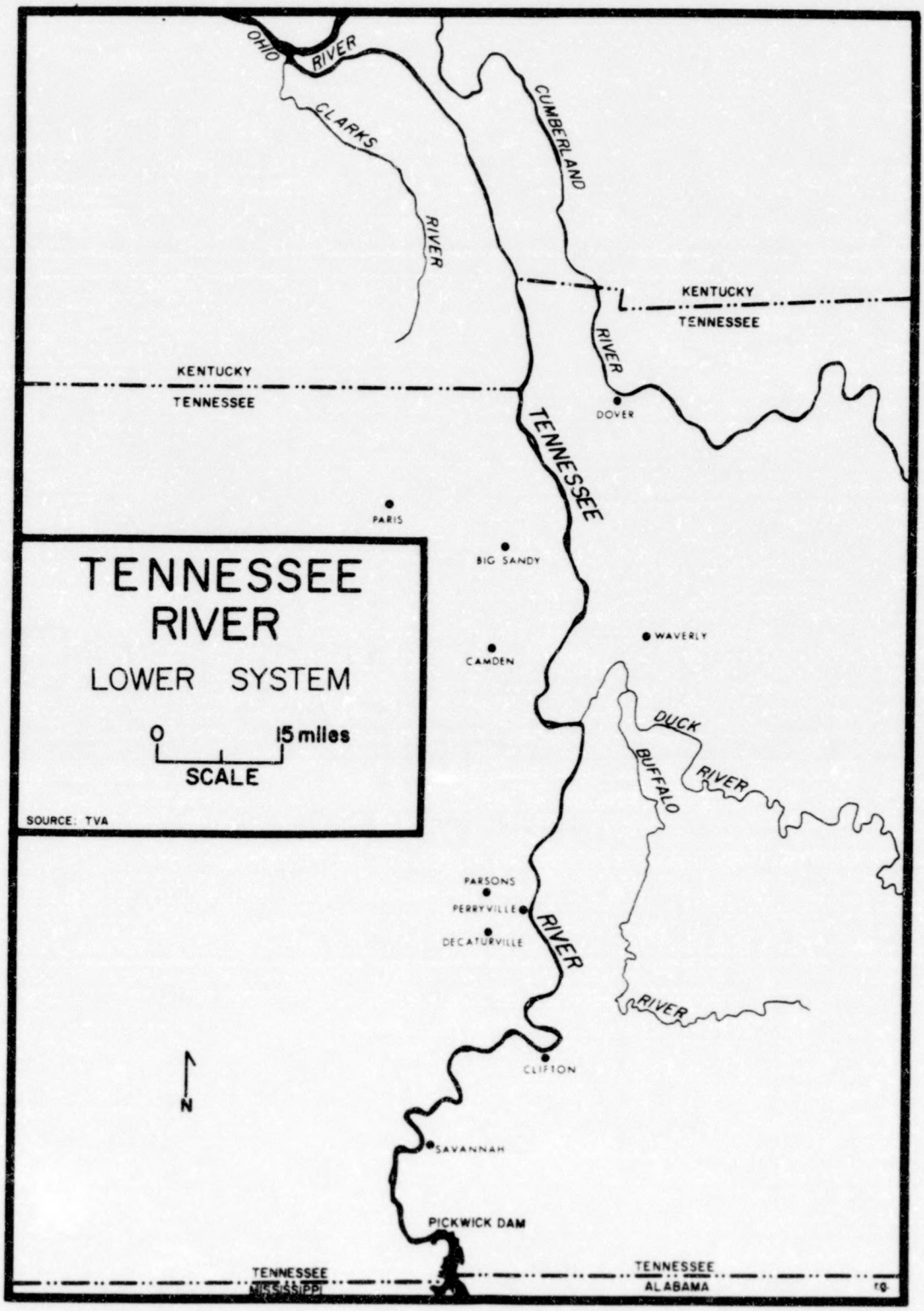
OHIO RIVER
CLARKS RIVER
CUMBERLAND RIVER
KENTUCKY
TENNESSEE
KENTUCKY
TENNESSEE
DOVER
TENNESSEE RIVER
PARIS
BIG SANDY
WAVERLY
CAMDEN
DUCK RIVER
BUFFALO RIVER
PARSONS
PERRYVILLE
DECATURVILLE
RIVER
RIVER
CLIFTON
N
SAVANNAH
PICKWICK DAM
TENNESSEE
MISSISSIPPI
TENNESSEE
ALABAMA
TENNESSEE RIVER
LOWER SYSTEM
0
15 miles
SCALE
SOURCE: TVA

FIGURE 12

state line. Today, there are about 200 people involved in the mussel industry of the West Tennessee area. This number decreases yearly as the productive ability of the river declines. Production declines are a direct result of the overharvesting by divers, the increased demands of the cultured pearl industry of Japan, and a lack of governmental control on harvesting.

Observations by this writer[8] noted the extreme amount of overharvesting that has occurred. In 1969, it was commonplace for a diver to collect a ton of mussels a day. Divers generally work in groups of five to ten boats. Once a productive bed of clams is located, divers can collect all the mussels from the bed in a week or less--depending on the overall size of the population. Virtually all commercial shells are extracted from the river bottom, and little concern is shown for the size of the shells collected. No thought is given to leaving a number of shells for possible reproduction.

Divers have depleted the mussel beds of the lower Tennessee River to such a degree that "brail" fishermen are now rare. Occasionally, "brail" collectors are in operation below Pickwick Dam, but now even the diving for clams has become rare. In 1972, there were only 23 divers operating on the lower Tennessee. These divers found productive beds

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[8] The author has been employed as a commercial shell diver since 1969, by the Stafford Shell Company of Perryville, Tennessee.

rare, and consequently the average mussel catch per boat was about one-quarter ton per day.

An example of the decreased mussel population may be noted from a report by Scruggs (1960: 38) who stated that the "pigtoe" mussel (Pleurobema cordatum) was the most abundant commercial species taken by mussel fishermen along the Tennessee River. Today, the "pigtoe" shell is so rare that even one specimen may not be found in five tons of shells. With the decline of the "pigtoe" population, the Japanese have changed their demands from the "pigtoe" clam to the larger "washboard" mussel (Megalonaias gigantea). At the present time, even the recently abundant "washboard" is near extinction.

In 1969, the Japanese market would not accept "dead" shells. By 1972, however, shell divers had diverted their search for the scarce live mussel, to seeking collections of "dead" shells. Aside from the acceptance of "dead" shells by Japan, an increase in the price per ton paid to divers has brought about an intensified search for living or dead mussels on the Tennessee River. Isom (1969: 420) stated that the Japanese cultured pearl industry requires about 3000 tons of mussel shells a year. The Tennessee Valley Authority (1966: 3) estimated the mussel population in the Tennessee to be roughly 26,000 tons and of that amount only 17,000 tons were commercially valuable shells. From 1966 to 1969, over 8000 tons of clams were reported harvested from all the Tennessee (T.V.A., 1970: n.p.). From

this data, the Tennessee River can no longer supply the needs of the Japanese market. Accompanying the obvious decrease in the shell production, attempts have been made to regulate the harvesting of clams on the river.

As noted by Isom (1969: 397) legislation regulating mussel harvesting, enacted in 1965 and 1966, should help to halt the rapid depletion of the mollusk population. The State of Tennessee set up sanctuaries where musseling and other activities detrimental to clams were prohibited. Control of these sanctuaries has been lacking. Isom and Yokley (1968: 41) stated that the Duck River (Figure 12) had been closed to mussel harvesters since July, 1965. The river may have been legally closed to shell collecting, but this author has observed collecting by divers on the Duck River on two occasions. State agencies have failed to stop such illegal collecting.

A five mile sanctuary has been designated in the tailwaters of Pickwick Dam. Again, this writer has noted "brail" fishermen dragging for mussels in the "protected" area on a number of occasions. These violations of state regulations have also gone undetected by governmental agencies.

Accompanying the sanctuary legislation, Tennessee also initiated a size limit on commercial clams. Mussels less than two and one-half inches in diameter must be returned to the river (T.V.A., 1966: 10). Although it is the responsibility of the mussel fishermen to do this, it is very rarely done. The enforcement of this law is under the juris-

diction of the Tennessee State Game and Fish Commission. In five years of shell collecting on the lower Tennessee River, this author has noted only one spot check of mussel boats. It has also been observed by this writer that while the size limitation laws are on record, the Game and Fish Commission officers along the Tennessee are generally unaware of the regulations.

Frequently, small mussels are taken from the river bottom. These undersized specimens generally are wasted because the fishermen includes them in his regular catch, but they are eliminated during the final processing stage before being shipped to Japan. The shell material is not only lost, but the reproductive potential is forfeited.

While overharvesting has taken the largest toll on the fresh-water mussel population of the Tennessee River, the increased demands by the cultured pearl industry, and the lack of enforcement of legislation to protect mussels, has aided greatly in the resource depletion. This. however, is not to insist that the mussel shell industry has been the lone factor in the continued loss of the clam population. Still another factor--river alterations--has caused a decline in the available naiad resource.

Habitat Alterations

The construction of mainstream dams on the Tennessee River have aided the progress of man in many ways: hydroelectric power, navigation, and flood control. At the same

time, the building of dams has altered the habitat of the fresh-water mussel. Mussels are sedentary animals and are greatly affected by the water that is around them. The majority of commercially valuable naiads thrive most successfully in moving water, with a substrate consisting of firm mud or sand and gravel. As long as water flows past the clam, the animal will receive a fresh supply of nutrients, but the damming of the Tennessee has slowed the flow of water, causing drastic changes in the ecological conditions to which the mussel fauna is accustomed (Athearn, 1967: 44-45).

It has been observed by this author that silt may cover large areas of the river bottom. The depth of the silt varies from a few inches in most areas to as much as three feet in isolated sections of the river. Below the mouth of the Duck River, (Figure 12) mussels were found buried as much as two feet into the mud. The normal substrate was found to be sand and gravel, and upon digging down to the firmer bottom, naiad shells were found dead.[9] Scruggs (1960: 1-40) stated that the effects of impoundment on the fresh-water mussel has been devasting. Of great concern to Scruggs was the silting of reservoirs and the effects on young mussels. He found that the majority of commercial shells were not tolerant to the siltation. Only the "deertoe" (Truncilla

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[9] Similar conditions have been observed in the Kentucky section (commercial diving is not permitted in Kentucky) of the Tennessee River. While mussels were found in abundance, dead naiads were located, in layers, deep in the silt.

donaciformis) which is of only slight commercial importance, was found in abundance in a juvenile stage.

Ellis (1931: 5) noted that the Tennessee River, above its mouth at Paducah, Kentucky (Figure 12) was observed to change from a relatively clear stream, to one turbid with silt in suspension in the course of a few hours following a local thunderstorm in the Duck River region. As a result, the mussel populations are affected in several ways by the erosion silt.

Locomotion by naiads is very slow and generally mussels are unable to move from areas where the habitat conditions have become unsuitable. When obstructions are large, such as the Tennessee mainstream dams, the suspended material in the water will settle for a great distance upstream. Even if the silt material is of a non-pollutant nature, the settling to the bottom will smother mussels. As a result of this sediment settling, the oxygen content of the water is altered, and young clams are affected to a greater extent by the change in the oxygen balance (Ellis, 1931: 6-7).

Bates (1962: 235) noted that normal pre-impoundment mussel populations have been slow to move from the main river channel of the Tennessee River. Bates states that siltation has eliminated a sizable portion of the commercial assemblage and there is little evidence that these species have moved to more favorable surroundings. One commercial species has, however, been observed invading the shallows of Kentucky Reservoir. Bates found that the "maple-leaf" (Quadrula

quadrula) had established itself in the former flood-plain areas of the lake.

Even if some commercial species adapt to the impoundment environment, their growth and structure may be greatly altered. Chamberlain (1931: 713-737) explained that alterations in the size and growth rates may be determined by the water conditions around the mussel. Coker, et. al., (1922: 82) earlier found similar characteristics when they stated, "the rate of growth of mussels generally is much higher and the size attained is greater in rivers than in lakes."

This author has noted that the "washboard" (Megalonaias gigantea) has changed in overall structure. Shells collected by this writer appear to be smaller in diameter, and the thickness of the shell is somewhat thinner. The number of shells that make up a box[10] has increased from about 280 clams to approximately 310 since 1969. While there has been a noticeable change of the structure of the Tennessee River mussel, the quality of the nacre has also been altered.

Dave Stafford, owner of Stafford Shell Company, Perryville, Tennessee, noted that while the weight of the mussel has decreased, the quality of the shell has also been affected. Stafford stated that more discoloration appears in the nacre of young mussels. Spotting is much more common, con-

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[10] A box is approximately 250 pounds of shells. It is the measurement used to weigh out the catch of a commercial fisherman.

sequently, the desired qualities that the Japanese market insist upon are becoming harder to provide by the American mussel industry. Pollution is given as a reason for the quality change, according to Stafford, but this author tends to disagree with this evaluation. This writer believes that the effects of impoundment have caused the change in shell quality. Coker, et. al., (1922: 94-110 and 123-125) indicated that the slow movement of water and accompanying siltation can cause established clam populations to lose the luster of the nacre. Spotting may occur when stagnant water makes up the environment of some commercial mussels. The changing quality of the mussel may bring an end to the mussel industry before overharvesting eliminates the remaining population.

Another noteworthy affect of impoundment is the wide-range influence that the changing character of one stream may have on another. During a mussel fauna study of the Duck River, Isom and Yokley (1968: 41-42) sampled the bottom fauna of the Buffalo River (Figure 12)--a tributary of the Duck--and found the fauna in a terminal existence. The river exists in a pristine state, receiving no industrial or municipal wastes and little agricultural erosion. Isom and Yokley thus surmised that the impoundment of the lower Tennessee River caused a subsequent change in the lower portion of the Buffalo River. While this example is conjecture by Isom and Yokley, it may eventually reveal results as to the full extent of man-made river environments.

Impoundment effects on mussel fauna populations may soon have a more devastating influence on naiads if increased pollution of the Tennessee River is allowed to occur. With increased industrial development along the river, an increase in pollutants will undoubtedly result.

Environmental Pollution

Industrial and municipal pollution of waterways in the United States is a tremendous problem that has aided greatly in the depletion of the fresh-water mussel. While this is a fairly common occurrence in many streams and rivers, the Tennessee River and its mussel fauna have generally escaped severe damage due to pollution.

As related by Isom, (1969: 408) industrial pollution has been blamed for mussel yield declines, but there is little evidence to indicate that it has been a serious problem. The Tennessee Valley Authority (1966: 7) similarly stated that, while water quality in the Tennessee is less than desirable in certain isolated areas, the general mussel decline cannot be blamed on pollution. Although Stafford recently noted that he felt pollution is the cause of the poor quality of the commercial clam, it is not mentioned in the published research on the mussel fauna.

To the shell diver, pollution is the main problem in the decline of the commercial shell. Divers seldom recognize other detrimental factors in the deterioration of the naiad population. Overharvesting is rarely admitted by the harvest-

ers, and there is little knowledge of the effects of damming on the mussel. The divers concern of pollution cannot go unwarranted, however. In the fall of 1970, a group of divers of the Stafford Shell Company, Perryville, Tennessee dove for shells near Savannah, Tennessee (Figure 12). Shells collected from the once very productive area were 97 percent dead and most of these shells were of no commercial value (Grace, 1972: 49). Pollution could have been the cause of this large mussel kill. As stated by the T.V.A., there are isolated areas of less than desirable water quality.

Pollutants that may be released into the reservoirs of the Tennessee River may eventually affect the bottom fauna to a larger degree than has been experienced in the past. Cairns, et. al., (1971: 79-80) noted various factors that relate to the damage that acidic or caustic materials may have on invertebrates, such as mussels. It was observed that while most aquatic ecosystems have the abiltiy to assimilate a certain amount of waste material, the major concern is whether the water system has the ability to assimilate the pollutant from its concentrated state. An example of this is noted by Cairns, et. al., (1970: 182-192) after research was done on the Clinch River, pertaining to the biological recovery of that river after a fly ash spill. It was found that while all bottom fauna was eliminated below the spill, the mussel fauna was reestablished two years later. The Clinch is a flowing stream in the area of the spill site, and the assimilation of the caustic

material returned the river to a "clean" state. After the return of normal water quality, clams re-inhabitated with a fairly high rate of success.

A similar water quality change could occur on the Tennessee River, however, it is not likely that the rate of recovery would be as successful. Sluggish water flow caused by the mainstream dams on the Tennessee would cause an acidic or caustic spill to remain concentrated. Thus, after settling to the bottom, the pollution would undoubtedly cause long-range damage to all bottom dwelling animals. Since mussels are filter feeders and normal life functions are directed by the quality of water that is available, inability to relocate would render the clam helpless. Danglade (1912: 1-3) observed a similar situation that existed on the Illinois River. He stated that the upper portion of the Illinois carried an enormous amount of industrial and municipal waste, and behind the locks and dams located at Kampsville, Illinois, the mussel supply was very poor as compared to earlier years. From this observation it may be asserted that, aside from normal silting the concentration of pollutants possibly had a detrimental affect on the fauna of the area.

Similar observations have been made by this writer. During the summer of 1973, a survey of the commercial mussels of the Powell River was undertaken by this author and Sally Dennis of the Tennessee Valley Authority.[11] The purpose

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[11] Support for this research was given by T.V.A. in the form of a grant (number TV-38696-A).

of the study was to locate commercially valuable naiad populations and to evaluate their economic potential. Although commercial mussels were found to occupy the Powell, they ere not established in large populations to warrant commercial exploitation. The major find of the research was that there were naiads occupying the river. Sources had indicated that the prospects of locating any mussels would be slight because of the acid mine drainage that had been observed in the headwaters of the Powell. Evidently, the recovery of the clam population has been successful, but the effects of impoundment are noted in the lower portion of the river.

The Powell River does not have a dam constructed on its course of flow, but the Clinch River is dammed to form Norris Lake. Being a tributaty of the Clinch, the Powell possibly has been affected indirectly by the harnessing of the Clinch. This is a simialr situation to that noted by Isom and Yokley (1968: 34-42) concerning the Buffalo River. The lower section of the Powell River may have lost its mussel fauna due to the collecting of pollutants that appear to have concentrated here due to impoundment.

Pollution, while not an immediate cause of the decline in the fresh-water mussel population of the Tennessee River, should be of greater concern in the future. The Tennessee is increasingly being developed as an area of industrial expansion. Private industry is constantly moving into the Tennessee Valley and as the population of the region in-

creases there surely will be greater stress placed on the water quality of the river. Thus, the pressure of environmental pollution will have an affect on the bottom habitat of the mussel.

Recommendations[12]

From the literature reviewed and personal observations of this author, certain recommendations are in order. First, if mussel fisheries are allowed to continue, enforcement agencies should actively inspect the shell product that is extracted by fishermen. Appropriate action should be taken against those who are found to possess naiads of less than two and one-half inches in diameter. Similar control should be leveled toward mussel buyers. Secondly, sanctuary areas should be expanded and patroled on a regular basis. If harvesters are found to be fishing in these areas, one deterrent of further such violations would be the revoking of the fishermen's license.

The third recommendation is one that will not be received with enthusiasm from the remaining mussel industry. The practice of SCUBA diving for mussels should be completely eliminated. Collecting methods should be restricted to "brail" harvesting--with limits on the size of "brails" used. In

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[12] Recommendations for the preservation of the commercial fresh-water mussel, drawn by this writer, were based largely on those regulations suggested by Coker (1914: 3-23). Variations exist due to the changes that have occurred in the use of the mussel and in the harvesting methods.

conjunction, it is further recommended that there be closed seasons on musseling. This could be set up to correspond with the proper breeding periods of the commercial naiads.

It may appear at this point that all recommendations are leveled toward the restricting of the mussel industry. Since the rate of depletion of the mussel population has been estimated at 23 times greater than natural reproduction, overharvesting is considered by this writer, to be the major factor in the decline of the mussel resource. Therefore, the most strict regulations are recommended for controlling the harvest. While it is felt that immediate action should be taken in these areas, it is also recommended that certain investigations should be undertaken by the proper authorties.

First, artifical propagation should be examined and attempts should be made to reestablish some portion of the river mussel population. At the same time, propagation could eventually supply enough mussels for the demand of the market.

Secondly, study of the effects of impoundment on the mussel should be continued, hopefully revealing ways in which man can aid the mollusk in adapting to a new river environment. Lastly, it is suggested that tighter controls be affixed to industrial and municipal pollution. While pollution is not presently a severe problem in the Tennessee River, without proper action and controls, it could soon be of greater consequence in the elimination of our fresh-water mussel resource.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Mussel fisheries have been altered greatly throughout history, but since 1890, the changes have been more drastic. Prehistoric Indians utilized mussels largely as a source of food and their fishing was generally limited to shoal areas. This type of exploitation had little damaging effect on the overall naiad population. Devastation of the clam assemblage began when the shell of these aquatic animals was found to be an excellent material for the making of buttons.

Since the introduction of the button industry, many streams and rivers have been depleted of their entire commercial mussel fauna. Although the Tennessee River commercial shell has rapidly declined, the river remains the largest producer of shell material for the cultured pearl industry. Isom (1969: 420) suggested that the Tennessee fishery might provide the entire 3000 ton annual shell requirement of the Japanese pearl industry. This assumption is becoming increasingly unlikely.

Increased overharvesting since the introduction of SCUBA divers and the failure of governmental agencies to control harvesting has drawn the commercial mussel nearer

to extinction. Overharvesting is neither the sole nor the primary cause of the mussel decline. Alterations of the natural naiad habitat have aided in the elimination of the mussel population. Beds that existed before impoundment are now covered by slack water, and a once suitable environment for clams has been changed by slow-moving current and the eventual deposition of silt. These factors have affected the natural propagation and survival of young mussels.

In conjunction with the alterations of the natural river, pollution has caused some changes in the fresh-water mussel population. Although not extensive in the Tennessee River, pollution has been noted in isolated areas. Increased pollution of the river may soon have a devastating affect on the remaining population.

While overharvesting, river alterations, and pollution have been noted as the major factors in the decline of the fresh-water mussel, there are other factors that with more research, may prove to have increasingly detrimental affects on the naiad. One possible factor in the decline of the mussel is the rapid growth of the Asiatic clam (Corbicula), which is of little economic value. Sinclair and Isom (1961 and 1963) have done extensive studies of the Asiatic clam and found that, aside from the nuisance this clam has presented to industry, Corbicula may compete with the fresh-water mussel for habitat space. Asiatic clams have an extremely high rate of reproduction as compared to the mollusk.

This author has noted that Corbicula grows with such rapidity that when divers return to mussel beds productive only one year earlier, they often find that Asiatic clams have occupied the entire bed and generally the area is void of commercial mussels. This, of course, is not true evidence that the rapid intrusion of Corbicula has caused a decline in the commercial shell population. It does imply, however, that the possibility exists and that further research should be carried out.

Another possible cause of the decline of the fresh-water mussel is the elimination of certain fish species. Coker, et. al., (1922: 151-155) reports that part of the metamorphic cycle of the mussel is a time when the immature mussel, or glochidia, is attached to a fish host. Coker notes that the glochidia will not attach to fish species indiscriminately, but for each mussel species there is a restricted fish host.

Coker and his associates experimented for a number of years for ways to artifically propagate mussels. It was found that reproduction, aided by man, cannot be conducted successfully and economically unless more accurate knowledge of what fish species serve as host for the various species of commercial mussels. While Coker found certain fish definitely to be host of certain mussels, the artifical propagation of commercial fresh-water naiads has never proven to be totally successful. This is one aspect of the life history of the mollusk that needs further

study. It is not inconceivable that artifical reproduction could eventually provide the 3000 ton yearly demands of the Japanese cultured pearl industry.

In conclusion, this writer feels that the preservation of the remaining fresh-water mussel population should be of immediate and utmost concern to conservation groups and governmental agencies. If action is not taken in the near future, the existing naiad population may soon disappear, and with it, the mussel fishery will vanish.

Legislation has been leveled toward the protection of the mussel resource, however, it has been rather ineffective. As noted by this author, areas that are restricted to harvesting have been invaded by mussel fishermen and no action has been noted to prevent such actions. Also, as previously stated by this writer, undersized clams are commonly extracted from the Tennessee River. Little, if any, action by governmental authorities controls the two and one-half inch size limit. The failure of enforcement of regulatory legislation continues, and thus the commercial mollusk population is on the verge of extinction.

The recommendations suggested by this author may seem severe, but the Tennessee River is closer to losing its naiad resource with each passing year. The survival of the mussel fishery is considered of less importance than the survival of the mussel fauna assemblage. The economies of the United States and Japan can withstand the loss of the

mussel industry, but can the other ecosystems of streams and rivers withstand the loss of the fresh-water mussel?

COMMERCIAL NAIADS INHABITING THE TENNESSEE RIVER, 1965

Species	Common Name*	Faunal Group	Commercial Importance
Fusconaia ebenus	Niggerhead	Ohioan	+++
Megalonaias gigantea	Washboard	Ohioan	++
Amblema costata	Three-ridge	--	++
Quadrula quadrula	Maple-leaf	Ohioan	++
Quadrula pustulosa	White wartyback	--	+
Quadrula metanevra	Monkey face	Ohioan	+
Tritogonia verrucosa	Pistolgrip	--	-
Plethobasus cooperianus	Pimpleback	Ohioan	-
Pleurobema cordatum	Ohio River pigtoe	--	+++
Plagiola lineolata	Butterfly	Ohioan	+
Ligumia recta latissima	Black sandshell	--	+
Lampsilis anodontoides	Yellow sandshell	Ohioan	+

Source: Isom, 1969: 402-403.

*Common names are mostly after Coker, 1915.
-- = unknown or doubtful origin.
+++, ++, +, -, = degree of importance in descending order.

RELATIVE RANK OF FRESH-WATER PEARL AMONG THE DIFFERENT MATERIALS EMPLOYED FOR BUTTON MANUFACTURE AT VARIOUS DATES

Material	1899	1904	1912 [a]	1914
Fresh-water pearl.....	$1,176,285	$3,359,167	$6,173,486	$4,879,844
Ocean pearl.....	1,951,558	1,511,107	.....	2,489,364
Metal.....	887,521	1,312,741	.....	763,287
Vegetable ivory.....	1,144,677	1,305,766	.....	2,885,503
Cloth.....	468,121	766,091	.....	.....
Bone.....	137,401	124,454	.....	329,934
All others (e).....	701,810	660,703	.....	4,885,266
Button blanks made for sale.....	656,936	d 916,003	2,511,217	.....
All other products.....	.....	c1,177,737	187,607	.....
Aggregate.....	7,695,910	11,133,769 b	.....	e 20,791,985
Buttons, total.....	6,467,373	9,040,029 b	.....	16,233,198

Source: Coker, 1921: 67.

a Fresh-water only

b Exclusive of buttons to the value of more than $1,000,000, made in 1904, by establisnments engaged primarily in the manufacture of other products

c Partly fresh-water pearl products

d Probably fresh-water pearl chiefly

e Includes blanks, or molds, snap fasteners, and all other products in amount of $4,558,787

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