TENNESSEE VALLEY AUTHORITY

Water Resources
Aquatic Biology Department

System Engineering
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QUANTITATIVE EVALUATION OF COMMERCIAL MUSSEL POPULATIONS IN THE TENNESSEE RIVER PORTION OF WHEELER RESERVOIR, ALABAMA

Norris and Knoxville, Tennessee
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EXECUTIVE SUMMARY

A stratified random sampling design was used to obtain data on densities, age and growth, and recruitment of commercial species in 75 miles of Wheeler Reservoir. A total of 293 quadrat samples were excavated by divers using a $0.25/m^2$ quadrat sampler. Sample contents were sieved down to 6 mm to collect juvenile mussels. Twenty-four species were found, six were relicts. For all strata sampled, mussel densities were estimated at 460 million mussels or $2.33/m^2$. Densities in line transects in four mussel beds identified by commercial musselers averaged $1.42/m_2$. Nineteen of 38 species reported in the literature were relict or not collected and are uncommon or rare riverine species which have not adapted to impoundment.

Scruggs (1960) assessed the status of *Pleurobema cordatum*, a riverine species which was abundant and most valuable commercial species. He estimated 39 million mussels (20.6 million pigtoes) representing 18 species in an eight-mile reach of Wheeler. During the present study, for the same eight-mile reach, only five species were found, with densities totaling 14.3 million mussels. The five species were *Elliptio crassidens* (7.1 million), *Quadrula pustulosa* (1.8 million), *Potamilus alatus* (1.8 million), *Lasmigona complanata* (1.8 million), and *Obliquaria reflexa* (1.8 million). *Pleurobema cordatum* densities throughout the reservoir are now estimated at 10.3 million with *Megalonaias nervosa* (87.7 million), presently the most valuable commercial species. Drought conditions (1983-1988) may have affected reproduction and/or survival of thick-shelled species. With the

exception of Obliquaria reflexa and Quadrula pustulosa, only thin-shelled species were represented in the 1-5 age-class.

INTRODUCTION

The Tennessee Valley Authority (TVA) conducts periodic water resources issues analyses (WRIA's) in local drainage basins that comprise the larger Tennessee River system. As part of this continuing series of analyses, an initial assessment was made in 1989 of the Wheeler Reservoir Watershed Region (Cox et al. 1990). The purpose of the study was to develop information and increased awareness by TVA, other Federal and State Agencies, industries, lake-user associations, citizens interest organizations, and the general public of significant water resources problems within Wheeler Reservoir. One issue of concern identified in this WRIA assessment was reported declines in densities of commercial mussel stocks, especially in the area of Decatur, Alabama.

The primary objective of the present follow-up study was to determine the status of commercial mussel populations throughout Wheeler Reservoir. To meet this objective, size and age-class composition, standing crop estimates, and distributions were determined for all mussel species in 1991. Davies et al. (1992) conducted a roving mussel census funded by the Alabama Universities/TVA Research Consortium (AUTRC) to describe the economic importance of commercial mussels in Wheeler Reservoir.

Background

Beginning in 1936, the Tennessee River was impounded by TVA primarily for hydroelectric power, flood control, and navigation.

Construction on Wheeler Dam, the first built by TVA was started in 1933 and completed in 1936. Wilson Dam had been completed in 1924 by the U. S. Corps of Engineers. Predictions made by the U. S. Bureau of Fisheries, TVA, and commercial musselers that impoundments would eliminate or destroy mussel habitat resulted in a complete halt of musseling on Wheeler Reservoir as soon as it filled (Scruggs 1960; Isom 1969).

Nine years after the impoundment of Wheeler Lake (1945), commercial musselers found large beds of shell during exploratory sampling in the lake. Musseling resumed throughout the Tennessee River and shell harvest, primarily for the button industry, increased from 3,700 tons in 1945 to 10,000 tons in 1947 (Isom 1969). Post-impoundment mussel harvest on the lower Tennessee River gradually moved upstream as productive mussel beds were discovered in the newly created reservoirs. However, with the development of the plastic button in the late 1940's, the demand for shells for the button industry was short-lived.

Beginning in the early 1950's, the Japanese discovered that freshwater mussel shells from the United States were ideal material for implantation in oysters to form the nucleus for cultured pearls. The mussel shells were cut into small blocks, which were then tumbled and polished into smooth, round beads for surgical implanting in the oysters. This development resulted in a sudden, rapid demand for shells and was a tremendous economic boost for the declining American musseling industry. The mainstream reservoirs of the Tennessee River became the nation's most important source of shell for shipment to Japan. Between

1956 and 1957, most of the shells were harvested from Kentucky, Wheeler, Guntersville, and Chickamauga reservoirs (Scruggs 1960).

New collection techniques were also developed by the commercial shell industry. Scuba-equipped divers located and harvested dead shells not collected by musselers dragging crowfoot brails. Divers discovered that they could find more live than dead shells and that diving was a more efficient method for harvesting shell than brailing. To fully exploit the commercial mussel resources, barges equipped with air compressors, cooking vats, and shakers (tumblers) for commercial diving and shell processing were moved on-site to locations with dense mussel concentrations. Because several divers were working on each barge, tons of shell were harvested in a short period of time.

The annual shell harvest from the Tennessee River exceeded 10,000 tons for a number of years (Isom 1969). Tonnages started to decline in 1956, despite increased effort and more efficient collecting methods. Concerns about the dwindling mussel resource prompted industry representative to request the United States Fish and Wildlife Service (USFWS) to begin an investigation of the status of the resource and to recommend measures which would favor improvements in mussel species valuable to the industry. Although plastics had replaced shell in the manufacturing of buttons, the market demand for preferred shells used by the Japanese for pearl culture was increasing. During 1956 and 1957, the USFWS studied mussel species composition, size-classes, and percentages of catch by individuals using crowfoot brail in

Kentucky, Wheeler, Guntersville, and Chickamauga reservoirs. More intensive studies were made in Wheeler and Chickamauga to determine mussel densities, rate of exploitation by harvesting, and age and growth of Pleurobema cordatum. Special emphasis was given to studying P. cordatum in an eight-mile section of Wheeler Reservoir, because of the species' natural abundance there, high-quality shell, and because, economically, it was the most valuable commercial shell (Scruggs 1960).

From the records of mussel species reported in the literature and from the 1991 study, 38 are documented from Wheeler Reservoir (Scruggs 1960; Isom 1969; Bates 1975; TVA 1979; Ahlstedt 1992). Significant changes have occurred in the fauna since the 1956-1957 post-impoundment study of commercial mussel stocks (Scruggs 1960). Of the 38 species, 31 are considered by the author to be riverine, i. e. those species which evolved in the free-flowing reaches of the Tennessee River prior to impoundment.

Commercial musseling has increased steadily since the mid-1970's, especially in the southeastern United States and in northern states bordering the upper Mississippi River. Coincidentally with this increased effort, a number of studies have also addressed commercial harvest and value, recruitment levels, distribution, age and growth, and the effects of brailing on mussel stocks (Sickel 1982,1989; Bates and Dennis 1985; Heath 1988; Tennessee Wildlife Resources Agency 1990; Leroy Koch, Missouri Department of Conservation, personal communication. In Alabama, mussel harvest licenses increased from 350 in 1989 to 2,356 in 1991 (Fred Harders, Alabama Department of Conservation and Natural Resources, personal communication). The large increase in commercial musseling licenses sold in Alabama, and in bordering Tennessee as well, was in direct response to a price war between commercial buyers for number-one grade washboards, Megalonaias nervosa; the price peaked at $19.80/kg in September, 1991 (Davies, 1992). The commercial export value of shell shipped to Japan from the United States (10,000 metric tons annually) was estimated at $70 million dollars in 1991 (Ron Kibort, Tennessee Shell Company, personal communication). The value of shell harvested annually from Alabama has been estimated at $22 million.

Study Area

Wheeler Reservoir is approximately 75 miles in length and is located on the Tennessee River between Guntersville and Wheeler dams (Tennessee River Mile TRM 349.0-274.9) (Figure 1). The river flows in a general northwesterly direction through northern Alabama and is bordered by southern Appalachian ridges and limestone valleys. The reservoir has a local drainage between the two dams of 5,140 mi^2 and receives flows from seven major tributary streams. The main channel varies from 20 to 50 feet in depth.

Since impoundment of Wheeler Reservoir, and other reservoirs on the Tennessee River, the freshwater mussel fauna can be divided into species which inhabit the old river channel and those which have colonized the overbanks (old flood plain) of the river. In Wheeler Reservoir downstream from Guntersville Dam, the original river channel is well defined as far as Decatur (TRM 305), a distance of approximately 44 river miles. At Decatur, the river slows and spreads out into extensive, shallow overbanks with average depths of 2-5 feet near Brown's Ferry Nuclear Plant (TRM 294). The old river channel becomes completely undiscernible, except for buoys which mark the navigation channel.

Two areas of Wheeler Reservoir are designated state protected mussel sanctuaries and are off-limits to commercial musselers. The first sanctuary extends from Guntersville Dam (TRM 349) downstream to the mouth of Shoal Creek (TRM 347); the second extends from the upstream end of Hobbs Island (TRM 337) downstream to Whitesburg Bridge (TRM 333).

MATERIALS AND METHODS

The survey design was stratified random sampling with sampling effort approximately proportional to strata area. This sampling design was used because it is relatively easy to implement and provides increased accuracy of population estimates.

The study area was divided into three major areas (figure 1): lower reservoir, Wheeler Dam (TRM 275) upstream to state route 72 bridge at Decatur (TRM 305); middle reservoir, (TRM 305) upstream to state route 231 bridge (TRM 333.2); and upper reservoir, from TRM 333.2 upstream to Guntersville Dam (TRM 349). The lower and middle reservoir was further sub-divided into old river channel, overbank, and tributary embayments. The upper reservoir could only be sub-divided into old river channel and embayments because no overbanks were identified in this riverine section of reservoir.

Detailed, 7.5 minute topographic maps of Wheeler Reservoir were marked to delineate sampling boundaries of tributary streams and embayments. Using TVA's Geographic Information System, total area of each strata were determined (table 1) and each strata was subdivided into 0.1 square kilometer cells. The 0.1 square kilometer cells were numbered and computer generated random numbers were used to select sample sites.

Samples were collected at each location by divers equipped with surface-supplied air (hooka) and boat-to-diver communications equipment. At each sample location, a 0.25 square-meter quadrat sampler was used to obtain data on mussel densities (Ahlstedt 1991). The quadrat sampler was placed on top of the substrate and excavated by hand or with a small garden shovel. All substrate material within the sampling frame was removed to a depth of approximately 4-6 inches and placed in 5-gallon buckets in accordance with methods described by Miller and Payne (1990). The buckets were attached to a cable and lifted into a boat by electric winch for processing.

Processing involved dumping the contents of the container into a series of three, stacked, rectangular box sieves where the contents were screened, washed, and sorted by hand using a battery-operated pump. Sieve sizes measured one, one-half, and one-quarter inch. All material was washed on screens to visually collect all size-classes of mussels, especially juveniles for evidence of reproduction. Live mussels were identified to species, counted, and total shell lengths (anterior to posterior) were measured to the nearest 0.1 millimeter (mm) using vernier calipers. Specimens were aged by counting external growth rests on the shell, which were then recorded on field data sheets according to strata and river mile location in the reservoir. Depth, substrate type, relict shells, and the Asian clam, Corbicula fluminea, were also recorded on field data sheets. All live mussels found were returned to the substrate after measuring and aging.

Line transects and random searches were also conducted by divers in mussel beds identified by commercial musselers. A 50-meter cable marked at ten-meter intervals was positioned on top of the substrate and anchored by concrete blocks. Divers swam on each side of the cable collecting all mussels within arms reach of the cable. This approximated one-meter of habitat being sampled per marked meter length on each side of the cable. At the end of each ten-meter section, mussels collected were bagged and attached to the cable at the ten-meter mark. All mussels collected were identified to species, recorded on field data sheets, and immediately returned to the substrate.

RESULTS AND DISCUSSION

A total of 293 quadrat samples were collected throughout the 75 miles of Wheeler Reservoir. Mussels were also sampled along four line transects and three random searches (Figure 1). Eighteen species were collected alive and six species were relicts (Table 2). The four most common species found during quadrat sampling, in order of abundance, were Elliptio crassidens, Megalonaias nervosa, Potamilus alatus, and Obliquaria reflexa (Table 3). Three of the same species were also the most abundant on line transects and qualitative samples of known mussel beds; a large sample of Quadrula pustulosa at TRM 276.9, resulted in it replacing O. reflexa as the most common species in these samples. Amblema plicata was also abundant in line transects (Table 4). Total mussel populations for 1991 are estimated at 460.15 million mussels. Of the total, 57.67 million are non-commercial species (Figure 2).

Scruggs (1960) reported mussel densities for 18 species, 11 of which were of commercial value, during his 1956-1957 study of an eight-mile reach (TRM 308-316) of Wheeler Reservoir. He estimated a population of 38.96 million mussels, of which 20.56 million were Pleurobema cordatum and 3.44 million Cyclonaias tuberculata. Both species were also the most heavily harvested commercial mussels, with P. cordatum comprising 80% of the total shell harvest in 1956 and 1957. Neither of the two species were found in the same river section during the 1991 study. Only five species were reported in the same eight-mile reach, and populations there are presently estimated at 14.29 million mussels, with Elliptio crassidens (7.14 million) the most abundant (Figure 2).

The two most common species estimated to be present throughout the reservoir during 1991, were E. crassidens (115.74 million) and M. nervosa (87.66 million) (Figure 2). Davies et al. (1992) reported M. nervosa, P. cordatum, and Ellipsaria lineolata comprised 45%, 25%, and 10% of the commercial mussel harvest from Wheeler Reservoir.

Stratified Sampling

Thirteen species were reported from the old river channel, 10 from the overbanks, and 6 from the embayments. For all strata sampled, mussel densities were estimated at 460.15 million mussels or $2.33/m^2$ (Tables 3 and 5). Elliptio crassidens was the most abundant species, with populations estimated at 115.74 million, followed by M. nervosa (87.66 million), P. alatus (56.46 million), and Obliquaria reflexa (44.26 million).

The overbanks in the lower reservoir from Wheeler Dam (TRM 275) upstream to Decatur (TRM 305), was second in mussel species (10), but contained the highest numbers (157.85 million). Megalonaias nervosa was the most abundant with 45.10 million, followed by O. reflexa (25.37 million) and P. alatus (19.73 million) (Table 3). The majority of commercial musselers were observed diving in the lower reservoir overbanks during the 1991 study. Shell bars (15-20 feet in length) were observed for the first time being used extensively in the overbanks by divers to locate shell. Divers were able to locate and harvest shell effectively by pushing or pulling the bars through soft mud. The lower reservoir overbanks were also identified during the roving mussel census as the most heavily searched area for M. nervosa (Davies et al. 1992).

In the vicinity of Decatur in the lower reservoir strata on the south bank, mussels were practically non-existent, except along the navigation channel. Embayments downstream from Decatur produced no live mussels, and substrate washed during quadrat sampling produced an oil or petroleum smell. Decatur is located in a heavily industrialized section of Wheeler Reservoir. Commercial musselers refer to this area as the "dead zone", which also, according to them, extends upstream from Decatur a short distance into the middle reservoir.

Bioassay tests conducted in 1983 by U. S. Environmental Protection Agency (EPA), detected acute toxicity in effluent from the Amoco and Monsanto facilities at Decatur (Peltier 1983); however, there was no indication that these discharges were exerting significant toxicity throughout Wheeler Reservoir. Bioassay tests conducted by TVA on reservoir sediment porewater, near several wastewater outfalls at Decatur, were screened for acute (9-day) toxicity to 8-day old Anodonta imbecillis (Wade 1990). Toxicity was observed at two of the sites (Dry Branch embayment TRM 303.4L and south end of canal TRM 301.1L). Un-ionized ammonia concentrations in sediment porewater appeared to have been sufficiently high to cause mussel mortality. Further studies will be conducted to evaluate the role of ammonia and other sediment contaminants with respect to mussel impacts.

No mussels were found in the overbanks of the middle reservoir between Decatur (TRM 305) and state route 231 bridge (TRM 333.2), a short reach of approximately five river miles upstream from Decatur. The annual draw down of Wheeler Reservoir during the winter months for flood control exposes the overbanks to drying, and the reservoir is also periodically drawn down for weed and mosquito control, which may explain the absence of mussels in this reach.

The upper reservoir old river channel upstream from state route 231 bridge (TRM 333.2) to Guntersville Dam (TRM 349), had the highest species diversity (11), and was the second-most productive area for mussels in the reservoir, with populations estimated near 150 million (Table 3). Elliptio crassidens was the most abundant species (56.82 million); this also included, 23.24 million P. alatus and 15.50 million Q. pustulosa. This area was also identified during the 1991 study and during the roving mussel census as a high-use area for commercial musseling, especially bailers.

Old river channel sections in the lower and middle reservoir had considerably fewer species and total numbers of mussels than the upper reservoir river channel. Seven mussel species were found in the lower river channel, six species in the middle, and 11 species in the upper river channel. The most abundant mussel in the lower river channel was M. nervosa, and the most common species in the middle and upper river channel was E. crassidens (Table 3).

Tributary embayments in the lower reservoir accounted for five species, with a population estimate of over 15 million mussels; most common were Anodonta grandis, M. nervosa, and Tritogonia verrucosa. Only one species, Quadrula quadrula, was found in the middle reservoir embayments and populations were estimated at close to 4 million. No mussels were found in the upper reservoir embayments (Table 3).

Line Transects and Random Search

Sixteen mussel species (610 specimens) were collected during four line transects and three qualitative random searches in mussel beds identified by commercial musselers (Table 4). One of the six sites (TRM 347.2) is a state-protected mussel sanctuary. A total of 462 mussels were collected during line transects for an average of $1.42/m^2$. The most abundant species were *Q. pustulosa*, *M. nervosa*, and *E. crassidens*. The most productive sample from a commercial bed was in First Creek embayment (TRM 276.9), with densities averaging $1.31/m^2$. Line transects were also taken in the state-protected mussel sanctuary for comparisons between densities there and in nearby commercial beds. Mussel densities were the highest ($3.24/m^2$) in the sanctuary (Table 4). In contrast, quadrat sampling in the upper reservoir river channel produced considerably higher mean numbers of mussels ($16.57/m^2$) than line transects (Table 5). The differences in densities are probably the result of sampling techniques. Typically, only larger adult mussels are found during line transects, since small individuals are buried in the substrate or overlooked because of smaller size or water clarity. Quadrat excavations produced specimens of all sizes.

Age and Year-Class Composition

All mussel species collected during quadrat sampling were separated into seven age-classes and the years when they were reproduced: 1-5 (1986-1990), 6-10 (1981-1985), 11-15 (1976-1980), 16-20 (1971-1975), 21-25 (1966-1970), 26-30 (1961-1965), and 31-35 years (1956-1960) (Figure 3). The 11-15 age-class had the most specimens (40), followed by 39 in the 6-10 age-class. As might be expected, the 31-35 age-class had the lowest total with five. Of the seven species found in the 1-5 age-class, three (P. alatus, O. reflexa, and Q. pustulosa) have commercial value. The remaining four species (A. grandis, A. suborbiculata, Leptodea fragilis, and Truncilla donaciformis) have no commercial value because of their thin-shell.

Severe drought conditions from 1983 to 1988 resulted in reduced flows and poor water quality throughout the Tennessee Valley, and may have affected the reproductive life-cycle and/or survival of thick-shelled species. Although total numbers of mussels reported during quadrat sampling for 1991 was extremely low, age-class data suggests that reproduction of thick-shelled species was more predominant in the 6-10 and 11-15 age-classes before the drought. In the 1-5 age-class, reservoir conditions may have been more conducive for reproduction and survival in the thin-shelled species, more commonly associated with lentic conditions and habitats, than for thick-shelled riverine species. With the exceptions of A. grandis and L. complanata, all species listed in age-classes 6-10 and 11-15, are riverine species which have adapted and reproduced since Wheeler Reservoir was impounded. These same species, including A. grandis and L. complanata, occur abundantly in other TVA mainstream reservoirs (Isom 1969; TVA 1979; Sickel 1982; Bates and Dennis 1985; TWRA 1990).

Pleurobema cordatum, the Ohio pigtoe, was present only in the 21-25 and 31-35 age-class, and reproduction is either extremely limited, or has ceased in Wheeler Reservoir. This species is strictly a riverine mussel that apparently has not adapted to impoundment conditions in Wheeler Reservoir, or possibly, any reservoir in the Tennessee River system. Historically, P. cordatum was the most abundant and commercially valuable shell in Wheeler Reservoir during the mid 1950's (Scruggs 1960). Currently, it occurs only in the riverine portion of Guntersville Dam tailwater where the substrate is rocky and clean-swept of silt. Scruggs reported that overharvesting, low rate of natural recruitment, non-availability of a host-fish, and extensive silt deposits accumulated since the reservoir was impounded created, or contributed to, conditions unfavorable for the survival of the species.

Natural recruitment was less than one percent for pigtoes during Scruggs study, and most specimens were 15-years old, with many appearing to be 25-years old or older. Both Scruggs and Isom indicated that pigtoes would likely become extirpated as older specimens die-off. Davies et al. (1992) reported that, assuming a constant rate of harvesting pressure and ignoring natural mortality and recruitment, the 1991 estimated population of P. cordatum would be depleted by 90% in 24 years. At present, these same conditions apply not only to P. cordatum, but to 18 additional riverine species reported from Wheeler Reservoir (Table 2). All 19 species are presently rare or uncommon in Wheeler Reservoir, and have been observed as old, eroded individuals in other Tennessee River impoundments (Ahlstedt 1991; Jenkinson 1992).

Size-class Composition

Lengths of freshwater mussels measured in ten-millimeter increments are presented in table 6. The minimum legal-size established for Alabama commercial shell harvest is 3.75 inches (95 mm) for M. nervosa and P. alatus. For other commercial species, such as P. cordatum, A. plicata, E. crassidens, the legal-size is 2.25 inches (57 mm). The most numerous species was Elliptio crassidens, with 44 specimens and size ranges of 40-120 mm; however, only one specimen measured 40 mm and no others were below 80 mm. The second most common species was M. nervosa (31 specimens); again, there was only two specimens below 80 mm. Based on this size-class information, M. nervosa are well-represented in the legal harvest group above 95 mm, but, smaller size-classes are mostly absent. Potamilus alatus was fairly common (21 specimens) in harvestable sizes, with five specimens measured below 90 mm.

Of other commercial species which can be harvested at 57 mm, only one specimen of C. tuberculata at 80 mm and two specimens of E. lineolata at 90 mm were collected. Neither species had any recruitment in the smaller size-classes. Recruitment was poor for *Amblema plicata*, with only one specimen in the 50 mm size-class, and no small specimens of *Tritogonia verrucosa* or *P. cordatum* (10-50 mm) were found. However, both *A. plicata* and *P. cordatum* are better represented in the larger size-classes for commercial harvest at 60-100 mm, and *T. verrucosa* at 60-140 mm, respectively. Both *O. reflexa* and *Q. pustulosa* show good or better recruitment in the 20-40 and 30-50 mm size-classes, and *Q. quadrula* reported some recruitment at 50 mm. No specimens of *O. reflexa* measured had attained legal-size for harvesting, and those of *Q. pustulosa* had barely reached harvestable size. Specimens of *O. reflexa* were also not reported during the commercial mussel census, probably because of being undersized; however, *Q. pustulosa* and *Q. quadrula* comprised 0.18 and 0.25% of harvested shells, respectively (Davies et al. 1992). The remaining five species measured (*A. grandis*, *A. suborbiculata*, *L. complanata*, *L. fragilis*, and *T. donaciformis*) are not of commercial value because of their thin-shell, with the possible exception of *L. complanata*, which has been used some in the artificial culture of Tennessee River pearls.

SUMMARY

Commercial mussel stocks in Wheeler Reservoir has changed considerably since impoundment, in 1936. Commercial species harvested historically from the reservoir, have been replaced by mussels which were uncommon, or, of no commercial value, during that time period. The present fauna consists of riverine and thin-shelled invader species that have adapted to lenthic conditions and soft-bottomed substrates which now pre-dominate the reservoir. Nineteen of 38 species reported in the literature are presently uncommon or rare, and may survive as old, non-reproducing individuals.

Historically, the most valuable commercial species in Wheeler Reservoir was Pleurobema cordatum, which accounted for 80% of all mussels harvested during 1956 and 1957. This species has since been replaced by Megalonaias nervosa, as the most valuable commercial shell, comprising 45% of all shells harvested.

Reservoir wide mussel population densities were estimated at $2.33/m^2$ or 460.15 million mussels. Of these totals, approximately 58 million were non-commercial species. Elliptio crassidens was the most common mussel, with populations estimated at 116 million, followed by M. nervosa (88 million), P. alatus (56 million), and O. reflexa (44 million). The overbanks in the lower reservoir and the old channel in the upper section were the most productive area sampled. Megalonaias nervosa (45 million) was the most abundant species in the lower reservoir overbank, while E. crassidens dominated the upper old channel.

Embayments sampled near Decatur showed no live mussels, and substrate washed during sampling produced an oil or petroleum smell. Bioassay tests identified un-ionized ammonia in sufficient high concentrations to cause mussel mortality on 8-day old A. imbecillis. Commercial musselers refer to this area as the "dead zone".

The most productive area sampled during line transects in commercial mussel beds was in First Creek embayment. In comparison, mussel densities were greater in the state protected mussel sanctuary. Quadrat excavations throughout the upper reservoir old river channel produced considerably higher mean densities of mussels than line transects.

Mussel recruitment was extremely limited in the 1-5 year age-class. Only three commercially valuable species, P. alatus, O. reflexa, and Q. pustulosa, were collected in relatively low numbers in this age-class. Severe drought conditions, from 1983-1988, may have affected the reproductive life-cycle and/or survival of thick-shelled species. Most thick-shelled species had apparently reproduced before the onset of the drought.

Based on the results of a one-year mussel census on Wheeler Reservoir, M. nervosa, P. cordatum, and E. lineolata comprised 45%, 25%, and 10% of all shells harvested. Measurement data for M. nervosa, found mostly larger size-classes for harvesting. No recruitment was reported for C. tuberculata, E. lineolata, P. cordatum, and T. verrucosa. All four species reported were of harvestable size. Recruitment was also poor for A. plicata, E. crassidens, P. alatus, and Q. Quadrula, with most specimens of commercial legal-size. Both O. reflexa and Q. pustulosa showed some recruitment; however, O. reflexa had not attained harvestable size.

Both age and size-class data shows poor recruitment of commercial species, except O. reflexa and Q. pustulosa. This may be the result of the small number of individuals found during the

1991 study, or, an indication that certain mussels had not recovered from the effects of drought. Another possible explanation for poor recruitment is overharvesting. Because commercial musseling is open year-round, shells are being taken during spawning seasons, and possibly, before they reach sexual maturity. This may be having long-term affects on future recruitment of mussel stocks in the reservoir. Mussel studies are needed to determine proper management strategies for controlling and regulating commercial species and harvest. The mussel fauna in Wheeler Reservoir will continue to change as older, non-reproducing, riverine species die-off, and are replaced by commercial and non-commercial species which have invaded and/or adapted to impoundment conditions.

RECOMMENDATIONS

Because of concerns voiced by Alabama's Game and Fish Division over the increased number of mussel fishing licenses sold in 1991 (2,356), and the future of the resource, a meeting was held at the Wheeler Refuge Visitor Center in Decatur, Alabama, on January 23, 1992 to discuss commercial musseling in the State. Those in attendance included: representatives from TVA, USFWS, Auburn University, Alabama commercial musselers union, and State fish and game biologists, and law enforcement personnel. Preliminary results of this study along with Davies et al. (1992) mussel harvest estimates were instrumental in establishing these new regulations.

On July 15, 1992, the State of Alabama signed into law all new commercial mussel fishing regulations proposed, with the exception of, raising license fees and payment of 5 cents per pound for all mussels harvested in Alabama. Recent changes and additions to Alabama regulations regarding commercial shell harvest is as follows:

Waters Open

1. Coosa River from Jordan Dam upstream to the Alabama-Georgia State Line.
2. Alabama River from mouth to Robert F. Henry Dam with the exception of the Cahaba River.
3. Tombigbee River from mouth to U. S. Interstate 59.
4. Black Warrior River from mouth to U. S. Interstate 59.
5. Tennessee River and its impoundments except Guntersville Dam downstream to the mouth of Shoal Creek, head of Hobbs Island downstream to Whitesburg Bridge, Wheeler Dam downstream to the mouth of Town Creek on the south bank and the mouth of Bluewater Creek on the north bank, Wilson Dam to the head of Seven-Mile Island.

Species Listed for Harvest	Size Limit (Inches)
Threeridge - *Amblema plicata*	2 5/8
Purple wartyback - *Cyclonaias tuberculata*	2 5/8
Butterfly - *Ellipsaria lineolata*	2 5/8
Elephant-ear - *Elliptio crassidens*	2 5/8
Spike - *Elliptio dilatata*	2 5/8

Ebonyshell - <u>Fusconaia</u> <u>ebena</u>	2 5/8
Wabash pigtoe - <u>Fusconaia</u> <u>flava</u>	2 5/8
Washboard - <u>Megalonaias</u> <u>nervosa</u>	4
Ohio pigtoe - <u>Pleurobema</u> <u>cordatum</u>	2 5/8
Pink heelsplitter - <u>Potamilus</u> <u>alatus</u>	4
Monkeyface - <u>Quadrula</u> <u>metanevra</u>	2 5/8
Wartyback - <u>Quadrula</u> <u>nodulata</u>	2 5/8
Pimpleback - <u>Quadrula</u> <u>pustulosa</u>	2 5/8
Mapleleaf - <u>Quadrula</u> <u>quadrula</u>	2 5/8
Pistolgrip - <u>Tritogonia</u> <u>verrucosa</u>	2 5/8

<u>Seasons</u>

The season for legal mussel fishing is open year-round except during the prescribed waterfowl hunting season, Swan Creek, Crow Creek, Mud Creek, and Raccoon Creek Wildlife Management Areas shall be closed. That area of the Wheeler Wildlife Area between Interstate 65 and U. S. Highway 31 shall be closed to mussel harvest October 15 to December 31. Mussel fishing in the freshwaters of this State shall be restricted to five (5) days each week (Monday through Friday) and shall be closed on all federal holidays.

<u>Method of Measuring Shells</u>

Mussels or their shells shall be measured from their dorsal to ventral surfaces by passing or attempting to pass the mussel or mussel shell by the weight of the mussel or mussel shell through a ring of the appropriate inside diameter. There shall be no allowance of undersize mussels or their shells.

Method of Harvest

The methods will remain the same with the addition of limiting shell bars to six feet.

License Fees

No change.

Mussel Buyers Report

A standardized report form will be developed for mussel buyers.

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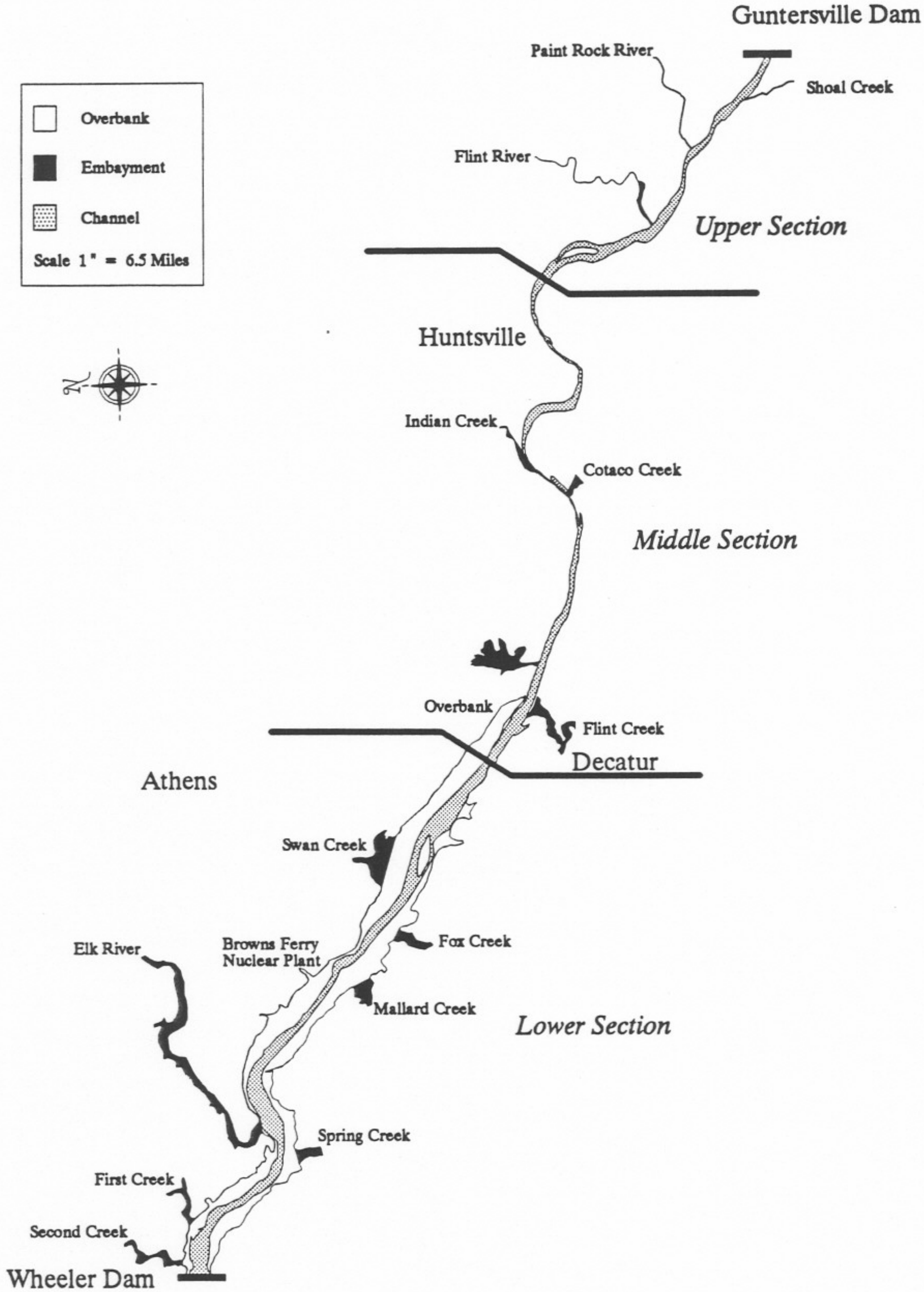

Figure 1. Wheeler Reservoir map showing stratification scheme used in 1991 mussel study.

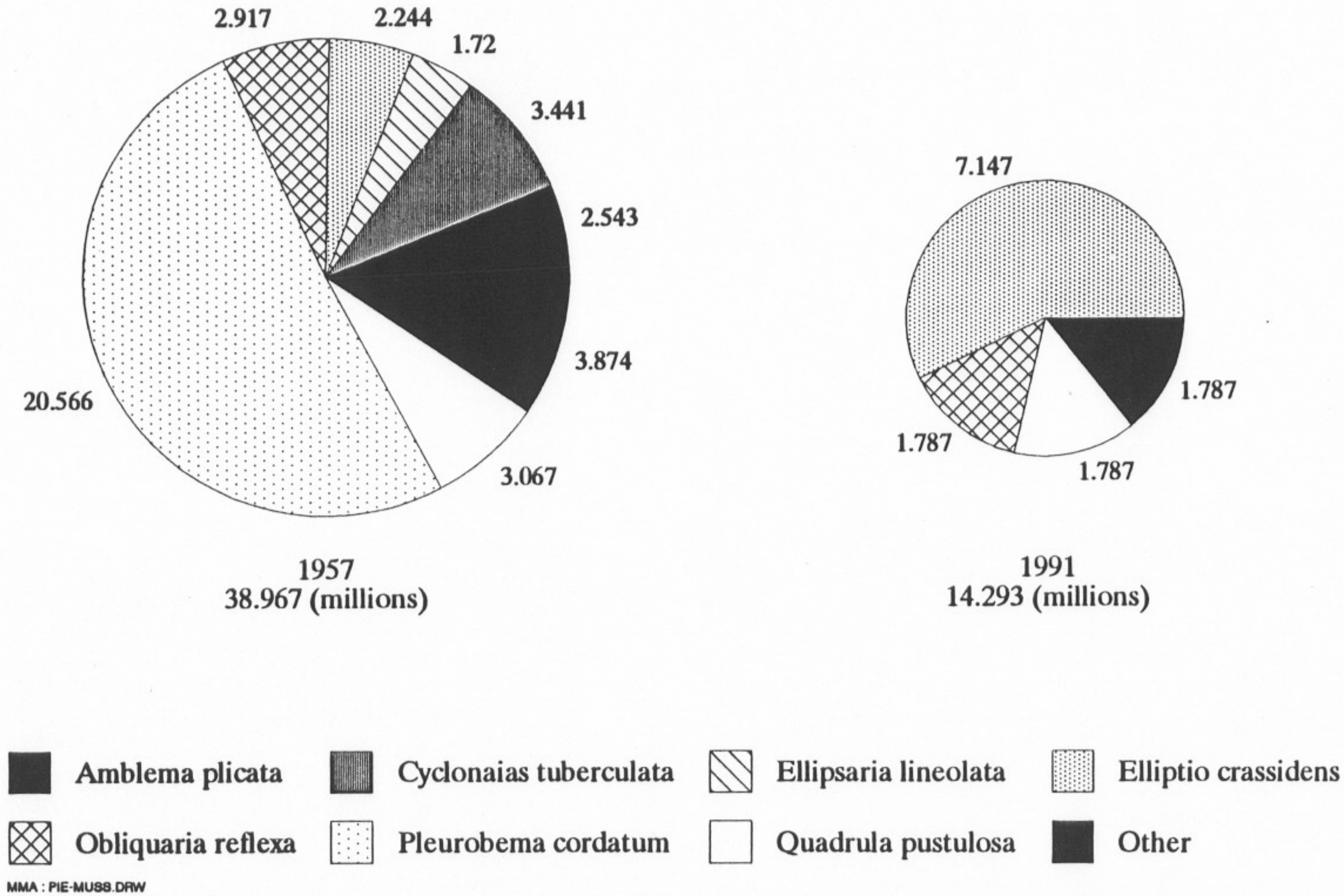

Figure 2. Comparison of estimated numbers of freshwater mussels, by species, between Scrugg's (1960) study and 1991 results for the same eight mile reach of Wheeler Reservoir (TRM 308-316).

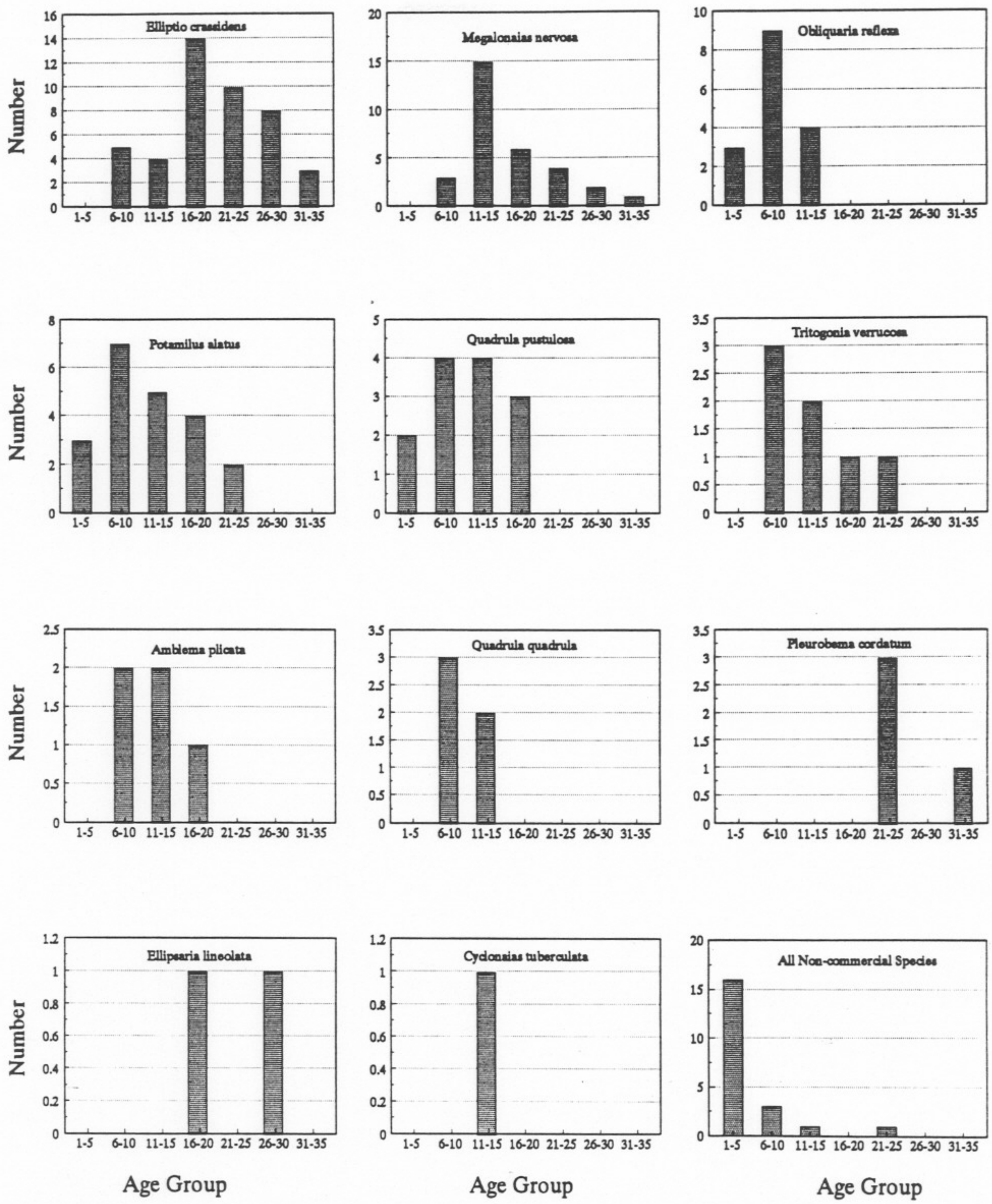

Figure 3. Numbers of freshwater mussels, by species, collected in each five-year age class, Wheeler Reservoir, 1991.

Table 1. Area and number of namples collected for each stratum for the Wheeler Reservoir nussel survey, 1991.

Stratum	Area (Hectares)	Number of Samples
Lower Section		
Old Channel	3707.5	50
Overbank	8878.7	126
Embayment	2508.8	39
Middle Section		
Old Channel	2170.2	33
Overbank	684.3	10
Embayment	766.7	15
Upper Section		
Old Channel	904.0	14
Embayment	89.0	6
Total	19709.3	293

Table 2. Freshwater mussel species reported from Wheeler Reservoir.

	Scruggs (1960)	Isom (1969)	Bates (1975)	TVA (1979)	Ahlstedt (1991)
Actinonaias ligamentina+@	-	X	-	-	-
Amblema plicata+	X	X	X	X	X
Anodonta grandis	-	-	X	X	X
Anodonta imbecillis	-	-	-	X	-
Anodonta suborbiculata	-	-	X	X	X
Cumberlandia monodonta+@	-	-	-	-	R
Cyprogenia stegaria*+@	-	X	-	X	R
Cyclonaias tuberculata+	X	X	X	X	X
Ellipsaria lineolata+	X	X	X	X	X
Elliptio crassidens+	X	X	X	X	X
Elliptio dilatata+@	X	X	-	X	-
Fusconaia ebena+	-	X	-	X	-
Lampsilis abrupta*+@	-	X	-	X	X
Lampsilis ovata+@	-	X	-	X	-
Lampsilis teres+@	-	-	-	X	X
Lasmigona complanata	-	-	X	X	X
Leptodea fragilis	-	-	X	X	X
Ligumia recta+@	-	-	-	X	R
Megalonaias nervosa+	X	X	X	X	X
Obliquaria reflexa+	X	X	X	X	X
Obovaria olivaria+@	X	-	-	-	-
Obovaria retusa*+@	-	-	-	-	R
Plethobasus cooperianus*+@	X	-	-	X	-
Plethobasus cyphyus+@	X	-	-	X	-
Pleurobema coccineum+@	-	-	-	X	-
Pleurobema cordatum+@	X	X	X	X	X
Pleurobema oviforme+@	-	-	-	X	-
Pleurobema pyramidatum+@	-	-	-	X	-
Potamilus alatus+	X	X	X	X	X
Potamilus ohiensis	-	-	X	-	-
Ptychobranchus fasciolaris+@	X	-	-	-	-
Quadrula fragosus*+@	X	-	-	-	-
Quadrula metanevra+	X	X	X	X	-
Quadrula pustulosa+	X	X	X	X	X
Quadrula quadrula+	-	X	X	X	X
Toxolasma lividus+@	-	-	-	X	R
Toxolasma parvus	-	-	X	X	R
Tritogonia verrucosa+	X	X	X	X	X
Truncilla donaciformis	X	-	X	X	X
TOTAL NUMBER OF SPECIES	18	18	19	32	24

* Endangered
\+ Riverine species
@ Non-reproducing riverine species in Wheeler Reservoir
X-Live, R-Relict

Table 3. Numbers of freshwater mussels (±95% confidence interval) by species for each stratum, Wheeler Reservoir, 1991. Data for the middle overbank and upper embayment strata are not presented since no mussels were collected.

	Lower Reservoir			Middle		Upper	Total
	Old Channel	Overbank	Embayment	Old Channel	Embayment	Old Channel	
	MILLIONS OF MUSSELS						
Commercial							
Amblema plicata	0.00	8.46±12.56	0.00	0.00	0.00	5.17±7.02	13.62±14.38
Cyclonaias tuberculata	2.97±5.93	0.00	0.00	0.00	0.00	0.00	2.97±5.93
Ellipsaria lineolata	0.00	0.00	0.00	0.00	0.00	5.17±7.02	5.17±7.02
Elliptio crassidens	5.93±8.32	5.64±11.30	0.00	47.35±35.51	0.00	56.82±47.17	115.74±60.69
Megalonaias nervosa	29.66±22.42	45.10±28.82	2.57±5.14	0.00	0.00	10.33±11.82	87.66±38.72
Obliquaria reflexa	5.93±11.86	25.37±21.46	0.00	2.63±5.23	0.00	10.33±15.95	44.26±29.72
Pleurobema cordatum	0.00	0.00	0.00	0.00	0.00	10.33±9.07	10.33±9.07
Potamilus alatus	2.97±5.93	19.73±14.58	0.00	10.52±16.48	0.00	23.24±20.91	56.46±30.93
Quadrula pustulosa	0.00	14.10±12.36	2.57±5.14	2.63±5.23	0.00	15.50±12.49	34.80±19.04
Quadrula quadrula	0.00	8.46±9.62	0.00	0.00	4.09±5.57	0.00	12.55±11.12
Tritogonia verrucosa	2.97±5.93	5.64±7.91	2.57±5.14	0.00	0.00	7.75±8.23	18.93±13.85
Commercial Total	50.42±30.09	132.48±52.93	7.72±11.39	63.13±38.73	4.09±5.57	144.64±58.23	402.48±93.59
Non-Commercial							
Anodonta grandis	0.00	8.46±9.62	5.15±7.19	0.00	0.00	0.00	13.60±12.01
Anodonta suborbiculata	0.00	0.00	2.57±5.14	0.00	0.00	0.00	2.57±5.14
Lasmigona complanata	0.00	0.00	0.00	2.63±5.23	0.00	0.00	2.63±5.23
Leptodea fragilis	8.90±13.14	16.91±15.74	0.00	7.90±8.81	0.00	2.58±5.16	36.28±22.91
Truncilla donaciformis	0.00	0.00	0.00	0.00	0.00	2.58±5.16	2.58±5.16
Non-Commercial Total	8.90±13.16	25.37±18.21	7.72±8.68	10.52±10.02	0.00	5.17±7.02	57.67±27.01
Combined Total	59.32±31.71	157.85±59.12	15.44±15.71	73.66±37.87	4.09±5.57	149.80±59.62	460.15±98.83

Table 4. Number of freshwater mussels collected in line transects (TR) and random search (RS) samples from Wheeler Reservoir, 1991.

TENNESSEE RIVER MILE	276.9	287.4	292.7	313.2	313.9	346	347.2 **	
METHOD	TR	TR	TR	RS	RS	RS	TR	Total
Amblema plicata	24	-	1	-	-	2	17	44
Anodonta grandis	1	1	-	-	-	-	-	2
Anodonta suborbiculata	-	1	-	-	-	-	-	1
Cyclonaias tuberculata	-	-	-	-	-	8	4	12
Ellipsaria lineolata	-	-	-	-	-	16	16	32
Elliptio crassidens	4	1	-	2	13	61	83	152
Lampsilis abrupta*	-	-	-	-	-	1	-	1
Lampsilis anodontoides	-	-	-	1	-	-	-	1
Megalonaias nervosa	24	48	34	1	-	8	4	119
Obliquaria reflexa	16	-	2	1	-	1	-	20
Pleurobema cordatum	-	1	-	-	1	4	12	18
Potamilus alatus	10	5	6	3	5	4	17	50
Quadrula metanevra	-	-	-	-	-	3	-	3
Quadrula pustulosa	100	2	2	2	-	10	9	125
Quadrula quadrula	7	-	-	-	-	-	-	7
Tritogonia verrucosa	10	-	-	-	-	1	-	11
TOTAL NUMBER OF SAMPLES	30	50	10	2	4	2	10	108
TOTAL NUMBER OF MUSSELS	196	59	45	10	19	119	162	610
TOTAL NUMBER PER M^2	1.31	0.24	0.90				3.24	
TOTAL NUMBER OF SPECIES	9	7	5	6	3	12	8	50

* Endangered
** Mussel Sanctuary

Table 5. Numbers of freshwater mussels per square meter (±95% confidence interval) by species for each stratum, Wheeler Reservoir, 1991. Data for the middle overbank and upper embayment strata are not presented since no mussels were collected.

	Lower Reservoir			Middle		Upper	Total
	Old Channel	Overbank	Embayment	Old Channel	Embayment	Old Channel	
	NUMBER PER SQUARE METER						
Commercial							
Amblema plicata	0.00	0.10±0.14	0.00	0.00	0.00	0.57±0.78	0.07±0.07
Cyclonaias tuberculata	0.08±0.16	0.00	0.00	0.00	0.00	0.00	0.02±0.03
Ellipsaria lineolata	0.00	0.00	0.00	0.00	0.00	0.57±0.78	0.03±0.04
Elliptio crassidens	0.16±0.22	0.06±0.13	0.00	2.18±1.64	0.00	6.29±5.22	0.59±0.31
Megalonaias nervosa	0.80±0.60	0.51±0.32	0.10±0.21	0.00	0.00	1.14±1.31	0.45±0.20
Obliquaria reflexa	0.16±0.32	0.29±0.24	0.00	0.12±0.24	0.00	1.14±1.76	0.23±0.15
Pleurobema cordatum	0.00	0.00	0.00	0.00	0.00	1.14±1.00	0.05±0.05
Potamilus alatus	0.08±0.16	0.22±0.16	0.00	0.48±0.76	0.00	2.57±2.31	0.28±0.16
Quadrula pustulosa	0.00	0.16±0.14	0.10±0.21	0.12±0.24	0.00	1.71±1.38	0.18±0.10
Quadrula quadrula	0.00	0.10±0.11	0.00	0.00	0.53±0.73	0.00	0.07±0.06
Tritogonia verrucosa	0.08±0.16	0.06±0.09	0.10±0.21	0.00	0.00	0.86±0.91	0.09±0.07
Commercial Total	1.36±0.81	1.49±0.60	0.31±0.45	2.91±1.78	0.53±0.73	16.00±6.44	2.04±0.47
Non-Commercial							
Anodonta grandis	0.00	0.10±0.11	0.21±0.29	0.00	0.00	0.00	0.07±0.06
Anodonta suborbiculata	0.00	0.00	0.10±0.21	0.00	0.00	0.00	0.01±0.03
Lasmigona complanata	0.00	0.00	0.00	0.12±0.24	0.00	0.00	0.01±0.03
Leptodea fragilis	0.24±0.35	0.19±0.18	0.00	0.36±0.41	0.00	0.29±0.57	0.18±0.12
Truncilla donaciformis	0.00	0.00	0.00	0.00	0.00	0.29±0.57	0.01±0.03
Non-Commercial Total	0.24±0.35	0.29±0.21	0.31±0.35	0.48±0.46	0.00	0.57±0.78	0.29±0.14
Combined Total	1.60±0.86	1.78±0.67	0.62±0.63	3.39±1.74	0.53±0.73	16.57±6.60	2.33±0.50

Table 6. Lengths of freshwater mussel species from Wheeler Reservoir, 1991.

	Millimeters (mm)																
SPECIES	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	TOTALS
Amblema plicata	.	.	.	.	1	1	.	1	1	1	.	.	.	.	.	.	5
*Anodonta grandis**	.	.	1	.	.	.	.	.	.	1	.	.	.	.	3	.	5
*Anodonta suborbiculata**	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Cyclonaias tuberculata	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1
Ellipsaria lineolata	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	2
Elliptio crassidens	.	.	.	1	.	.	.	3	3	15	19	3	.	.	.	.	44
*Lasmigona complanata**	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1
*Leptodea fragilis**	2	8	2	1	.	.	.	.	.	.	.	.	.	.	.	.	13
Megalonaias nervosa	.	.	.	.	1	.	.	1	1	8	7	6	2	2	2	1	31
Obliquaria reflexa	.	2	7	7	.	.	.	.	.	.	.	.	.	.	.	.	16
Pleurobema cordatum	.	.	.	.	.	1	.	1	1	1	.	.	.	.	.	.	4
Potamilus alatus	.	.	.	1	.	3	.	.	1	2	5	2	2	2	3	.	21
Quadrula pustulosa	.	.	4	3	4	2	.	.	.	.	.	.	.	.	.	.	13
Quadrula quadrula	.	.	.	.	2	2	.	1	.	.	.	.	.	.	.	.	5
Tritogonia verrucosa	.	.	.	.	.	1	.	2	.	.	2	.	.	2	.	.	7
*Truncilla donaciformis**	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
TOTALS	3	11	14	13	8	10	0	10	9	28	33	12	4	6	8	1	170

* Non-commercial species