To the Graduate Council:

I am submitting herewith a thesis written by Steven Albin Ahlstedt entitled "Twentieth Century Changes in the Freshwater Mussel Fauna of the Clinch River (Tennessee and Virginia)." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

Larry Wilson, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

The Graduate School

TWENTIETH CENTURY CHANGES IN THE FRESHWATER MUSSEL FAUNA OF THE CLINCH RIVER (TENNESSEE AND VIRGINIA)

A Thesis

Presented for the

Master of Science

Degree

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Steven Albin Ahlstedt

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ABSTRACT

This study investigated the current status of freshwater mussel populations in the Clinch River since first being reported by Ortmann (1918). Freshwater mussel species have declined from a reported 60 species to the 47 species identified in this study. Impoundments have drastically reduced the mussel fauna in the lower Clinch and mussels have failed to recolonize a portion of the upper Clinch below Carbo, Virginia, following two major toxic spills in 1967 and 1970.

There was a distinct longitudinal distribution of mussel species in the upper Clinch with an increase in the number of species downstream with increasing stream size. Abrupt changes in stream gradient were effective physical barriers for mussel distributions in the upper Clinch.

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CHAPTER I

INTRODUCTION

The Clinch River of Tennessee and Virginia is one of several major tributary streams forming the headwaters of the upper Tennessee River above Chattanooga. These tributary streams have developed highly diverse aquatic faunas, especially among the freshwater mussels. Ortmann (1918) referred to the upper Tennessee River region as one of the major centers for freshwater mussel diversity and perhaps the most prolific region in the world for this particular group. Particularly interesting among freshwater mussels are those species endemic to this region, referred to by Ortmann as the Cumberlandian faunal group because they are found only in the southern Appalachian Mountains and the Cumberland Plateau region. Ortmann (1924, 1925) later defined the Cumberlandian region as including only the drainages of the Tennessee River system from the headwaters to the vicinity of Muscle Shoals in Colbert and Lauderdale counties, Alabama; and the Cumberland River system extending from the headwaters to the vicinity of Clarksville, Montgomery County, Tennessee. The Cumberlandian region is one of six major areas with distinct endemic species of freshwater mussels. The other five regions include: (1) Atlantic, (2) Pacific, (3) Mississippi (Interior basin or Ohioan of some authors), (4) Ozarks, (5) West Floridian or Appalachicolan (van der Schalie and van der Schalie 1950).

Over the past 85 years, a rich freshwater mussel fauna has been reported from the Clinch River. Prior to the lower sections of the Clinch River being impounded by Norris dam in the mid-1930s, studies made by Charles C. Adams and Arnold E. Ortmann (both reported in Ortmann 1918) documented the richness of this fauna at 26 collecting sites tranversing almost the entire length of the Clinch River, a distance of approximately 563 stream kilometers (350 miles). At this time, collecting efforts were primarily limited to those sites accessible by railroad; however, their studies represent the only complete documentation of the original mussel fauna in the Clinch prior to impoundment and environmental changes caused by man. Since the completion of Norris dam on the Clinch River at 128-km (CRM 79.8) by the Tennessee Valley Authority (TVA) in 1936, the lower reaches of the Clinch have been further impounded by Melton Hill dam at 37-km (CRM 23), completed by TVA in 1963 and approximately 96-km (60 miles) downstream from Norris dam. Further, the lowermost portion of the Clinch River below Melton Hill dam is inundated by the backwaters of Watts Bar Reservoir (filled in 1942), a mainstream impoundment on the Tennessee River. Thus, approximately 241-km (150 miles) of the lower Clinch River in Tennessee are impounded. These impounded waters cover some of the richest mussel-containing riffle and shoal habitats once found in the Clinch. Although some mussels still survive in the more riverine reaches of the Clinch below Norris and Melton Hill dams, the communities are very depauperate and are limited to a few old individuals

probably present before construction of the dams. A few young specimens (evidence of reproduction) have been observed; this suggests that there are some environmentally tolerant species or individuals produced in or recruited from tributary streams, possibly by way of their fish hosts.

The upper free-flowing reaches of the Clinch above Norris Reservoir are situated in remote areas somewhat removed from human population centers. The mountainous terrain and inaccessibility have been a major hindrance for large scale development in this region. Except for a few isolated areas where toxic spills have occurred and strip-mining is in progress, the upper Clinch today contains the richest faunal assemblage of freshwater mussels remaining in the Tennessee River system. This fauna is not without change, however. Certain species of mussels, especially those belonging to the genus Epioblasma (= Dysnomia), have been nearly eliminated from the Clinch, while others maintain apparently healthy populations. Some of these mussel species may be considered as extirpated from the Clinch River fauna, extinct, or still surviving but reduced to such low numbers that they would be found only by chance while sampling. In any case, documented impacts have already occurred that reduced the mussel fauna in certain portions of the Clinch and future changes or declines can be expected because of current developments related to oil and gas exploration and the proposed funding of a coal slurry pipeline. Any major finds of oil and gas deposits or the construction and operation of a coal slurry pipeline

would open previously isolated portions of the Clinch watershed to additional development, thus increasing water demands that would result in additional pollution of the Clinch.

This study was initiated to:

1. assess the current status of freshwater mussels in the upper free-flowing reaches of the Clinch including observations on the fauna below Norris and Melton Hill dams; and
2. determine what changes have occurred in the faunal assemblage since being surveyed by Adams and Ortmann (Ortmann 1918).

During the course of this study, from 1978 to 1983, mussel data were accumulated at 204 collecting sites from both the upper free-flowing reaches of the Clinch and the lower impounded portion. The largest of these projects was the Cumberlandian Mollusk Conservation Program (CMCP). This program was designed to improve conditions for the survival of endangered and other stream dwelling mollusks that exist only in the headwaters of the Tennessee and Cumberland rivers (Jenkinson 1981). As one part of this program, float surveys of several rivers including the upper Clinch River were completed in order to update distribution records for Cumberlandian mussel species. Additional records from other TVA mussel studies on the Clinch have been compiled for this study. These records include mussel surveys at proposed bridge sites, barge terminals, waste treatment plants, and an industrial site. Further, an intensive mussel study was also completed on the Clinch River at the proposed

Breeder Reactor site and at a mussel relocation project at St. Paul, Virginia. The author participated at each of these projects as a biologist/mussel taxonomist except for studies conducted at the proposed barge terminals.

CHAPTER II

LITERATURE REVIEW

Many species of freshwater mussels originally were described from streams in the upper Tennessee River drainage which includes the Clinch River. Pilsbry and Rhoads (1897) first reported 16 species of freshwater mussels from one site on the lower Clinch River in Roane County, Tennessee (now impounded). In 1899, Charles C. Adams, while conducting his studies of the pleurocerid river snail Io, made extensive collections of mussels at 11 sites throughout the Clinch River. From 1912 to 1915, Arnold E. Ortmann made additional mussel collections in the Clinch River including some sites previously sampled by Adams. Ortmann (1918) later compiled his information with that of Adams and reported it with other mussel studies from the upper Tennessee River drainage. This report was to become the most important study of that region's freshwater mussel fauna known prior to impoundment and pollution of these streams. While studying snails, Goodrich (1913) published records of 30 species of freshwater mussels from five sites in the upper Clinch in southwest Virginia collected during a field trip with Ortmann. In 1909, Boepple and Coker (1912) investigated the market value of shells left by pearl fishermen in the lower reaches of the Clinch below Clinton, Tennessee (now impounded). Thousands of shells representing 16 mussel species were observed. During the period 1935 to 1937,

Hickman (1937) made extensive collections in the Clinch below the Norris dam construction site prior to closure of the dam in 1936. Thirty-nine species of mussels were reported. Cahn (1936) made similar collections of the Clinch below Norris dam upon closure of the structure. Forty-five species of mussels were found in the dewatered riverbed below the dam.

More recently, extensive freshwater mussel collections of the upper Clinch River above Norris Reservoir were reported by Stansbery (1973). From 1963 to 1971, an undetermined number of sites were sampled for mussels by Stansbery who reported 53 species of mussels. This represents the largest number of mussel species ever reported from the upper free-flowing reaches of the Clinch above Norris Reservoir. An excellent account of the mussel fauna in the upper Clinch was also reported by Bates and Dennis (1978) who sampled the Clinch from 1972 to 1975; 38 species were reported from 33 collecting sites. Included with this survey are limited data on the mussel fauna in the downstream impounded reaches of the lower Clinch. Seven species of mussels were reported from the impounded portions of the lower Clinch (Bates 1975; Bates and Dennis 1978). Neves et al. (1980) surveyed the endangered freshwater mussels of Virginia. This study included only the Virginia portion of the upper Clinch and included 32 species of mussels at 6 collecting sites.

CHAPTER III

DESCRIPTION OF THE STUDY AREA

The Clinch River originates in a mountainous region near Bluefield, Tazewell County, Virginia, and flows in a southwesterly direction 563 stream kilometers (350 miles) to its confluence with the Tennessee River at 913-km (Tennessee River Mile--TRM 567.8) in Watts Bar Reservoir near Kingston, Tennessee. Of its total length, only 322-km (200 miles) of the Clinch River remains free-flowing.

The Clinch River basin has an area of 5,180 km^2 (4,413 square miles) and includes two major physiographic regions; the Ridge and Valley and the Cumberland Plateau. This drainage area represents 10.8% of the Tennessee River basin.

The Ridge and Valley Province is characterized by long, subparallel ridges separated by narrow valleys consisting of folded shale, limestone, and dolomites interspersed by numerous sinkholes and extensive underground drainage (Masnik 1974). The Clinch River drainage in the Cumberland Plateau have horizontally bedded sedimentary strata dominated by shales, sandstone, and coal seams, and are considerably more recent (carboniferous) than Ridge and Valley strata (silurian or earlier).

The climate for the Clinch River basin is temperate, with an average annual temperature of 12°C (53°F) and precipitation of 117 cm (46 inches) annually. Because of the steep mountainous terrain, approximately 41% of the annual precipitation leaves the

watershed as surface runoff (Crossman et al. 1973). The mean average discharge for the unregulated flows of the Clinch above Tazewell, Tennessee, is 58 m^3/sec (2,048 CFS) with a maximum flow of 2,778 m^3/sec (98,100 CFS) recorded during the April 1977 flood (TVA 1978). Low flows generally average 3 m^3/sec (103 CFS) during late summer and early fall.

Approximately 50% of the Clinch River watershed is forested, with farming accounting for most of the remaining land use. Other land use practices include strip-mining for coal and rock quarrying. Coal mining is largely restricted to the northern portion of the Clinch River basin (Cumberland Plateau Province) and appears to have had little effect on the water quality of the Clinch because of the buffering capacity of limestone and dolomite formations which neutralize acid mine wastes (Crossman et al. 1973; Masnik 1974).

Two major toxic spills in the upper Clinch River in Virginia have had significant effects on the river's fauna. In 1967, a dike surrounding a fly ash settling lagoon collapsed at the Appalachian Power Company coal fired steam-electric plant near Carbo, Virginia, releasing a highly caustic alkaline slurry (pH=12) into the Clinch. During this period an estimated 162,000 fish were killed in the Virginia portion of the Clinch (106-km); an additional 54,000 fish were killed in the Tennessee portion of the Clinch (38-km) where the polluted mass was diluted (Anonymous 1967; Cairns et al. 1971). In June 1970, a second spill involving an undetermined amount of sulfuric acid was released into the Clinch from the same steam-electric

plant. As a result of this spill, approximately 5,300 fish were killed in a 35-km reach downstream from the plant (Cairns et al. 1971). In addition to these short term, catastrophic events, high levels of suspended solids are delivered by tributary streams such as Dump's Creek near Carbo, Guest River below St. Paul (Crossman et al. 1973), and Lick Creek above St. Paul. In 1979, Lick Creek was observed by the author to be running black with coal fines.

CHAPTER IV

COLLECTION TECHNIQUES AND DATA ANALYSIS

Sampling Procedures

Mussel surveys were conducted either at river points accessible by road or float-surveyed between access points using canoes and flatbottom boats (Figures 1 and 2). During float surveys, each riffle or shoal encountered was sampled for mussels as were the pool areas at the head of each shoal. Each set of locality data was taken from 1:24000 topographic maps and consisted of the following: name of the river, landmark, date, river mile, county, and state. In general, each site was sampled using wading, snorkeling, and scuba-diving sampling techniques. All mussel specimens observed were removed from the substrate by hand and placed in nylon mesh collecting bags for sorting and identification. Occasionally a garden rake was used to dislodge mussels buried in the substrate. Approximately four to five divers were utilized for most aspects of these surveys and average time spent for each person per site is estimated at between 60 and 90 minutes. In addition to instream sampling, stream banks were searched for muskrat shell middens. Shell middens were a prime source for locating fresh-dead specimens of mussel species which may be rare or overlooked while sampling. All fresh-dead shells (i.e., evidence of flesh inside the shell and shiny nacre with hinge ligament intact) were identified in the field, recorded on field data sheets, and placed in cloth collecting bags with an

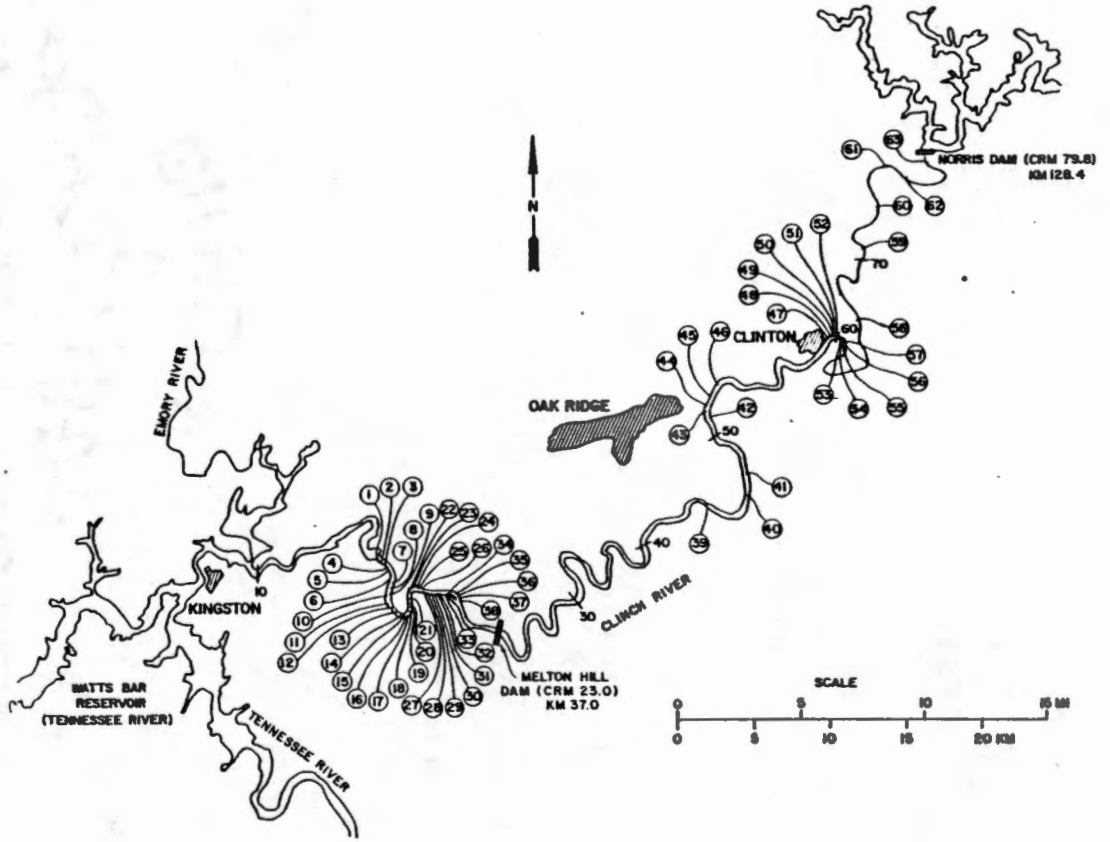


FIGURE 1. Lower Clinch River mussel collecting sites.

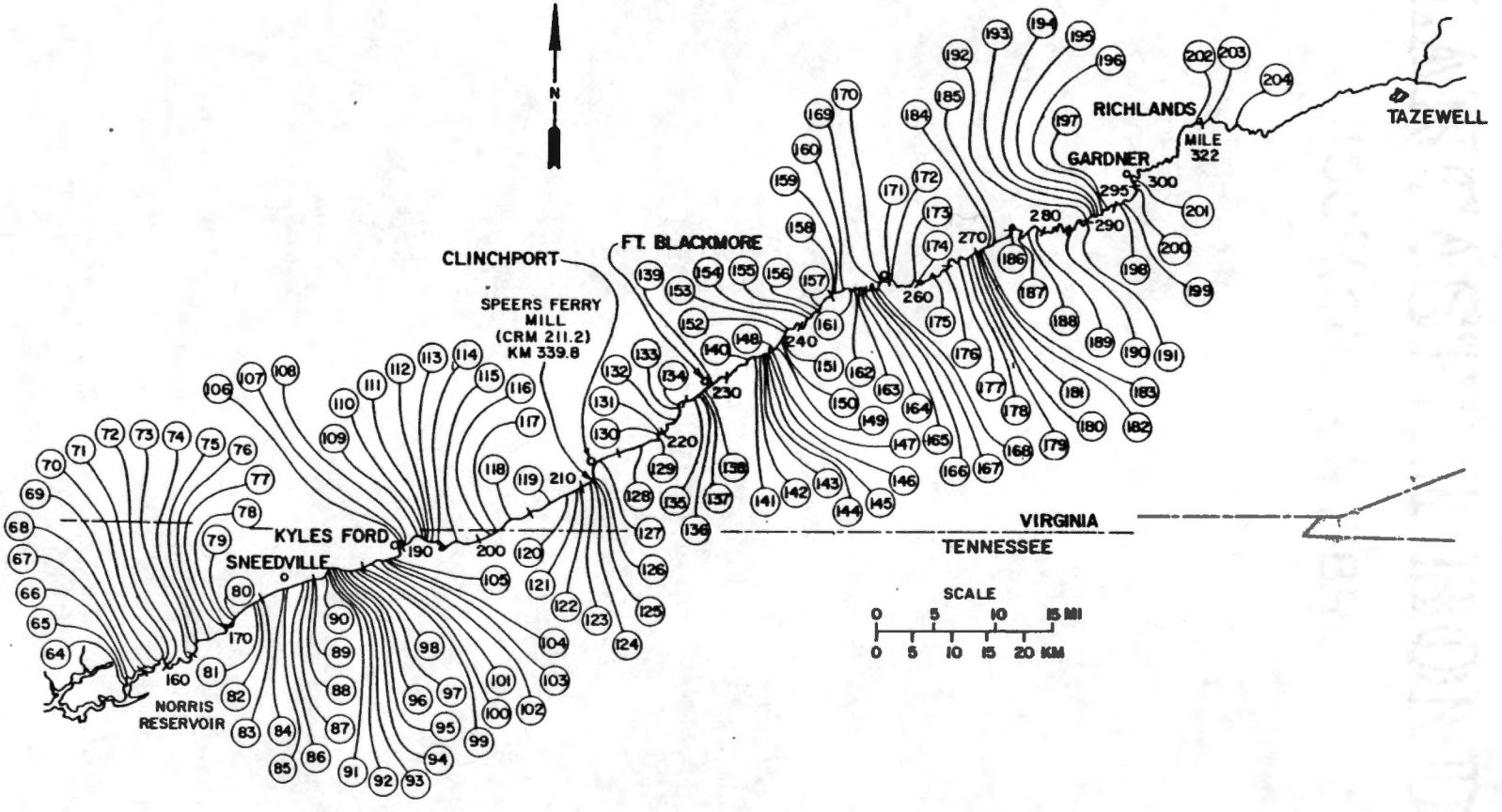


FIGURE 2. Upper Clinch River mussel collecting sites.

appropriate field identification label. Specimens were returned to the TVA fisheries laboratory at Norris, Tennessee, for cleaning, verification, cataloging, and storage. All live mussels found were identified in the field, recorded on field data sheets, and immediately returned to the river substrate. Specimens of federally-listed endangered mussels were photographed before being returned to the river substrate.

Treatment of Data

In order to examine the similarity between collecting sites in the Clinch River, a similarity coefficient was computed for each 32-km (20 mile) reach of the Clinch. Separate cluster analysis was performed on all recent mussel data and Ortmann's (1918) survey data. The coefficient of association used is the Jaccard Coefficient (S_j) (Sneath and Sokal 1973):

$$S_j = a/(a + b + c)$$

where a is the number of species in both of two reaches, b is the number of species occurring in the first reach but not the second, and c is the number of species occurring in the second reach but not the first.

The method used in this analysis was the unweighted pair group method using arithmetic means (UPGMA). This is the most frequently used clustering method.

Correlations were computed between the number of mussel species found in each 32-km reach of the Clinch, and elevation, gradient,

and river kilometer. Correlations were computed separately for both survey collections.

CHAPTER V

ABUNDANCE AND DISTRIBUTION OF MUSSELS

The taxonomic nomenclature used in this report follows Ortmann's (1918) species records from the Clinch with recent synonyms and name changes according to Stansbery (1973) and Bates and Dennis (1978) (Table 1).

The Clinch River mussel survey was divided into two river sections: the lower and upper Clinch (Table 2, Figures 1 and 2). The lower Clinch refers to sampling sites 1 through 63 located in the impounded reaches of the Clinch below Norris and Melton Hill dams. The upper Clinch refers to sampling sites 64 through 204 which occurs in the free-flowing portion of the Clinch above Norris Reservoir.

Lower Clinch

Twenty species of freshwater mussels were found at 63 collecting sites in the lower Clinch (Table 2; Figures 1 and 3). Three species (*Anodonta grandis*, *A. suborbiculata*, and *Lasmigona complanata*) are new to the Clinch River fauna. One federally listed endangered species (*Lampsilis orbiculata*) was also reported from the lower Clinch.

Freshwater mussels were found at practically every site in the lower Clinch; however, species diversity and abundance were extremely low in comparison to the 53 species reported by Ortmann (1918) from this area (Table 3). Generally, from one to four species were present at each site with the largest numbers observed at

TABLE 1. Clinch River Mussel Species Collected by Ortmann (1918) with Recent Nomenclatorial Changes According to Stansbery (1973), and Bates and Dennis (1978)

Ortmann 1918		Recent
Margaritanidae		
Cumberlandia monodonta	=	*Cumberlandia monodonta*[1,2]
Unionidae		
Unioninae		
Amblema plicata costata	=	*Amblema costata*[2]
Rotundaria tuberculata	=	*Cyclonaias tuberculata*[1,2]
Elliptio niger	=	*Elliptio crassidens*[1,2]
Elliptio dilatatus	=	*Elliptio dilatatus*[1,2]
Fusconaia barnesiana *Fusconaia barnesiana bigbyensis* *Fusconaia barnesiana tumescens*	=	*Fusconaia barnesiana*[1,2]
Fusconaia cor *Fusconaia cor analoga*	=	*Fusconaia edgariana*[1,2]
Fusconaia cuneolus *Fusconaia cuneolus appressa*	=	*Fusconaia cuneolus*[1,2]
Fusconaia pilaris *Fusconaia pilaris bursa-pastoris* *Fusconaia pilaris lesueriana*	=	*Fusconaia subrotunda*[1]
Lastena lata	=	*Lastena lata*[1,2]
Lexingtonia dolabelloides *Lexingtonia dolabelloides conradi*	=	*Lexingtonia dolabelloides*[1,2]
Plethobasus cooperianus	=	*Plethobasus cooperianus*[2]
Plethobasus cyphyus	=	*Plethobasus cyphyus*[1,2]

TABLE 1 (Continued)

Pleurobema obliquum	=	*Pleurobema cordatum*[1,2]
Pleurobema obliquum catillus *Pleurobema obliquum coccineum*	=	*Pleurobema coccineum*[1]
Pleurobema obliquum cordatum	=	*Pleurobema plenum*[1]
Pleurobema obliquum rubrum	=	*Pleurobema rubrum* (= *P. pyramidatum*)[1]
Pleurobema oviforme *Pleurobema oviforme argenteum* *Pleurobema oviforme holstonense*	=	*Pleurobema oviforme*[1,2]
Quadrula cylindrica *Quadrula cylindrica strigillata*	=	*Quadrula cylindrica*[1,2]
Quadrula intermedia	=	*Quadrula intermedia*[1,2]
Quadrula pustulosa	=	*Quadrula pustulosa*[1,2]
Anodontinae		
Alasmidonta marginata	=	*Alasmidonta marginata*[1,2]
Alasmidonta minor	=	*Alasmidonta viridis*[1]
Lasmigona badia	=	*Lasmigona holstonia*[1,2]
Lasmigona costata	=	*Lasmigona costata*[1,2]
Strophitus edentulus	=	*Strophitus rugosus*[2]
Lampsilinae		
Nephronaias ligamentina gibba	=	*Actinonaias carinata*[2]
Nephronaias pectorosa	=	*Actinonaias pectorosa*[1,2]
Toxolasma lividum	=	*Toxolasma lividus*[1]
Lemiox rimosus	=	*Conradilla caelata*[1,2]
Cyprogenia stegaria	=	*Cyprogenia irrorata*[1,2]
Dromus dromas caperatus	=	*Dromus dromas*[1,2]
Truncilla arcaeformis	=	*Epioblasma arcaeformis*[1]
Truncilla capaeformis	=	*Epioblasma capsaeformis*[1]
Truncilla interrupta	=	*Epioblasma brevidens*[1]

TABLE 1 (Continued)

Truncilla haysiana	=	*Epioblasma haysiana*[1]
Truncilla lenior	=	*Epioblasma lenior*[1]
Truncilla propinqua	=	*Epioblasma propinqua*[1]
Truncilla stewardsoni	=	*Epioblasma stewardsoni*[1]
Truncilla torulosa gubernaculum	=	*Epioblasma torulosa gubernaculum*[1]
Truncilla triquetra	=	*Epioblasma triquetra*[1]
Lampsilis fasciola	=	*Lampsilis fasciola*[1,2]
Lampsilis orbiculata	=	*Lampsilis orbiculata*[1,2]
Lampsilis ovata *Lampsilis ovata ventricosa*	=	*Lampsilis ovata*[1,2]
Medionidus plateolus	=	*Medionidus conradicus*[1,2]
Eurynia recta	=	*Ligumia recta*[1]
Eurynia fabalis	=	*Villosa fabalis*[1]
Eurynia nebulosa	=	*Villosa nebulosa*[1]
Eurynia perpurpurea	=	*Villosa perpurpurea*[1]
Eurynia trabalis	=	*Villosa trabalis*[1]
Eurynia vanuxemensis	=	*Villosa vanuxemi*[1]
Obliquaria reflexa	=	*Obliquaria reflexa*[1,2]
Obovaria retusa	=	*Obovaria retusa*[1,2]
Paraptera fragilis	=	*Leptodea fragilis*[1,2]
Paraptera leptodon	=	*Leptodea leptodon*[1,2]
Plagiola lineolata	=	*Plagiola lineolata*[1,2]
Proptera alata	=	*Proptera alata*[2]
Ellipsaria fasciolaris	=	*Ptychobranchus fasciolaris*[1,2]
Ellipsaria subtenta	=	*Ptychobranchus subtentum*[1,2]
Amygdalonaias truncata	=	*Truncilla truncata*[1,2]

[1]Stansbery (1973).

[2]Bates and Dennis (1978).

TABLE 2. Location of all Clinch River Collecting Sites in Kilometers (km) and Miles (CRM)

Site	km	(CRM)	Location
1	22.5	(14.0)	Gallaher Bridge - Roane Co., TN
2	22.8	(14.2)	Above Gallaher Bridge - Roane Co., TN
3	23.2	(14.4)	Above Gallaher Bridge - Roane Co., TN
4	23.5	(14.6)	Gauging Station - Roane Co., TN
5	23.8	(14.8)	Roane Co., TN
6	24.1	(15.0)	Roane Co., TN
7	24.5	(15.2)	Roane Co., TN
8	24.8	(15.4)	Roane Co., TN
9	25.1	(15.6)	Roane Co., TN
10	25.4	(15.8)	Roane Co., TN
11	25.7	(16.0)	Below Poplar Springs Creek - Roane Co., TN
12	26.1	(16.2)	Above Poplar Springs Creek - Roane Co., TN
13	26.4	(16.4)	Roane Co., TN
14	26.7	(16.6)	Dug Ridge - Roane Co., TN
15	27.0	(16.8)	Below Caney Creek - Roane Co., TN
16	27.4	(17.0)	Mouth Caney Creek - Roane Co., TN
17	27.7	(17.2)	Above Caney Creek - Roane Co., TN
18	28.0	(17.4)	Above Caney Creek - Roane Co., TN
19	28.3	(17.6)	Above Caney Creek - Roane Co., TN
20	28.6	(17.8)	Above Caney Creek - Roane Co., TN
21	29.0	(18.0)	Below Grubb Islands - Roane Co., TN
22	29.3	(18.2)	Below Grubb Islands - Roane Co., TN
23	29.6	(18.4)	Grubb Islands - Roane Co., TN
24	29.9	(18.6)	Grubb Islands - Roane Co., TN
25	30.2	(18.8)	Above Grubb Islands - Roane Co., TN
26	30.6	(19.0)	Roane Co., TN
27	30.7	(19.1)	Roane Co., TN
28	30.9	(19.2)	Roane Co., TN
29	31.2	(19.4)	Below Raccoon Creek - Roane Co., TN
30	31.4	(19.5)	Below Jones Island - Roane Co., TN

TABLE 2 (Continued)

Site	km	(CRM)	Location
31	31.5	(19.6)	Below Jones Island - Roane Co., TN
32	31.9	(19.8)	Jones Island - Roane Co., TN
33	32.2	(20.0)	Jones Island - Roane Co., TN
34	32.5	(20.2)	Jones Island - Roane Co., TN
35	32.8	(20.4)	Jones Island - Roane Co., TN
36	33.1	(20.6)	Below Mouth Whiteoak Lake - Roane Co., TN
37	33.5	(20.8)	Mouth Whiteoak Lake - Roane Co., TN
38	33.8	(21.0)	Above Whiteoak Lake - Roane Co., TN
39	72.1	(44.8)	Above Solway Bridge - Knox/Anderson Co., TN
40	75.8	(47.1)	Across Bull Run Steam Plant - Anderson Co., TN
41	77.2	(48.0)	Below Edgemoor Bridge - Anderson Co., TN
42	81.6	(50.7)	Above Braden Branch - Anderson Co., TN
43	82.1	(51.0)	Below Oak Ridge Daymark - Anderson Co., TN
44	82.5	(51.3)	Below Elza Daymark - Anderson Co., TN
45	83.3	(51.8)	Above Elza Daymark - Anderson Co., TN
46	84.3	(52.4)	Below Lost Bottoms Daymark - Anderson Co., TN
47	95.7	(59.5)	Above Southern Railroad Tressel - Anderson Co., TN
48	95.9	(59.6)	Anderson Co., TN
49	96.1	(59.7)	Anderson Co., TN
50	96.2	(59.8)	Anderson Co., TN
51	96.4	(59.9)	Anderson Co., TN
52	96.5	(60.0)	Below Clinton Island - Anderson Co., TN
53	96.7	(60.1)	Clinton Island - Anderson Co., TN
54	96.9	(60.2)	Clinton Island - Anderson Co., TN
55	97.0	(60.3)	Clinton Island - Anderson Co., TN
56	97.2	(60.4)	Clinton Island - Anderson Co., TN
57	97.3	(60.5)	Head of Clinton Island - Anderson Co., TN
58	107.2	(66.6)	Hwy. 61 Bridge - Anderson Co., TN
59	113.4	(70.5)	Fish Trap - Anderson Co., TN
60	117.1	(72.8)	Above River Ridge -Anderson Co., TN
61	122.0	(75.8)	Massengill Bridge - Anderson Co., TN

TABLE 2 (Continued)

Site	km	(CRM)	Location
62	124.1	(77.1)	Above Millers Island - Anderson Co., TN
63	128.0	(79.5)	Below Norris Dam - Anderson Co., TN
64	242.6	(150.8)	Below Hwy. 25E. Bridge - Claiborne/ Grainger Co., TN
65	243.8	(151.5)	Below Hwy. 25E Bridge - Claiborne/ Grainger Co., TN
66	244.4	(151.9)	Hwy. 25E Bridge - Claiborne/Grainger Co., TN
67	247.5	(153.8)	Claiborne/Grainger Co., TN
68	250.5	(155.7)	Kelly Branch - Claiborne/Grainger Co., TN
69	254.4	(158.1)	Hancock Co., TN
70	256.2	(159.2)	Grissom Island - Hancock Co., TN
71	256.3	(159.3)	Grisson Island - Hancock Co., TN
72	257.4	(160.0)	The Narrows - Hancock Co., TN
73	265.2	(164.8)	Hancock Co., TN
74	266.8	(165.8)	Above Evans Knob - Hancock Co., TN
75	267.7	(166.4)	Manning Ferry - Hancock Co., TN
76	270.3	(168.0)	Hancock Co., TN
77	273.2	(169.8)	Hancock Co., TN
78	274.3	(170.5)	Lawson Mill - Hancock Co., TN
79	277.1	(172.2)	Swan Island - Hancock Co., TN
80	277.2	(172.3)	Swan Island - Hancock Co., TN
81	280.3	(174.2)	Between River Knobs - Hancock Co., TN
82	280.8	(174.5)	Hancock Co., TN
83	281.3	(174.8)	Hancock Co., TN
84	285.3	(177.3)	Hwy. 33 Sneedville Bridge - Hancock Co., TN
85	285.4	(177.4)	Hwy. 33 Sneedville Bridge - Hancock Co., TN
86	287.5	(178.7)	Fall Branch - Hancock Co., TN
87	288.7	(179.4)	Hancock Co., TN
88	289.3	(179.8)	Farmers Branch - Hancock Co., TN
89	289.5	(179.9)	Above Farmers Branch - Hancock Co., TN
90	291.6	(181.2)	Frost Ford - Hancock Co., TN

TABLE 2 (Continued)

Site	km	(CRM)	Location
91	291.7	(181.3)	Frost Ford - Hancock Co., TN
92	292.5	(181.8)	Hancock Co., TN
93	293.2	(182.2)	Hancock Co., TN
94	293.8	(182.6)	Hancock Co., TN
95	294.3	(182.9)	Alder Hollow - Hancock Co., TN
96	294.9	(183.3)	Brooks Island - Hancock Co., TN
97	295.3	(183.5)	Brooks Island - Hancock Co., TN
98	295.6	(183.7)	Above Brooks Island - Hancock Co., TN
99	296.1	(184.0)	Davis Branch - Hancock Co., TN
100	296.9	(184.5)	Above Davis Branch - Hancock Co., TN
101	299.3	(186.0)	Hancock Co., TN
102	300.9	(187.0)	Hancock Co., TN
103	301.4	(187.3)	Below Webb Island - Hancock Co., TN
104	301.7	(187.5)	Webb Island - Hancock Co., TN
105	301.8	(187.6)	Above Webb Island - Hancock Co., TN
106	304.6	(189.3)	Above Livesay Mill - Hancock Co., TN
107	305.1	(189.6)	Kyles Ford - Hancock Co., TN
108	305.2	(189.7)	Kyles Ford - Hancock Co., TN
109	308.9	(192.0)	Mouth of N.F. Clinch River - Hancock Co., TN
110	309.6	(192.4)	Wallens Bend - Hancock Co., TN
111	310.1	(192.7)	Hancock Co., TN
112	310.5	(193.0)	Hancock Co., TN
113	311.0	(193.3)	Hancock Co., TN
114	312.1	(194.0)	Walnut Grove Church - Hancock Co., TN
115	318.6	(198.0)	Hancock Co., TN
116	323.7	(201.2)	Hancock Co., TN
117	325.0	(202.0)	Shelby Creek - Hancock Co., TN
118	327.3	(203.4)	Scott Co., VA
119	332.9	(206.9)	Unnamed Island - Scott Co., VA
120	335.3	(208.4)	Above Watts Branch - Scott Co., VA
121	337.1	(209.5)	Bobs Branch - Scott Co., VA

TABLE 2 (Continued)

Site	km	(CRM)	Location
122	337.9	(210.0)	Scott Co., VA
123	339.2	(210.8)	Scott Co., VA
124	339.7	(211.1)	Gauging Station - Scott Co., VA
125	340.0	(211.3)	Speers Ferry - Scott Co., VA
126	340.8	(211.8)	Above Mouth of Copper Creek - Scott Co., VA
127	343.4	(213.4)	Above Stock Creek - Scott Co., VA
128	349.2	(217.0)	Scott Co., VA
129	352.5	(219.1)	Below Hwy. Bridge at Hill - Scott Co., VA
130	352.7	(219.2)	Below Craft Mill - Scott Co., VA
131	352.9	(219.3)	Below Craft Mill - Scott Co., VA
132	359.3	(223.3)	Below Swinging Bridge at Slant - Scott Co., VA
133	360.6	(224.1)	McDowell Branch - Scott Co., VA
134	360.7	(224.2)	Above McDowell Branch - Scott Co., VA
135	363.3	(225.8)	The Suck - Scott Co., VA
136	364.1	(226.3)	Pendleton Island - Scott Co., VA
137	364.3	(226.4)	Pendleton Island - Scott Co., VA
138	364.6	(226.6)	Pendleton Island - Scott Co., VA
139	365.9	(227.4)	Fort Blackmore Bridge - Scott Co., VA
140	374.3	(232.6)	Island at Staunton Creek - Scott Co., VA
141	376.0	(233.7)	Grays Island - Scott Co., VA
142	376.5	(234.0)	Grays Island - Scott Co., VA
143	377.3	(234.5)	Grays Island - Scott Co., VA
144	377.6	(234.7)	Grays Island - Scott Co., VA
145	378.0	(234.9)	Below Benges Creek at Unnamed Island - Scott Co., VA
146	378.2	(235.1)	Above Benges Creek at Unnamed Island - Scott Co., VA
147	378.4	(235.2)	Above Benges Creek at Unnamed Island - Scott Co., VA
148	378.9	(235.5)	Scott Co., VA
149	380.2	(236.3)	Below Wolf Run Creek - Scott Co., VA

TABLE 2 (Continued)

Site	km	(CRM)	Location
150	381.3	(237.0)	Above Bridge at Dungannon - Scott Co., VA
151	381.7	(237.2)	Dungannon - Scott Co., VA
152	382.5	(237.7)	Unnamed Island Below Mill Island - Scott Co., VA
153	383.4	(238.3)	Mill Island - Scott Co., VA
154	388.6	(241.5)	Island Above Townes Tunnel - Scott Co., VA
155	389.1	(241.8)	Scott Co., VA
156	391.0	(243.0)	Miller Yard - Scott Co., VA
157	391.1	(243.1)	Miller Yard - Scott Co., VA
158	394.2	(245.0)	Above Bangor - Wise/Russell Co., VA
159	394.8	(245.4)	Above Bangor - Wise/Russell Co., VA
160	397.3	(246.9)	Wise/Russell Co., VA
161	398.2	(247.5)	Hale Hollow - Wise/Russell Co., VA
162	399.0	(248.0)	Below Tributary at Hasn Hollow - Wise/ Russell Co, VA
163	401.6	(249.6)	Burtons Ford - Wise/Russell Co., VA
164	401.8	(249.7)	Above Burtons Ford - Wise/Russell Co., VA
165	401.9	(249.8)	Above Burtons Ford - Wise/Russell Co., VA
166	403.7	(250.9)	Wise/Russell Co., VA
167	405.6	(252.1)	Below Castle Run Creek - Wise/Russell Co., VA
168	406.4	(252.6)	Above Castle Run Creek - Wise/Russell Co., VA
169	407.1	(253.0)	Wise/Russell Co., VA
170	408.4	(253.8)	Below Robinette Branch - Wise/Russell Co., VA
171	410.9	(255.4)	Island Above St. Paul - Wise/Russell Co., VA
172	411.3	(255.6)	Below Lick Creek - Russell Co., VA
173	417.2	(259.3)	Russell Co., VA
174	418.3	(260.0)	Russell Co., VA
175	421.2	(261.8)	Dry Run Bend - Russell Co., VA
176	425.1	(264.2)	Carterton Bridge - Russell Co., VA
177	431.5	(268.2)	Above Carbo - Russell Co., VA
178	433.5	(269.4)	Above Carbo - Russell Co., VA

TABLE 2 (Continued)

Site	km	(CRM)	Location
179	433.8	(269.6)	Above Carbo at Mill Creek - Russell Co., VA
180	434.8	(270.2)	Russell Co., VA
181	435.7	(270.8)	At Island Below Cleveland - Russell Co., VA
182	435.9	(270.9)	At Island Below Cleveland - Russell Co., VA
183	436.0	(271.0)	At Island Below Cleveland - Russell Co., VA
184	436.7	(271.4)	Hwy. Bridge Below Cleveland - Russell Co., VA
185	437.6	(272.0)	Above Cleveland - Russell Co., VA
186	441.7	(274.5)	Hwy. Bridge Below Artrip - Russell Co., VA
187	445.0	(276.6)	Russell Co., VA
188	447.3	(278.0)	Unnamed Island - Russell Co., VA
189	449.6	(279.4)	Hwy. Bridge at Nash Ford - Russell Co., VA
190	459.9	(285.8)	Above Dilly Branch - Russell Co., VA
191	466.3	(289.8)	Russell Co., VA
192	467.1	(290.3)	Russell Co., VA
193	467.9	(290.8)	Russell Co., VA
194	468.7	(291.3)	Below Thompson Branch - Russell Co., VA
195	469.8	(292.0)	Russell Co., VA
196	471.4	(293.0)	Above Hubbard Hole - Russell Co., VA
197	473.0	(294.0)	Above Lewis Creek - Russell Co., VA
198	475.6	(295.6)	Russell Co., VA
199	476.7	(296.3)	Russell Co., VA
200	482.1	(299.6)	Mouth of Little River - Russell Co., VA
201	484.3	(301.0)	Russell Co., VA
202	517.6	(321.7)	At Railroad Bridge - Russell Co., VA
203	519.1	(322.6)	Below Bridge at Cedar Bluff - Tazewell Co., VA
204	521.0	(323.8)	Above Cedar Bluff - Tazewell Co., VA)

Mussel Species	Collecting Sites[1]																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Actinonaias carinata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Actinonaias pectorosa[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alasmidonta marginata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amblema costata	2	3	4	1	-	-	-	-	-	-	-	-	-	1	-	2	-
Anodonta grandis	2	-	-	1	-	-	-	-	-	1	-	2	-	-	-	1	-
Anodonta suborbiculata	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Conradilla caelata[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cumberlandia monodonta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyclonaias tuberculata	1	-	2	2	-	-	1	2	-	-	-	-	-	3	-	-	2
Cyprogenia irrorata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dromus dromas[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elliptio crassidens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elliptio dilatatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma brevidens[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma capsaeformis[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma triquetra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia barnesiana[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia cuneolus[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia edgariana[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia subrotunda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis fasciola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis orbiculata[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis ovata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lasmigona complanata	-	-	-	-	-	-	1	-	-	2	-	-	-	-	-	-	1
Lasmigona costata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lastena lata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptodea fragilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lexingtonia dolabelloides[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ligumia recta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Medionidus conradicus[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plethobasus cyphyus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema cordatum	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Pleurobema plenum[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema rubrum	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema oviforme[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Proptera alata	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-
Ptychobranchus fasciolaris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ptychobranchus subtentum[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula cylindrica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula metanevra	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Quardula pustulosa	3	1	9	3	6	1	5	2	2	14	4	10	2	14	4	6	1
Quadrula sparsa[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strophitus rugosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Truncilla truncata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa nebulosa[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa perpurpurea[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa vanuxemi[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total number of species	6	2	3	5	1	1	3	2	1	3	2	4	1	3	1	4	3

FIGURE 3. Number of Each Naiad Species Found During Qualitative Sampling of the Clinch River Between 1978 and 1983.

[1]Collecting sites (1-63 lower Clinch, 64-204 upper Clinch).

[2]Cumberland form (16).

[3]Endangered species (7).

Mussel Species	Collecting Sites[1] 18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Actinonaias carinata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Actinonaias pectorosa[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alasmidonta marginata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amblema costata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anodonta grandis	-	1	-	-	2	2	4	1	1	-	-	-	2	1	2
Anodonta suborbiculata	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-
Conradilla caelata[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cumberlandia monodonta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyclonaias tuberculata	-	-	-	-	-	1	-	1	-	-	-	-	2	-	-
Cyprogenia irrorata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dromus dromas[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elliptio crassidens	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Elliptio dilatatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma brevidens[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma capsaeformis[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma triquetra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia barnesiana[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia cuneolus[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia edgariana[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia subrotunda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis fasciola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis orbiculata[3]	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Lampsilis ovata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lasmigona complanata	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-
Lasmigona costata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lastena lata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptodea fragilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lexingtonia dolabelloides[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ligumia recta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Medionidus conradicus[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plethobasus cyphyus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema cordatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema plenum[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema rubrum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema oviforme[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Proptera alata	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-
Ptychobranchus fasciolaris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ptychobranchus subtentum[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula cylindrica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula metanevra	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Quardula pustulosa	3	-	-	-	-	4	1	4	2	-	-	1	7	-	1
Quadrula sparsa[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strophitus rugosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Truncilla truncata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa nebulosa[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa perpurpurea[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa vanuxemi[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total number of species	1	1	0	1	2	4	3	4	3	1	0	2	4	2	2

FIGURE 3 (continued)

Mussel Species	Collecting Sites[1]														
	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
Actinonaias carinata	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Actinonaias pectorosa[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alasmidonta marginata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amblema costata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anodonta grandis	3	1	1	-	1	3	-	1	-	9	1	2	-	2	-
Anodonta suborbiculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conradilla caelata[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cumberlandia monodonta	-	-	-	-	-	-	1	-	-	2	-	-	-	-	-
Cyclonaias tuberculata	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Cyprogenia irrorata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dromus dromas[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elliptio crassidens	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-
Elliptio dilatatus	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-
Epioblasma brevidens[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma capsaeformis[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma triquetra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia barnesiana[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia cuneolus[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia edgariana[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia subrotunda	-	-	-	-	-	-	-	-	-	9	-	-	-	-	-
Lampsilis fasciola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis orbiculata[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis ovata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lasmigona complanata	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Lasmigona costata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lastena lata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptodea fragilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lexingtonia dolabelloides[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ligumia recta	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Medionidus conradicus[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plethobasus cyphyus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema cordatum	-	-	-	-	-	-	-	-	-	12	1	1	-	3	-
Pleurobema plenum[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema rubrum	-	-	-	-	-	-	-	1	-	7	-	-	-	-	1
Pleurobema oviforme[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Proptera alata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ptychobranchus fasciolaris	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Ptychobranchus subtentum[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula cylindrica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula metanevra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quardula pustulosa	-	-	-	-	-	2	5	-	-	2	-	3	1	1	-
Quadrula sparsa[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strophitus rugosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Truncilla truncata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa nebulosa[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa perpurpurea[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa vanuxemi[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total number of species	1	1	1	0	2	2	2	2	0	12	2	3	1	3	1

FIGURE 3 (continued)

Mussel Species	Collecting Sites[1] 48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
Actinonaias carinata	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-
Actinonaias pectorosa[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alasmidonta marginata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amblema costata	-	-	-	-	1	-	-	-	-	-	1	-	1	-	-
Anodonta grandis	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-
Anodonta suborbiculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conradilla caelata[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cumberlandia monodonta	-	-	-	-	-	-	-	-	-	-	-	6	2	-	-
Cyclonaias tuberculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyprogenia irrorata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dromus dromas[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elliptio crassidens	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Elliptio dilatatus	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Epioblasma brevidens[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma capsaeformis[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma triquetra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia barnesiana[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia cuneolus[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia edgariana[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia subrotunda	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Lampsilis fasciola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis orbiculata[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis ovata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lasmigona complanata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lasmigona costata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lastena lata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptodea fragilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lexingtonia dolabelloides[2]	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Ligumia recta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Medionidus conradicus[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plethobasus cyphyus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema cordatum	-	-	1	-	-	-	-	-	3	-	1	-	-	-	-
Pleurobema plenum[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema rubrum	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Pleurobema oviforme[2]	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-
Proptera alata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ptychobranchus fasciolaris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ptychobranchus subtentum[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula cylindrica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula metanevra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quardula pustulosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula sparsa[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strophitus rugosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Truncilla truncata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa nebulosa[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa perpurpurea[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa vanuxemi[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total number of species	0	0	1	0	1	1	1	1	1	1	4	1	4	1	0

FIGURE 3 (continued)

Mussel Species	Collecting Sites[1]														
	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
Actinonaias carinata	-	-	1	2	1	1	1	27	5	1	1	10	1	1	1
Actinonaias pectorosa[2]	-	-	1	1	-	-	1	2	1	-	-	1	-	-	-
Alasmidonta marginata	-	-	-	1	-	1	-	-	1	-	-	1	-	-	-
Amblema costata	-	-	-	-	-	-	-	1	1	-	1	-	1	1	1
Anodonta grandis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anodonta suborbiculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conradilla caelata[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cumberlandia monodonta	-	1	1	-	-	-	1	-	7	1	1	12	1	-	1
Cyclonaias tuberculata	-	-	-	-	1	1	1	5	1	1	1	-	-	1	1
Cyprogenia irrorata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Dromus dromas[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Elliptio crassidens	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-
Elliptio dilatatus	-	-	1	2	1	1	1	1	1	1	1	3	1	1	-
Epioblasma brevidens[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma capsaeformis[2]	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
Epioblasma triquetra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Fusconaia barnesiana[2]	-	-	-	-	1	1	1	1	-	-	-	-	-	-	1
Fusconaia cuneolus[2,3]	-	-	-	-	-	1	-	1	-	-	-	1	-	-	-
Fusconaia edgariana[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia subrotunda	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Lampsilis fasciola	-	-	-	1	-	1	1	1	1	-	-	1	-	-	-
Lampsilis orbiculata[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis ovata	-	-	1	-	1	-	-	-	1	-	-	2	-	-	-
Lasmigona complanata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lasmigona costata	-	-	-	1	-	1	1	5	6	1	1	7	1	-	-
Lastena lata	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-
Leptodea fragilis	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-
Lexingtonia dolabelloides[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ligumia recta	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-
Medionidus conradicus[2]	-	-	1	-	-	-	1	-	2	1	-	5	-	-	-
Plethobasus cyphyus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema cordatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema plenum[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema rubrum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema oviforme[2]	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Proptera alata	-	1	-	1	1	-	-	1	2	1	1	-	-	1	1
Ptychobranchus fasciolaris	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-
Ptychobranchus subtentum[2]	-	-	1	1	1	-	1	5	4	-	-	1	-	-	-
Quadrula cylindrica	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Quadrula metanevra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quardula pustulosa	-	-	-	-	1	-	-	1	1	-	-	-	-	1	1
Quadrula sparsa[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strophitus rugosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Truncilla truncata	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
Villosa nebulosa[2]	-	-	-	-	-	-	-	-	3	-	1	-	-	-	1
Villosa perpurpurea[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa vanuxemi[2]	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Total number of species	0	2	7	8	9	9	10	12	19	7	8	17	6	7	11

FIGURE 3 (continued)

Mussel Species	Collecting Sites[1]														
	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Actinonaias carinata	-	52	2	17	6	10	9	4	31	2	2	22	8	2	24
Actinonaias pectorosa[2]	-	6	1	2	-	1	1	3	9	-	-	9	-	-	10
Alasmidonta marginata	-	-	-	1	-	-	-	-	1	-	-	-	-	1	-
Amblema costata	-	1	-	-	-	-	-	-	1	2	-	-	1	-	-
Anodonta grandis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anodonta suborbiculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conradilla caelata[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cumberlandia monodonta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyclonaias tuberculata	-	1	-	4	2	1	3	6	4	13	1	5	1	-	-
Cyprogenia irrorata	-	-	-	8	-	1	-	-	3	7	1	9	-	3	-
Dromus dromas[2,3]	-	1	1	1	5	7	-	1	8	1	-	5	-	5	1
Elliptio crassidens	-	-	1	1	-	-	-	1	1	-	-	-	-	-	-
Elliptio dilatatus	-	-	-	-	-	-	1	-	1	1	1	1	-	1	-
Epioblasma brevidens[2]	-	-	1	2	1	1	-	-	1	-	-	2	-	-	-
Epioblasma capsaeformis[2]	-	-	1	3	-	2	-	-	3	-	1	16	1	4	2
Epioblasma triquetra	-	1	-	8	1	1	-	-	1	1	2	1	-	-	1
Fusconaia barnesiana[2]	-	1	-	1	-	1	-	-	12	1	-	3	-	1	-
Fusconaia cuneolus[2,3]	-	-	-	3	-	-	-	-	1	1	-	2	-	-	-
Fusconaia edgariana[2,3]	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Fusconaia subrotunda	-	3	-	-	-	1	-	-	-	-	-	-	1	-	6
Lampsilis fasciola	-	-	1	1	-	1	-	1	3	-	-	5	-	1	-
Lampsilis orbiculata[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis ovata	1	3	1	2	-	-	-	2	1	-	-	-	1	-	2
Lasmigona complanata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lasmigona costata	1	2	1	1	-	-	-	2	4	-	-	-	1	-	3
Lastena lata	-	1	-	1	1	1	-	-	16	-	1	11	-	11	1
Leptodea fragilis	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Lexingtonia dolabelloides[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ligumia recta	-	-	-	1	-	-	1	1	-	-	-	-	-	-	-
Medionidus conradicus[2]	-	1	-	3	-	-	1	-	5	-	-	19	-	-	2
Plethobasus cyphyus	-	-	-	-	-	-	-	-	2	1	-	2	1	-	-
Pleurobema cordatum	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-
Pleurobema plenum[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema rubrum	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Pleurobema oviforme[2]	-	-	-	1	-	-	-	-	1	-	-	-	-	-	1
Proptera alata	-	-	1	1	1	1	-	-	1	-	1	1	1	-	1
Ptychobranchus fasciolaris	-	-	-	1	-	1	-	-	-	1	1	2	-	-	1
Ptychobranchus subtentum[2]	-	2	1	2	1	1	1	-	15	-	-	13	1	7	-
Quadrula cylindrica	-	-	1	-	-	-	-	-	3	-	-	-	4	-	-
Quadrula metanevra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quardula pustulosa	-	1	-	7	-	1	-	-	6	20	7	4	-	1	-
Quadrula sparsa[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strophitus rugosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Truncilla truncata	-	-	1	8	1	1	-	-	2	2	-	7	-	-	-
Villosa nebulosa[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa perpurpurea[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa vanuxemi[2]	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-
Total number of species	3	14	14	25	9	17	7	9	29	14	10	21	11	11	14

FIGURE 3 (continued)

Mussel Species	Collecting Sites[1]														
	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107
Actinonaias carinata	25	6	8	20	7	4	4	320	13	80	1	28	4	10	496
Actinonaias pectorosa[2]	2	-	2	7	4	-	1	9	-	10	1	3	1	3	225
Alasmidonta marginata	-	-	-	-	1	-	1	-	6	-	1	-	1	1	1
Amblema costata	-	-	3	-	1	-	2	4	1	4	-	10	1	17	18
Anodonta grandis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anodonta suborbiculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conradilla caelata[2,3]	-	-	-	-	1	-	-	2	-	-	-	-	-	1	3
Cumberlandia monodonta	-	-	-	-	1	-	-	-	-	-	1	1	1	2	24
Cyclonaias tuberculata	2	4	-	-	4	-	1	72	2	4	1	6	1	7	31
Cyprogenia irrorata	1	1	-	1	1	3	4	62	1	-	-	-	-	6	8
Dromus dromas[2,3]	-	-	-	-	1	-	-	-	-	1	-	-	-	1	-
Elliptio crassidens	-	-	-	-	1	-	1	-	-	-	1	-	-	-	3
Elliptio dilatatus	2	-	2	-	4	-	-	-	-	1	-	-	-	4	46
Epioblasma brevidens[2]	1	-	-	-	1	-	2	20	-	1	-	-	-	-	3
Epioblasma capsaeformis[2]	-	2	-	1	11	-	-	1	-	2	1	1	1	4	12
Epioblasma triquetra	9	1	1	1	1	1	1	33	-	-	-	-	-	1	4
Fusconaia barnesiana[2]	3	1	1	-	4	1	3	16	-	1	1	2	1	17	32
Fusconaia cuneolus[2,3]	-	-	-	-	7	-	2	5	-	-	-	-	-	-	27
Fusconaia edgariana[2,3]	-	-	-	-	-	-	-	2	-	-	-	-	-	11	4
Fusconaia subrotunda	-	-	-	1	-	-	-	3	1	2	-	2	-	5	46
Lampsilis fasciola	2	-	-	-	2	1	2	6	-	-	1	-	2	-	17
Lampsilis orbiculata[3]	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Lampsilis ovata	3	2	-	1	1	-	-	10	-	4	1	2	1	2	15
Lasmigona complanata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lasmigona costata	3	4	1	1	1	1	-	8	1	5	1	4	1	3	23
Lastena lata	1	-	-	-	-	-	-	4	-	-	-	-	-	1	6
Leptodea fragilis	-	-	-	-	1	-	-	5	-	1	1	-	-	-	-
Lexingtonia dolabelloides[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ligumia recta	4	2	1	-	1	-	1	4	-	1	-	2	1	1	2
Medionidus conradicus[2]	-	-	-	5	2	-	1	-	-	-	1	1	-	4	88
Plethobasus cyphyus	2	-	1	2	1	1	1	25	-	1	-	1	1	1	2
Pleurobema cordatum	-	1	-	-	1	-	1	12	1	-	-	-	-	-	1
Pleurobema plenum[3]	-	-	-	-	2	-	1	5	-	-	-	-	-	-	-
Pleurobema rubrum	-	-	-	-	-	-	-	14	-	-	-	-	-	-	-
Pleurobema oviforme[2]	-	-	-	-	1	-	1	8	-	4	-	-	-	1	7
Proptera alata	2	1	-	-	1	-	1	32	3	4	1	6	1	4	2
Ptychobranchus fasciolaris	1	-	2	-	1	-	-	3	-	3	-	2	-	-	16
Ptychobranchus subtentum[2]	1	1	6	2	3	1	3	1	-	3	1	-	-	3	125
Quadrula cylindrica	-	-	-	-	1	-	-	1	-	-	1	-	1	24	20
Quadrula metanevra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quardula pustulosa	1	4	1	-	2	-	5	219	-	-	1	1	1	5	8
Quadrula sparsa[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strophitus rugosus	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-
Truncilla truncata	1	1	-	-	1	-	2	109	-	-	-	-	-	10	7
Villosa nebulosa[2]	-	-	-	-	2	-	-	-	-	-	-	-	-	-	11
Villosa perpurpurea[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa vanuxemi[2]	-	1	-	-	1	-	-	-	-	-	-	-	-	1	1
Total number of species	19	15	12	11	34	8	22	32	9	19	17	16	16	28	34

FIGURE 3 (continued)

Mussel Species	Collecting Sites[1]														
	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122
Actinonaias carinata	6	6	28	16	2	4	16	1	10	1	13	23	1	1	1
Actinonaias pectorosa[2]	4	1	7	9	-	7	9	-	10	1	3	12	-	1	1
Alasmidonta marginata	3	-	1	-	-	-	-	-	-	1	-	-	1	-	1
Amblema costata	-	3	3	-	-	-	1	1	6	1	2	1	1	-	-
Anodonta grandis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anodonta suborbiculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conradilla caelata[2,3]	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Cumberlandia monodonta	-	3	-	-	-	-	7	1	-	1	7	1	-	-	-
Cyclonaias tuberculata	-	4	1	-	-	2	4	1	5	1	2	3	1	1	-
Cyprogenia irrorata	-	-	1	-	-	-	-	-	1	1	-	1	1	1	1
Dromus dromas[2,3]	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elliptio crassidens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elliptio dilatatus	2	-	2	-	-	6	4	1	4	1	10	2	1	1	-
Epioblasma brevidens[2]	1	-	1	-	-	-	-	1	-	1	-	2	1	1	1
Epioblasma capsaeformis[2]	5	2	4	4	-	2	-	-	-	1	-	9	1	1	1
Epioblasma triquetra	-	-	1	-	-	-	-	-	-	1	-	2	1	-	-
Fusconaia barnesiana[2]	1	-	6	1	-	2	-	1	-	1	1	1	-	1	1
Fusconaia cuneolus[2,3]	21	-	-	-	-	2	-	1	4	1	2	1	-	1	1
Fusconaia edgariana[2,3]	-	-	-	-	-	-	-	1	1	1	1	1	-	1	-
Fusconaia subrotunda	-	3	-	1	-	4	1	1	7	1	3	2	1	1	-
Lampsilis fasciola	1	-	2	-	-	1	-	1	-	1	-	1	1	1	-
Lampsilis orbiculata[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis ovata	-	6	-	-	-	1	-	-	-	1	-	1	-	-	-
Lasmigona complanata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lasmigona costata	-	-	7	14	-	10	13	1	10	1	5	5	1	1	-
Lastena lata	-	-	1	-	-	-	-	-	-	1	1	1	1	-	-
Leptodea fragilis	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-
Lexingtonia dolabelloides[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ligumia recta	-	1	-	-	-	-	-	-	-	1	-	1	-	-	-
Medionidus conradicus[2]	5	-	4	7	-	3	1	1	-	1	3	11	-	1	1
Plethobasus cyphyus	-	-	-	-	-	-	-	-	-	1	-	1	-	-	1
Pleurobema cordatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema plenum[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema rubrum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema oviforme[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Proptera alata	-	9	2	3	1	-	2	1	3	1	-	-	-	-	-
Ptychobranchus fasciolaris	-	-	2	-	-	2	-	1	7	1	4	2	1	1	-
Ptychobranchus subtentum[2]	17	1	14	15	-	14	10	1	1	1	1	9	1	1	1
Quadrula cylindrica	-	2	-	-	-	1	-	-	-	1	-	2	1	1	-
Quadrula metanevra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quardula pustulosa	-	-	-	-	-	-	1	1	-	1	-	-	-	-	-
Quadrula sparsa[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strophitus rugosus	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Truncilla truncata	-	2	-	1	-	-	-	1	1	1	-	2	-	-	1
Villosa nebulosa[2]	8	-	-	1	-	-	-	1	2	1	-	-	-	1	1
Villosa perpurpurea[2]	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Villosa vanuxemi[2]	-	-	1	-	-	-	1	1	-	1	-	-	-	-	1
Total number of species	13	13	19	11	2	15	13	21	16	31	15	27	16	18	14

FIGURE 3 (continued)

Mussel Species	Collecting Sites[1]														
	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137
Actinonaias carinata	1	18	1	-	1	1	26	22	30	99	75	15	15	219	126
Actinonaias pectorosa[2]	1	21	1	-	1	-	4	4	32	85	51	4	41	183	113
Alasmidonta marginata	-	-	-	-	-	-	1	1	-	-	-	-	-	4	1
Amblema costata	1	-	1	-	1	1	7	4	17	8	-	-	2	68	15
Anodonta grandis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anodonta suborbiculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conradilla caelata[2,3]	-	-	-	-	-	-	1	-	-	1	-	-	-	5	2
Cumberlandia monodonta	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Cyclonaias tuberculata	1	2	1	-	1	-	4	3	3	5	2	1	5	30	15
Cyprogenia irrorata	-	1	-	-	-	-	2	-	-	-	-	-	-	3	-
Dromus dromas[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elliptio crassidens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elliptio dilatatus	1	1	-	-	-	1	11	4	7	26	2	-	4	132	27
Epioblasma brevidens[2]	1	-	-	1	1	1	1	2	-	1	-	-	1	8	-
Epioblasma capsaeformis[2]	1	2	1	2	-	-	1	5	-	1	-	-	-	39	-
Epioblasma triquetra	-	-	-	-	-	-	1	1	-	-	1	-	-	3	-
Fusconaia barnesiana[2]	-	-	-	-	1	1	4	4	1	-	-	-	-	22	3
Fusconaia cuneolus[2,3]	1	-	1	-	-	-	2	2	4	3	-	-	-	78	8
Fusconaia edgariana[2,3]	1	-	-	-	1	-	1	1	-	-	-	-	-	16	-
Fusconaia subrotunda	1	1	1	-	1	-	11	11	25	81	19	2	14	77	151
Lampsilis fasciola	1	-	1	-	-	-	-	1	2	1	-	-	-	9	1
Lampsilis orbiculata[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis ovata	1	3	1	-	-	-	1	1	1	6	1	-	1	17	2
Lasmigona complanata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lasmigona costata	1	12	1	-	1	-	12	4	3	4	-	1	2	82	17
Lastena lata	1	-	-	-	-	-	3	-	-	-	-	-	-	-	-
Leptodea fragilis	1	-	-	-	-	-	1	1	-	-	-	-	-	6	-
Lexingtonia dolabelloides[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ligumia recta	1	-	-	-	-	-	-	-	-	2	-	-	-	6	-
Medionidus conradicus[2]	1	-	-	-	-	1	-	2	1	1	-	-	-	5	1
Plethobasus cyphyus	1	-	-	-	1	-	-	-	2	2	-	-	-	2	1
Pleurobema cordatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Pleurobema plenum[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema rubrum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Pleurobema oviforme[2]	-	-	-	-	-	-	1	-	-	-	-	1	-	4	-
Proptera alata	1	-	-	-	1	-	1	-	-	2	-	-	-	14	1
Ptychobranchus fasciolaris	1	1	1	-	1	-	2	1	1	4	1	-	-	17	8
Ptychobranchus subtentum[2]	1	5	1	-	1	1	2	1	1	6	3	-	2	25	8
Quadrula cylindrica	1	-	-	-	-	1	-	-	1	6	-	1	-	70	3
Quadrula metanevra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula pustulosa	-	-	-	-	-	-	1	-	-	17	-	-	-	2	-
Quadrula sparsa[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strophitus rugosus	1	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Truncilla truncata	-	-	-	-	-	-	1	3	-	-	-	-	-	7	-
Villosa nebulosa[2]	1	-	-	1	1	1	1	-	-	2	-	-	-	17	-
Villosa perpurpurea[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
Villosa vanuxemi[2]	1	-	-	-	-	-	1	-	-	-	-	-	-	7	-
Total number of species	25	11	12	3	14	9	27	21	16	23	9	7	10	33	21

FIGURE 3 (continued)

Mussel Species	Collecting Sites[1]														
	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152
Actinonaias carinata	115	6	52	28	89	175	188	112	150	16	23	3	-	-	-
Actinonaias pectorosa[2]	93	4	25	3	129	173	63	82	235	7	78	82	-	-	-
Alasmidonta marginata	2	-	-	-	1	-	-	1	2	1	1	1	-	-	-
Amblema costata	61	1	14	12	14	16	31	14	65	15	1	-	-	-	-
Anodonta grandis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anodonta suborbiculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conradilla caelata[2,3]	3	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Cumberlandia monodonta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyclonaias tuberculata	17	-	10	-	67	15	8	13	64	6	4	-	-	-	-
Cyprogenia irrorata	1	-	-	-	-	-	-	-	2	1	-	-	-	-	-
Dromus dromas[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elliptio crassidens	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Elliptio dilatatus	70	1	-	5	6	14	16	17	17	5	2	-	-	-	-
Epioblasma brevidens[2]	1	-	-	-	-	-	-	1	1	-	-	-	-	-	-
Epioblasma capsaeformis[2]	3	-	-	-	1	-	-	3	2	1	-	-	-	-	-
Epioblasma triquetra	-	-	1	-	-	-	-	-	2	-	-	-	-	-	-
Fusconaia barnesiana[2]	-	1	-	-	5	-	-	1	2	-	-	1	-	-	-
Fusconaia cuneolus[2,3]	55	-	3	-	21	3	3	6	31	7	31	1	-	-	-
Fusconaia edgariana[2,3]	-	-	-	1	1	-	-	-	3	-	-	-	-	-	-
Fusconaia subrotunda	33	-	56	-	18	96	37	188	135	6	3	1	-	-	-
Lampsilis fasciola	8	-	4	-	3	1	1	7	4	3	14	5	-	-	-
Lampsilis orbiculata[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis ovata	7	1	-	1	6	7	8	23	15	9	23	7	-	-	-
Lasmigona complanata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lasmigona costata	54	4	35	22	114	23	18	18	48	55	33	6	-	-	-
Lastena lata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptodea fragilis	1	-	-	-	-	1	-	-	1	-	1	-	-	-	-
Lexingtonia dolabelloides[2]	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ligumia recta	4	2	-	1	-	1	-	1	2	-	-	-	-	-	-
Medionidus conradicus[2]	1	-	-	-	-	-	-	1	1	1	-	-	-	-	-
Plethobasus cyphyus	1	-	-	-	-	-	1	1	-	-	-	-	-	-	-
Pleurobema cordatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema plenum[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema rubrum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema oviforme[2]	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Proptera alata	5	2	5	4	3	4	3	11	9	5	7	2	-	-	-
Ptychobranchus fasciolaris	35	-	7	1	2	6	7	6	23	2	5	2	-	-	-
Ptychobranchus subtentum[2]	10	1	-	-	-	-	-	-	1	-	-	-	-	-	-
Quadrula cylindrica	13	1	8	1	1	4	3	-	15	2	-	-	-	-	-
Quadrula metanevra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quardula pustulosa	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Quadrula sparsa[2,3]	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-
Strophitus rugosus	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Truncilla truncata	1	-	-	-	1	-	2	-	6	-	-	-	-	-	-
Villosa nebulosa[2]	3	-	-	-	-	-	-	1	1	3	1	-	-	-	-
Villosa perpurpurea[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa vanuxemi[2]	2	1	-	-	-	-	-	-	1	-	-	-	-	-	-
Total number of species	28	13	12	11	18	15	16	22	30	18	15	11	0	0	0

FIGURE 3 (continued)

Mussel Species	Collecting Sites[1]														
	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167
Actinonaias carinata	-	16	-	1	2	-	-	-	-	8	-	1	8	17	-
Actinonaias pectorosa[2]	-	33	-	3	5	-	-	2	-	17	-	-	3	23	-
Alasmidonta marginata	-	-	-	-	-	-	-	-	-	-	-	1	2	1	-
Amblema costata	-	1	1	1	-	-	1	1	1	2	-	1	9	14	1
Anodonta grandis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anodonta suborbiculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conradilla caelata[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cumberlandia monodonta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyclonaias tuberculata	-	2	2	-	1	-	-	-	1	2	-	-	3	6	-
Cyprogenia irrorata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dromus dromas[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elliptio crassidens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elliptio dilatatus	-	-	-	2	-	-	-	-	-	-	-	2	-	-	-
Epioblasma brevidens[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma capsaeformis[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma triquetra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia barnesiana[2]	-	-	-	-	-	-	-	-	-	3	-	1	8	1	-
Fusconaia cuneolus[2,3]	-	2	-	2	3	-	-	-	1	-	-	1	4	2	-
Fusconaia edgariana[2,3]	-	-	-	1	-	-	-	-	-	-	-	2	-	1	-
Fusconaia subrotunda	-	2	1	2	-	-	-	1	-	-	-	-	1	6	-
Lampsilis fasciola	-	2	-	4	11	-	-	1	1	2	-	3	-	2	-
Lampsilis orbiculata[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis ovata	-	8	1	2	1	-	-	-	2	2	1	-	1	4	-
Lasmigona complanata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lasmigona costata	-	8	8	1	3	1	-	2	4	8	-	-	12	17	-
Lastena lata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptodea fragilis	-	-	2	-	-	-	-	-	-	1	-	-	3	5	1
Lexingtonia dolabelloides[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ligumia recta	-	1	-	-	-	-	-	-	-	-	-	1	1	-	-
Medionidus conradicus[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plethobasus cyphyus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema cordatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema plenum[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema rubrum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema oviforme[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Proptera alata	-	-	1	-	1	-	-	3	-	5	-	-	6	12	-
Ptychobranchus fasciolaris	-	-	-	-	1	-	-	-	-	1	-	-	3	3	-
Ptychobranchus subtentum[2]	-	-	-	2	-	-	-	-	-	-	-	-	2	1	-
Quadrula cylindrica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula metanevra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quardula pustulosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula sparsa[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strophitus rugosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Truncilla truncata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa nebulosa[2]	-	-	-	7	8	-	-	-	-	-	-	1	4	-	-
Villosa perpurpurea[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa vanuxemi[2]	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Total number of species	0	10	7	12	10	1	1	6	6	11	1	10	17	16	2

FIGURE 3 (continued)

Mussel Species	Collecting Sites[1]														
	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182
Actinonaias carinata	1	18	24	14	-	-	-	-	-	3	-	2	-	1	5
Actinonaias pectorosa[2]	-	43	78	12	-	-	-	-	-	16	1	9	1	37	13
Alasmidonta marginata	-	1	6	-	1	-	-	-	-	3	1	-	-	1	-
Amblema costata	-	29	162	4	1	-	-	-	-	-	-	-	-	2	4
Anodonta grandis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anodonta suborbiculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conradilla caelata[2,3]	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Cumberlandia monodonta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyclonaias tuberculata	-	3	8	3	-	-	-	-	-	-	-	-	-	-	-
Cyprogenia irrorata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dromus dromas[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elliptio crassidens	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Elliptio dilatatus	-	33	96	-	-	-	-	-	-	1	-	1	-	3	14
Epioblasma brevidens[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma capsaeformis[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma triquetra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia barnesiana[2]	-	73	65	-	-	-	-	-	-	2	-	-	1	-	4
Fusconaia cuneolus[2,3]	-	73	188	-	-	-	-	-	-	3	-	-	-	4	3
Fusconaia edgariana[2,3]	-	2	37	-	-	-	-	-	-	1	-	2	-	2	1
Fusconaia subrotunda	-	-	6	6	-	-	-	-	-	4	-	1	-	5	1
Lampsilis fasciola	-	10	54	-	-	-	-	-	-	-	1	2	-	1	-
Lampsilis orbiculata[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis ovata	-	7	45	1	-	-	-	-	-	-	-	1	-	2	-
Lasmigona complanata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lasmigona costata	-	16	53	3	-	-	-	-	-	18	-	14	-	70	44
Lastena lata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptodea fragilis	-	7	31	-	-	-	-	-	-	-	1	-	-	-	-
Lexingtonia dolabelloides[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ligumia recta	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-
Medionidus conradicus[2]	-	-	1	-	-	-	-	-	-	1	-	5	-	3	24
Plethobasus cyphyus	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Pleurobema cordatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema plenum[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema rubrum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema oviforme[2]	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-
Proptera alata	-	2	64	3	-	-	2	-	1	-	-	-	-	-	-
Ptychobranchus fasciolaris	-	1	3	1	-	-	-	-	-	1	-	1	-	2	1
Ptychobranchus subtentum[2]	-	-	-	1	-	-	-	-	-	-	-	1	-	2	1
Quadrula cylindrica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula metanevra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quardula pustulosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula sparsa[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strophitus rugosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Truncilla truncata	-	1	1	-	-	-	-	-	-	-	-	-	-	1	-
Villosa nebulosa[2]	-	62	653	-	-	-	-	-	-	3	-	-	-	2	-
Villosa perpurpurea[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa vanuxemi[2]	-	4	161	-	-	-	-	-	-	-	-	-	-	-	1
Total number of species	1	19	22	10	2	1	1	0	1	12	4	12	2	17	13

FIGURE 3 (continued)

Mussel Species	Collecting Sites[1] 183	184	185	186	187	188	189	190	191	192	193	194	195	196	197
Actinonaias carinata	6	2	-	-	-	1	-	-	-	-	-	-	-	-	-
Actinonaias pectorosa[2]	96	13	4	10	28	120	21	49	60	2	2	2	109	85	4
Alasmidonta marginata	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-
Amblema costata	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anodonta grandis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anodonta suborbiculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conradilla caelata[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cumberlandia monodonta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyclonaias tuberculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyprogenia irrorata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dromus dromas[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elliptio crassidens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elliptio dilatatus	5	2	-	1	4	2	1	7	1	1	-	-	5	4	-
Epioblasma brevidens[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma capsaeformis[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma triquetra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia barnesiana[2]	1	-	-	-	-	-	1	1	3	-	-	-	1	-	-
Fusconaia cuneolus[2,3]	1	-	-	-	1	-	1	-	-	-	-	-	-	-	-
Fusconaia edgariana[2,3]	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Fusconaia subrotunda	12	2	-	-	-	2	-	7	-	-	-	-	3	-	-
Lampsilis fasciola	2	2	1	1	1	2	4	2	-	-	1	-	3	1	2
Lampsilis orbiculata[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis ovata	6	-	-	-	1	3	-	1	-	-	-	-	-	-	-
Lasmigona complanata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lasmigona costata	77	45	6	8	19	62	12	12	3	1	-	-	9	12	1
Lastena lata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptodea fragilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lexingtonia dolabelloides[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ligumia recta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Medionidus conradicus[2]	8	3	2	-	8	1	3	1	3	-	1	1	4	3	-
Plethobasus cyphyus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema cordatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema plenum[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema rubrum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobema oviforme[2]	3	-	-	1	-	1	3	4	-	-	1	-	5	9	-
Proptera alata	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ptychobranchus fasciolaris	12	2	-	-	1	3	1	3	1	-	-	-	12	2	2
Ptychobranchus subtentum[2]	5	-	-	2	3	6	3	2	2	-	-	-	2	9	2
Quadrula cylindrica	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula metanevra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quardula pustulosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula sparsa[2,3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strophitus rugosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Truncilla truncata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa nebulosa[2]	1	1	1	2	12	3	5	4	1	-	-	-	1	11	1
Villosa perpurpurea[2]	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-
Villosa vanuxemi[2]	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Total number of species	18	9	7	9	10	14	11	12	8	3	4	2	11	9	6

FIGURE 3 (continued)

Mussel Species	Collecting Sites[1] 198	199	200	201	202	203	204
Actinonaias carinata	-	1	-	-	1	-	-
Actinonaias pectorosa[2]	12	29	10	2	1	-	-
Alasmidonta marginata	-	-	-	-	-	-	-
Amblema costata	-	-	-	-	-	-	-
Anodonta grandis	-	-	-	-	-	-	-
Anodonta suborbiculata	-	-	-	-	-	-	-
Conradilla caelata[2,3]	-	-	-	-	-	-	-
Cumberlandia monodonta	-	-	-	-	-	-	-
Cyclonaias tuberculata	-	-	-	-	-	-	-
Cyprogenia irrorata	-	-	-	-	-	-	-
Dromus dromas[2,3]	-	-	-	-	-	-	-
Elliptio crassidens	-	-	-	-	-	-	-
Elliptio dilatatus	1	1	1	-	-	-	-
Epioblasma brevidens[2]	-	-	-	-	-	-	-
Epioblasma capsaeformis[2]	-	-	-	-	-	-	-
Epioblasma triquetra	-	-	-	-	-	-	-
Fusconaia barnesiana[2]	-	-	2	-	7	-	-
Fusconaia cuneolus[2,3]	-	-	3	-	3	1	-
Fusconaia edgariana[2,3]	-	-	-	-	-	-	-
Fusconaia subrotunda	-	4	-	2	13	-	-
Lampsilis fasciola	-	2	-	-	1	-	-
Lampsilis orbiculata[3]	-	-	-	-	-	-	-
Lampsilis ovata	1	1	-	-	-	-	-
Lasmigona complanata	-	-	-	-	-	-	-
Lasmigona costata	2	16	1	1	-	-	-
Lastena lata	-	-	-	-	-	-	-
Leptodea fragilis	-	-	-	-	-	-	-
Lexingtonia dolabelloides[2]	-	-	-	-	-	-	-
Ligumia recta	-	-	-	-	-	-	-
Medionidus conradicus[2]	3	-	3	-	-	-	-
Plethobasus cyphyus	-	-	-	-	-	-	-
Pleurobema cordatum	-	-	-	-	-	-	-
Pleurobema plenum[3]	-	-	-	-	-	-	-
Pleurobema rubrum	-	-	-	-	-	-	-
Pleurobema oviforme[2]	2	-	3	-	1	-	-
Proptera alata	-	-	-	-	-	-	-
Ptychobranchus fasciolaris	6	2	5	1	1	-	-
Ptychobranchus subtentum[2]	1	-	1	1	2	-	-
Quadrula cylindrica	-	-	-	-	-	-	-
Quadrula metanevra	-	-	-	-	-	-	-
Quardula pustulosa	-	-	-	-	-	-	-
Quadrula sparsa[2,3]	-	-	-	-	-	-	-
Strophitus rugosus	-	-	-	-	-	-	-
Truncilla truncata	-	-	-	-	-	-	-
Villosa nebulosa[2]	1	6	10	-	8	5	-
Villosa perpurpurea[2]	-	-	-	-	-	-	-
Villosa vanuxemi[2]	-	1	-	-	-	-	-
Total number of species	9	10	10	5	10	2	0

FIGURE 3 (continued)

TABLE 3. Longitudinal Distribution of Freshwater Mussel Species in 32-km (20-mile) Reaches of the Clinch River with Historical Records Reported by Ortmann (O) (1918) Including Recent Collections from 1978 to 1983 by Ahlstedt (A)

	Collection Sites (kilometer/mile reach)																			
	Lower Clinch							Upper Clinch												
km	16	48	80	113	145	177	209	241	273	306	338	370	402	434	466	499	531	563
Mussel Species	Mi	10	30	50	70	90	110	130	150	170	190	210	230	250	270	290	310	330	350
Actinonaias carinata		O	-	O,A	O,A	O	-	O	A	A	O,A	O,A	A	O,A	A	A	-	A	-
Actinonaias pectorosa		-	-	-	-	-	-	O	A	A	O,A	O,A	A	O,A	O,A	A	A	A	-
Alasmidonta marginata		O	-	O	O	-	-	O	A	A	A	O,A	A	O,A	O,A	-	O	-	-
Alasmidonta viridis		-	-	-	-	-	-	-	-	-	-	O	-	O	O	-	O	O	-
Amblema costata		O,A	-	O,A	O,A	-	-	O	A	A	A	O,A	O,A	O,A	O,A	-	-	-	-
Anodonta grandis		A	A	A	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anodonta suborbiculata		A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conradilla caelata		-	-	-	O	-	-	-	-	-	A	A	A	O,A	-	-	-	-	-
Cumberlandia monodonta		-	-	O,A	O,A	O	O	O	A	A	A	A	-	-	-	-	-	-	-
Cyclonaias tuberculata		A	-	O,A	O	O	-	O	A	A	O,A	O,A	A	A	-	-	-	-	-
Cyprogenia irrorata		-	-	O	O	O	-	O	-	A	A	A	A	-	-	-	-	-	-
Dromus dromas		-	-	O	O	O	-	O	-	A	A	-	-	-	-	-	-	-	-
Elliptio crassidens		O,A	-	O,A	O,A	-	-	O	A	A	A	O	A	A	-	-	-	-	-
Elliptio dilatatus		O	-	O,A	O,A	O	-	O	A	O,A	O,A	O,A	A	O,A	O,A	A	O	O	-
Epioblasma arcaeformis		-	-	-	-	-	-	O	-	-	-	-	-	-	-	-	-	-	-
Epioblasma brevidens		-	-	O	-	-	-	O	-	A	A	O,A	A	-	-	-	-	-	-
Epioblasma capsaeformis		-	-	O	O	-	-	O	-	A	O,A	O,A	A	O	O	-	O	O	-
Epioblasma haysiana		-	-	O	O	-	-	O	-	-	-	-	-	-	-	-	O	-	-
Epioblasma lenior		-	-	-	-	-	-	-	-	-	-	O	-	-	-	-	-	-	-
Epioblasma propinqua		O	-	O	O	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma stewardsoni		-	-	-	O	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma torulosa gubernaculum		-	-	-	-	-	O	O	-	-	O	O	O	-	-	-	-	-	-
Epioblasma triquetra		-	-	O	O	-	-	O	-	A	O,A	O,A	A	-	-	-	-	-	-
Fusconaia barnesiana		O	-	O	O	O	-	O	A	A	O,A	O,A	A	O,A	A	A	O	O,A	O
Fusconaia cuneolus		-	-	O	O	-	-	O	A	A	O,A	O,A	A	A	A	A	-	A	-
Fusconaia edgariana		O	-	O	-	-	-	O	-	O,A	A	O,A	A	O,A	O,A	-	-	-	-
Fusconaia subrotunda		O	-	O,A	O,A	O	-	O	-	O,A	O,A	O,A	A	O,A	O,A	A	O,A	O,A	-
Lampsilis fasciola		O	-	O	O	-	-	O	A	A	A	O,A	A	O,A	O,A	A	O	O,A	-
Lampsilis orbiculata		A	-	O	O	-	-	-	-	-	A	-	-	-	-	-	-	-	-
Lampsilis ovata		-	-	O	O	-	-	O	A	A	A	O,A	A	O,A	O,A	A	O	O	-
Lasmigona complanata		A	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lasmigona costata		-	-	O	O	-	-	O	A	A	O,A	O,A	A	O,A	O,A	A	O,A	O	-
Lasmigona holstonia		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	O	O	O
Lastena lata		-	-	O	O	-	-	O	-	A	A	O,A	-	O	O	-	-	-	-
Leptodea fragilis		-	-	O	-	-	-	O	A	A	A	A	A	A	A	-	-	-	-
Leptodea leptodon		-	-	O	-	-	-	O	-	-	-	-	-	-	-	-	-	-	-
Lexingtonia dolabelloides		-	-	O	O,A	O	-	O	-	-	-	O	A	O	O	-	O	O	-
Ligumia recta		-	-	O,A	O	O	-	O	A	A	A	O,A	A	O,A	-	-	-	-	-
Medionidus conradicus		-	-	-	-	-	-	O	A	A	O,A	O,A	A	O,A	O,A	A	O	O	-
Obliquaria reflexa		O	-	O	O	O	-	-	-	-	-	-	-	-	-	-	-	-	-
Obovaria retusa		-	-	-	O	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plagiola lineolata		O	-	-	O	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plethobasus cooperianus		O	-	O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plethobasus cyphyus		-	-	O	O	O	-	O	-	O,A	A	O,A	A	A	-	-	-	-	-
Pleurobema coccineum		-	-	O	-	-	-	O	-	-	-	O	-	-	O	-	-	-	-
Pleurobema cordatum		A	-	O,A	O,A	O	-	O	-	A	A	-	A	-	-	-	-	-	-
Pleurobema oviforme		-	-	O	O,A	-	-	-	A	A	O,A	O,A	A	O	O,A	A	O	O,A	-
Pleurobema plenum		-	-	O	O	-	-	-	-	-	A	-	-	-	-	-	-	-	-
Pleurobema rubrum		O,A	-	O,A	O,A	O	-	O	-	A	A	-	A	-	-	-	-	-	-
Proptera alata		A	-	O	O	-	-	O	A	A	A	O,A	A	A	A	-	-	-	-
Ptychobranchus fasciolaris		-	-	O,A	O	O	-	O	A	A	A	O,A	A	O,A	O,A	A	A	A	-
Ptychobranchus subtentum		-	-	-	O	-	-	O	A	O,A	O,A	O,A	A	O,A	O,A	A	O,A	O,A	-
Quadrula cylindrica		-	-	O	O	O	-	O	A	A	A	O,A	A	O	O,A	-	O	O	-
Quadrula intermedia		-	-	-	-	-	-	-	-	-	-	O	-	-	O	-	-	-	-
Quadrula metanevra		A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quardula pustulosa		O,A	A	O,A	O	-	-	-	A	A	A	A	A	-	-	-	-	-	-
Quadrula sparsa		-	-	-	-	-	-	-	-	-	-	-	A	-	-	-	-	-	-
Strophitus rugosus		-	-	O	O	-	-	O	-	-	A	A	A	O	O	-	O	O	-
Toxolasma lividis		-	-	-	-	-	-	-	-	-	-	O	-	-	-	-	-	-	-
Truncilla truncata		-	-	O	O	-	-	O	-	A	A	A	A	A	A	-	-	-	-
Villosa fabalis		-	-	-	-	-	-	O	-	-	-	O	-	O	O	-	-	-	-
Villosa nebulosa		-	-	O	-	-	-	O	A	A	A	O,A	A	O,A	O,A	A	O	O,A	-
Villosa trabalis		-	-	-	-	-	-	-	-	-	-	O	-	-	-	-	-	-	-
Villosa vanuxemi		O	-	-	O	-	-	O	-	A	A	O,A	A	A	A	A	-	-	-
Villosa perpurpurea		-	-	-	-	-	-	-	-	-	-	O,A	A	O	O,A	-	O	O	-

sites 42 (12 species), 1 (6 species), and 4 (5 species). The low number of species collected from the lower Clinch probably reflects the impact caused by impoundment and stream channelization. Stream channelization is the deepening of the river channel by dredging for navigation and barge traffic. Numerous dead specimens were found imbedded in the substrate only in areas that had not been channelized and, with few exceptions, most live mussels were found along the backside of islands or in the overbanks of the channelized stream bed.

Quadrula pustulosa, Amblema costata, and Anodonta grandis were the most common species found in the lower Clinch with Q. pustulosa being the most numerous of the three. An unusually large number of species were found at site 42; 12 species were encountered and six of these occur nowhere else in the lower Clinch. Most of the 20 species found in the lower Clinch were old, eroded individuals, barely surviving; however, at least 4 species (Q. pustulosa, A. costata, A. grandis, and C. tuberculata) were reproducing and are often common components of impoundments.

Three species (Anodonta grandis, A. suborbiculata, and Lasmigona complanata) were found to occur only in the lower Clinch. These species are typical of post-impoundment situations; they have probably invaded the lower Clinch from populations in the upper Tennessee River. All three species were first reported from the lower Clinch in the early 1970's (Bates 1975; Bates and Dennis 1978).

Lampsilis orbiculata, a federally listed endangered species, was found at one site (site 27) in the lower Clinch below Melton Hill dam. Lampsilis orbiculata is extremely rare in the Clinch but appears to be doing fairly well in larger river impoundments with flow-through, river-lake conditions (Ahlstedt 1983h).

Upper Clinch

Forty-three species of freshwater mussels including 16 Cumberlandian forms are reported from 141 collecting sites in the upper Clinch River (Table 2, page 20; Figures 3, page 13, and 3) Five of the 16 Cumberlandian species (Conradilla caelata, Dromus dromas, Fusconaia cuneolus, Fusconaia edgariana, and Quadrula sparsa) are federally listed endangered species. Two additional endangered species (Lampsilis orbiculata and Pleurobema plenum) are also reported from the upper Clinch (Figure 3, page 27).

Ortmann (1918) reported 42 species of freshwater mussels from 14 sites in this reach of the Clinch and included 10 species not present during this study (Table 3). Those 10 species reported by Ortmann are, with few exceptions, now believed extirpated from the Clinch or considered extinct. Eleven additional species not reported by Ortmann from the upper Clinch were found during this study (Figure 3, page 27). These 11 species, with the exception of Quadrula sparsa, were reported by Ortmann only from the lower (now impounded) portion of the Clinch.

Mussels were both diverse and abundant throughout the upper Clinch. At least 30 collecting sites contained 18 or more species

of freshwater mussels. A noted decline or total absence of mussels were found primarily in the headwaters of the Clinch above site 150. Nineteen sites above site 150 had fewer than three species of mussels (Figure 3, page 27). This reach of the Clinch contains numerous alternating bedrock shelves and boulder substrate. Freshwater mussels were noticeably absent in areas with abrupt changes in stream gradient. Habitats essential for the colonization of freshwater mussels were practically non-existent at some of these sites. However, mussels were generally present but somewhat localized in pockets at sites containing rubble, gravel, and sand substrates.

Mussels were noticeably absent in a 14-km reach of the Clinch between sites 172 and 176. This river section was impacted by 198 million m^3 of caustic alkaline slurry (pH=12) in June 1967 when a fly ash spill from Appalachian Power Company's steam-electric generating plant at Carbo, Virginia, killed fish for 105-km downstream and eliminated the mussel fauna for at least 28-km below Carbo (Cairns et al. 1971). In June 1970, a sulphuric acid spill from the same generating plant impacted this same river reach for 24-km downstream to St. Paul and killed most mollusks for 18-km (Cairns et al. 1971). Between sites 172 and 176, the mussel fauna was devastated by these toxic spills. Only 6 live mussels representing 4 species were found in this reach of the Clinch; however, 12 mussel species were reported immediately above the steam plant at site 177 and gradual faunal recovery was apparently occurring downstream from

the steam plant at site 171. Freshwater mussels have probably been unable to recolonize this reach of the Clinch because of continued discharges of effluents from the steam plant and silt and coal fines from Dump's Creek and Lick Creek.

The largest concentration of mussel species found in the Clinch occurs between sites 86 and 146 (Figure 3, page 27; Figure 2, page 13). Over 27 species of mussels were reported from 11 sites in this reach. Thirty-four species were found at sites 97 and 107, and 33 occurred at site 136. Large concentrations of mussels were reported from a series of islands and island by-passes at Pendleton Island between sites 136 and 138. A total of 36 species have been identified from these 3 sites. This reach of the Clinch between sites 86 and 146 contains alternating bedrock shelves interspersed by long pools and numerous islands and riffles. Sites below site 86 were also found to contain a large species diversity and an abundance of individuals, especially at sites 71 and 81 where 19 and 25 species were reported. This reach of the Clinch has deep pools containing large populations of Amblema costata, Actinonaias carinata, Actinonaias pectorosa, and Proptera alata. Beginning below site 67, mussels gradually became sparse, primarily because of less suitable habitat, numerous bedrock shelves, and the effects of impoundment from Norris Reservoir.

Distribution of Mussels

Since the mid-1970's, several papers by Bates (1975), TVA (1976, 1979, 1983), Harker et al. (1980), Parmalee et al. (1980, 1982),

Pardue (1981), and Sickel (1982) have updated species distributions in the Tennessee and Cumberland rivers. Additional studies included in this report by Bates and Dennis (1978), Ahlstedt and Brown (1979), Ahlstedt (1980, 1981, 1983i), Neves et al. (1980), TVA (1980b, 1980c, 1982), Dennis (1981), Hatcher and Ahlstedt (1982), Schmidt (1982), and Starnes and Bogan (1982) also provided excellent current mussel distributions for many of the larger tributary streams of the Tennessee and Cumberland river systems. Results of these studies have been incorporated into the following comments concerning current distribution and abundance in the Tennessee and Cumberland drainages.

In general, most mussel species found in the Clinch River occurred in a variety of habitats with no apparent preferences. Only those species with noticeable habitat preference or unusual observations and comments were included in this section.

Cumberlandia monodonta is a relatively rare species in the upper Clinch in Tennessee and Virginia, and the lower Clinch. It was reported from 22 sites between sites 64 and 132 in the upper Clinch and at 4 sites (sites 39, 42, 59, and 60) in the lower impounded stretches (Figure 3, page 27; Figures 1 and 2, pages 12 and 13). Ortmann (1918) reported it from seven sites only in the lower (now impounded) portions of the Clinch, where he considered it locally abundant. Cumberlandia monodonta was rare in the Virginia portion of the river with the largest concentrations occurring in the Tennessee portion of the upper Clinch; however, a small but viable population still occurs at one site (site 60) in the lower Clinch.

Currently, C. monodonta is a widespread, Interior Basin species now considered rare in the Tennessee, Cumberland, and upper Mississippi rivers (Bogan and Parmalee 1983; Nelson and Freitag 1980), but common in the lower Meramec River (Buchanan 1980). It is also found in the Powell and Nolichucky rivers, both tributaries to Tennessee River. Cumberlandia monodonta has a preference for shallow areas, particularly along stream banks near water willow beds where it buries itself firmly into the sand and mud substrates and between bedrock ledges in fast-flowing current.

Amblema costata is a fairly common species in the upper Clinch in Tennessee and Virginia, and the lower Clinch. It was reported from 69 sites between sites 70 and 183 in the upper Clinch and at 9 sites between sites 1 and 60 in the lower impounded stretches (Figure 3, page 27; Figures 1 and 2, pages 12 and 13). Ortmann (1918) found it at 13 sites throughout the Clinch and commented that it was generally widespread in the upper Tennessee drainage. This species is more common in the Virginia portion of the upper Clinch where it extends into the headwaters near Cleveland (site 183).

Presently, Amblema costata is a widespread, Ohioan species present throughout the Tennessee and Cumberland rivers. Unusually large numbers of old, heavier specimens dominate some of the pools of the upper Clinch.

Cyclonaias tuberculata is an extremely common species in the upper Clinch in Tennessee and Virginia, as well as in the lower

Clinch. It was present at 75 sites between sites 67 and 171 in the upper Clinch and at 11 sites between sites 1 and 42 in the lower Clinch (Figure 3, page 27; Figures 1 and 2, pages 12 and 13). (1918) reported C. tuberculata from 12 sites throughout the Clinch and mentioned that it was generally abundant in larger rivers where it extends far into the headwaters. This species was found to occur into the headwater of the upper Clinch in Virginia where it disappears near St. Paul (site 171).

Cyclonaias tuberculata is a common, widespread, Ohioan species present throughout the Tennessee and Cumberland rivers and their tributary streams. Pardue (1981) reported it as very common in the upper Tennessee River. The author observed it to be common below Ft. Loudoun and Watts Bar dams. Unusually large, old specimens were observed in the deeper pools of the upper Clinch.

Ortmann (1918) reported two species of the genus Elliptio (E. dilatatus and E. crassidens) from the Clinch River, with E. dilatatus being the most common of the two. It occurs in the upper Clinch in Tennessee and Virginia, and in the lower Clinch. This species was present at 78 sites between sites 65 and 200 in the upper Clinch and 2 sites (42 and 60) in the lower Clinch (Figure 3, page 27; Figures 1 and 2, pages 12 and 13). Ortmann (1918) reported E. dilatatus from 20 sites throughout the Clinch and indicated that it was one of the most common, widely distributed species in the upper Tennessee region.

As an extremely common Interior Basin species, E. dilatatus is present throughout the Tennessee and Cumberland rivers and their tributary streams. It is very common in the majority of smaller, tributary streams and remains one of the most abundant species in the upper Clinch where it is present in all habitats.

Elliptio crassidens is a relatively rare species in the upper Clinch in Tennessee and Virginia, and in the lower Clinch. It was reported from 12 sites between sites 71 and 170 in the upper Clinch and at 3 sites (sites 31, 42, and 60) in the lower Clinch (Figure 3, page 27; Figures 2 and 2, pages 12 and 13). Ortmann (1918) found it at 10 sites throughout the Clinch and commented that it was everywhere in the larger rivers. Elliptio crassidens is primarily a big river species and therefore, as expected, is very rare in the upper headwaters of the Clinch in Virginia.

As an extremely common, widespread, Interior Basin species, E. crassidens is present throughout the Tennessee and Cumberland rivers but uncommon to rare in the smaller tributary streams. Pardue (1981) reported this mussel as the most common species in the upper Tennessee River. The author observed it to be extremely common below Ft. Loudoun and Watts Bar dams.

Four species of the genus Fusconaia (F. subrotunda, F. barnesiana, F. cuneolus, and F. edgariana) were reported by Ortmann (1918) during his study of the Clinch. All four species were found in this study, primarily in the upper Clinch above Norris Reservoir.

Fusconaia subrotunda is the most common of the four Fusconaia encountered. It was reported from 66 sites between sites 76 and 202 in the upper Clinch in Tennessee and Virginia, and at 2 sites (42 and 54) in the lower Clinch (Figure 3, page 27; Figures 1 and 2, pages 12 and 13). Ortmann (1918) reported F. subrotunda from 21 sites throughout the Clinch and commented it was more abundant in the headwaters, extending as far upstream as Cedar Bluff (site 202).

Fusconaia subrotunda is a widespread but uncommon Interior Basin species, present but rare in the Tennessee and Cumberland rivers. It becomes increasingly common in the tributary streams of the Tennessee River but is apparently absent or extirpated from the tributaries of the Cumberland. Unusually large specimens occur in some of the deeper pools of the upper Clinch.

Fusconaia barnesiana is a common species present only in the upper Clinch in Tennessee and Virginia. It was found at 63 sites between sites 67 and 202 (Figure 3, page 27; Figure 3, page 13). Ortmann (1918) reported it from 13 sites throughout the Clinch and commented that it was generally distributed over the upper Tennessee drainage, especially in the headwater sections of larger streams.

Recent records for F. barnesiana indicate it being a relatively common Cumberlandian species present only in the tributary streams of the Tennessee River. It is now apparently extirpated from the Tennessee River but remains a common species of the upper Clinch and many smaller tributaries. Fusconaia barnesiana typically occurs only in riffle and shoal areas in clean-swept substrates; it is rarely found in pools or slackwater areas.

Fusconaia cuneolus is a relatively common species present only in the upper Clinch in Tennessee and Virginia. It was reported from 56 sites between sites 68 and 203 (Figure 3, page 27; Figure 2, page 13). Ortmann (1918) reported F. cuneolus from nine sites throughout the Clinch and indicated it to be widespread in the upper Tennessee drainage. No information is given by Ortmann as to how common this species was in the Clinch or the upper Tennessee drainage; however, it was found to be more abundant in the Virginia portion of the Clinch, extending upstream as far as Cedar Bluff (site 203). Bates and Dennis (1978) found two specimens in the lower Clinch below Norris dam. During this study none were found; it is now believed extirpated from the lower Clinch.

In June 1976, Fusconaia cuneolus was federally listed as an endangered species. This rare Cumberlandian species is presently found only in tributaries of the Tennessee River (Bogan and Parmalee 1983; Neves 1983a). An unusually large concentration occurs in the upper Clinch River. Lesser known populations are found in the Powell, Little River, North Fork Holston, Elk, Sequatchie, and Paint Rock rivers (Neves 1983a). Fusconaia cuneolus is typically a riverine species found in moderate- to fast-flowing current in clean-swept rubble, gravel, and sand substrates. It is rarely found in pools or slackwater areas.

Fusconaia edgariana is the rarest of the four Fusconaia encountered. It was present in the upper Clinch in Tennessee and Virginia and occurred at 29 sites between sites 86 and 186 (Figure 3,

page 27; Figure 2, page 13). Ortmann (1918) found it at 11 sites throughout the Clinch and considered it abundant, especially in the Virginia portion of the Clinch.

In June 1976, Fusconaia edgariana was federally listed as an endangered species. This rare Cumberlandian species is presently found only in tributaries of the Tennessee River (Bogan and Parmalee 1980; Neves 1983b). The largest known concentrations are found in the upper Clinch and the North Fork Holston river above Saltville, Virginia. Lesser known populations occur in the Powell, Elk, and Paint Rock rivers (Neves 1983b). Fusconaia edgariana is typically a riverine species found in moderate- to fast-flowing current in clean-swept rubble, gravel, and sand substrates. It never occurs in deeper pools or slackwater areas.

Lastena lata is a relatively rare species present only in the upper Clinch in Tennessee and Virginia. It was reported from 21 sites between sites 74 and 129 (Figure 3, page 27; Figure 2, page 13). Ortmann (1918) found it at only six sites in the Clinch and considered it rare. The largest concentrations were found in the Tennessee portion of the river, and it was not found above Craft Mill, Virginia (site 129). Lastena lata is probably more widespread in the upper Clinch; however, it buries itself deeply into the substrate, making it a difficult mussel to find.

Considered a rare, but widespread, Ohioan species, L. lata is now apparently extirpated from the Tennessee and Cumberland rivers. This species is presently known only from the upper Clinch,

Powell, and Elk rivers, all tributaries to the Tennessee River. The largest known concentrations are probably found in the upper Clinch. This mussel is typically a shallow riffle or shoal species found in moderate- to fast-flowing current in rubble, gravel, and sand substrates. Lastena lata is extremely difficult to locate because of its long foot, which enables it to burrow deeply into the substrate. Specimens are found only after a great deal of digging effort.

Lexingtonia dolabelloides is generally a rare species in the Clinch, present at one site in the upper Clinch at Pendleton Island (site 137) and at one site in the lower Clinch (Figure 3, page 27; Figures 1 and 2, pages 12 and 13). Ortmann (1918) reported it from 10 sites throughout the Clinch and found it to be abundant in the headwaters. It is rare today in the upper river and its survival is tenuous in the lower Clinch.

Currently, L. dolabelloides is widespread, but a relatively rare Cumberlandian species now believed extirpated from the Tennessee River. This species continued survival in the Clinch and Powell rivers remains uncertain. The largest concentrations occur in the North Fork Holston, Duck, Elk, and Paint Rock rivers. It is typically a riverine species present only in shallow riffle and shoal areas with moderate- to fast-flowing current and clean-swept rubble, gravel, and sand substrates.

Ortmann (1918) reported two species of the genus Plethobasus (P. cyphyus and P. cooperianus) from the Clinch. Only P. cyphyus was found in this study.

Plethobasus cyphyus is relatively common in the upper Clinch in Tennessee and Virginia. It was reported from 29 sites between sites 86 and 173 (Figure 3, page 27; Figure 2, page 13). Ortmann indicated P. cyphyus to be a larger river species and found it at 11 sites throughout the Clinch. It occurs in the upper headwater of the Clinch in Virginia, but is absent above St. Paul (site 173). It is now believed to be extirpated from the lower Clinch.

Plethobasus cyphyus is a widespread Interior Basin species present in the Cumberland River drainage and tributaries to the Tennessee River. Another closely related species, Plethobasus cooperianus is now believed extirpated from the Clinch River. Plethobasus cooperianus is a federally listed, endangered, Interior Basin species presently known only from the Tennessee, Cumberland, and lower Ohio rivers (Ahlstedt 1983g).

Ortmann (1918) reported five species of the genus Pleurobema P. oviforme, P. cordatum, P. rubrum, P. plenum, and P. coccineum) from the Clinch. All but one (P. coccineum) were found during this study.

Pleurobema oviforme was an uncommon species in the upper Clinch in Tennessee and Virginia, and the lower Clinch. It was reported from 27 sites between sites 71 and 202 in the upper Clinch but only from site 55 in the impounded section (Figure 3, page 27; Figures 1 and 2, pages 12 and 13). Ortmann (1918) found it at 11 sites throughout the Clinch and indicated it to be widely distributed in rivers of eastern Tennessee where it extends into headwater tributaries. It is extremely rare in the lower Clinch with only two old specimens found during this study.

Considered an uncommon Cumberlandian species, P. oviforme is extremely rare in the Tennessee River and believed extirpated from the Cumberland River. This species is reported from tributary streams to the Tennessee and Cumberland rivers, with probably the largest concentrations occurring in the upper Clinch and North Fork Holston river above Saltville, Virginia. It has a definate preference for smaller headwater streams.

Pleurobema cordatum is a rare species that was found in the upper and lower Clinch. It was reported from 9 sites between sites 86 and 137 in the upper Clinch in Tennessee and Virginia, and at 9 sites between sites 1 and 58 in the lower Clinch (Figure 3, page 27; Figures 1 and 2, pages 12 and 13). Ortmann (1918) mentioned it to be a larger river species and found it at only six sites in the lower river. The occurrence of P. cordatum in the Virginia portion of the upper Clinch (site 137) is the first record of this species this far upstream. Its occurrence in the upper Clinch is unusual and rare for this otherwise larger river species, although occasional specimens are still encountered in the lower Clinch.

Currently, P. cordatum is a common, widespread, Interior Basin species present throughout the Tennessee and Cumberland rivers and the larger tributary streams of the Tennessee River. The larger river habitat in the lower Clinch, especially below Melton Hill dam, probably receives some recruitment from the upper Tennessee River, where P. cordatum is reported as common (Pardue 1981). Specimens

were found off the main river channel in the overbanks of the lower Clinch in slow- to moderately-flowing current.

Pleurobema rubrum is an extremely rare species in the upper Clinch in Tennessee and Virginia, and the lower Clinch. It was reported from 3 sites between sites 87 and 137 in the upper Clinch and from 5 sites between sites 1 and 57 in the lower Clinch (Figure 3, page 27; Figures 1 and 2, pages 12 and 13). Ortmann (1918) reported it from 10 sites in the lower Clinch and mentioned that it was abundant. The occurrence of P. rubrum in the Virginia portion of the upper Clinch (site 137) is the first record of this species this far upstream. It is primarily a species of larger rivers.

As an uncommon, to rare, Interior Basin species, P. rubrum is often confused or lumped taxonomically with P. cordatum (Stansbery 1983). Fresh-dead specimens have been observed by the author from commercial mussel fishermen cull piles on the Tennessee and Cumberland rivers. A small reproducing population occurs in the upper Clinch near Brooks Island (site 97) and in the overbanks of the lower Clinch.

Pleurobema plenum is an extremely rare species present only in the upper Clinch in Tennessee. It was reported from 3 sites between sites 97 and 100 (Figure 3, page 27; Figure 2, page 13). Ortmann (1918) collected P. plenum from only 3 sites, all in the lower Clinch and considered this species scarce in the upper Tennessee region.

In June 1976, P. plenum was federally listed as an endangered species. This rare Interior Basin species is presently found only in the Tennessee, Cumberland, Clinch, Green, and Barren rivers (Ahlstedt 1984). The largest concentrations probably occur in the Tennessee River. A small reproducing population occurs in the upper Clinch near Brooks Island (site 97). Pleurobema plenum is typically a big river shoal species and its presence in the upper Clinch is unusual.

Ortmann (1918) reported three species of the genus Quadrula (Q. pustulosa, Q. cylindrica, and Q. intermedia) during his study of the Clinch. Only two of these species (Q. pustulosa and Q. cylindrica) were encountered during this study. Two additional species of Quadrula (Q. sparsa and Q. metanevra) not found by Ortmann were present in this study. Ortmann considered Q. sparsa synonymous with another closely related species, Q. intermedia. Any Q. sparsa specimens that may have been found by Ortmann were probably lumped with Q. intermedia. During recent sampling, Q. sparsa has been positively identified from the upper Clinch. Quadrula metanevra was not found by Ortmann but was later listed by Cahn (1936) and Hickman (1937) from the lower Clinch prior to impoundment.

Quadrula pustulosa is the most common of the four Quadrula species found during this study. It was present at 31 sites between sites 67 and 146 in the upper Clinch in Tennessee and Virginia, and at 31 sites between sites 1 and 46 in the lower Clinch (Figure 3, page 27; Figures 1 and 2, pages 12 and 13). Ortmann (1918) reported

it from five sites in the lower (now impounded) river and commented that it rarely occurs in headwaters of the upper Clinch, being more common in the lower, big river section.

Recent collections indicate Q. pustulosa as a common, widespread, Interior Basin species present in the Tennessee and Cumberland rivers and their tributary streams. Pardue (1981) considered Q. pustulosa the most common Quadrula species in the upper Tennessee River.

Quadrula cylindrica is a relatively common species, but only in the upper Clinch in Tennessee and Virginia. It was found at 33 sites between sites 71 and 183 (Figure 3, page 27; Figure 2, page 13). Ortmann (1918) found it at 12 sites throughout the Clinch and commented that it was a frequent species of larger rivers, often extending into headwater tributaries. Quadrula cylindrica is now believed extripated from the lower Clinch.

Currently, Q. cylindrica is an uncommon, widespread, Interior Basin species now considered rare in the Tennessee and Cumberland rivers. Young specimens (5 to 7 years old) have been observed by the author at a commercial mussel fishermen's cook-out camp near Savannah, Tennessee. This represents the only recent record of it from the Tennessee River, but it remains widespread in tributary streams of the Tennessee and Cumberland rivers. Hundreds of live specimens have been observed in the upper Clinch at Pendleton Island, Virginia (site 137). Quadrula cylindrica has a definite preference for slackwater areas along stream banks and the transition

zone between pools and riffles. Specimens were almost always observed lying on their side in silt, over rubble and gravel, with at least half of the shell exposed.

Quadrula sparsa is an extremely rare species present only in the upper Clinch in Virginia. One live specimen was found at site 145 and 146 (Figure 3, page 27; Figure 2, page 13). Ortmann (1918) never considered Q. sparsa separate from Q. intermedia because of the close similarities between the two. However, Stansbery (1973) considered both Q. sparsa and Q. intermedia as valid species and reported both from the upper Clinch in Virginia. Quadrula intermedia was not found during this study but one fresh-dead specimen was collected in 1983 by Richard Neves (Virginia Polytechnic Institute, personal communication) from the upper Clinch at Pendleton Island (site 137). Ortmann (1918) reported it at two sites in the upper Clinch in Virginia and judged it to be rare. Both species are considered extremely rare in the upper Clinch.

In June 1976, Q. sparsa was federally listed as an endangered species. This rare Cumberlandian species is presently found only in the upper Clinch and Powell rivers (Ahlstedt 1983b). The largest populations known today occur in the upper Powell. Quadrula sparsa is typically a riverine species found only in shallow riffle and shoal areas in moderate- to fast-flowing current. It occurs in clean-swept rubble, gravel, and sand substrates, and is never found in standing pools or slackwater. They remain buried in the substrate except during spawning. Live specimens have been observed in the upper Powell totally exposed on the substrate while spawning in early May and June.

Quadrula intermedia a federally listed, endangered, Cumberlandian species, is presently known only from the upper Clinch, Powell, Duck, and Elk rivers (Ahlstedt 1983c). It is typically a riverine species found only in shallow riffle and shoal areas in moderate- to fast-flowing current. It occurs in clean-swept rubble, gravel, and sand substrates and is never found in standing pools or slackwater. Quadrula intermedia is always buried in the substrate except during spawning. Live specimens were observed in the upper Powell partially or totally exposed on the substrate while spawning in early May and June. This species was also observed to be sexually dimorphic, an observation previously unreported for the genus.

Quadrula metanevra is a rare species in the Clinch River, found only in the lower reaches at sites 4 and 29 (Figure 3, page 27; Figure 1, page 12). Ortmann (1918) did not find this species in the Clinch; however, Quadrula metanevra is a common, widespread, Interior Basin species present throughout the Tennessee and Cumberland rivers.

Two species of the genus Alasmidonta (A. marginata and A. viridis) were reported from the Clinch River. Alasmidonta marginata was the only species found in the Clinch. The closely related A. viridis was recently reported from Copper Creek, an upper Clinch River tributary (Ahlstedt 1981). Ortmann (1918) reported it from only four sites in the upper Clinch in Virginia, but noted it to be locally abundant in small streams throughout the upper Tennessee region.

Alasmidonta marginata is a relatively common species in the upper Clinch in Tennessee and Virginia. It was reported from 41 sites between sites 66 and 188 (Figure 3, page 27; Figure 2, page 13). Ortmann (1918) recorded it from 12 sites throughout the Clinch and commented that it was generally distributed over the upper Tennessee region and becomes more abundant in the headwater tributaries. This mussel is now believed extirpated from the lower Clinch.

As a widespread, Interior Basin species, A. marginata is now believed extirpated from the Tennessee and Cumberland rivers but relatively common in their tributary streams. It prefers fast-flowing currents in clean-swept rubble, gravel, and sand substrates.

Alasmidonta viridis was not found during the present study but is believed to still occur in the Clinch. This species may have been overlooked while sampling. It was found in Cooper Creek (Ahlstedt 1981) and is strictly a headwater species, occurring in shallow riffle and shoal areas in moderate- to fast-flowing current.

Ortmann (1918) reported two species of the genus Lasmigona (L. costata and L. holstonia) from the Clinch. Lasmigona costata was the only species found in the upper Clinch; however, another species of Lasmigona (L. complanata) now occurs in the lower Clinch. Lasmigona complanta was not found by Ortmann in the Clinch but was later reported by Bates (1975) and Bates and Dennis (1978). Lasmigona holstonia was not found during this study but may still occur in the extreme headwaters of the Clinch. Ortmann considered L. holstonia

to be locally abundant in small streams and reported it from three sites only in the upper Clinch in Virginia.

Lasmigona costata is an extremely common species in the upper Clinch in Tennessee and Virginia. It occurred at 100 sites between sites 66 and 201 (Figure 3, page 27; Figaure 2, page 13). Ortmann (1918) reported it from 16 sites throughout the Clinch and commented that it was abundant in small- to medium-sized streams but rare in larger rivers. This mussel is now believed extirpated from the lower Clinch.

Currently, L. costata is an extremely common Interior Basin species occurring in the Tennessee and Cumberland rivers and their tributaries. It prefers the headwater portions of streams where it becomes locally abundant in all habitats.

Lasmigona complanata is an extremely rare species present at 6 sites between sites 7 and 37 in the lower Clinch (Figure 3, page 27; Figure 1, page 12). This species is not part of the original Clinch River mussel fauna but is often found to colonize the overbanks of rivers that have been impounded (Bates 1962, 1975). Since L. complanata was found only in the lower Clinch below Melton Hill dam, it probably invaded that area from sources in the upper Tennessee River.

Recent surveys indicate L. complanata as a common, widespread, Interior Basin species occurring in the Tennessee and Cumberland rivers, and their tributaries. Lasmigona complanata prefers soft mud and sand substrates off the main river channel in the overbanks.

Strophitus rugosus is an extremely rare species in the upper Clinch in Tennessee and Virginia. Occasional specimens were found at 7 sites between sites 92 and 144 (Figure 3, page 27; Figure 2, page 13). Ortmann (1918) reported it from 12 sites throughout the Clinch and found it to be abundant both in the larger rivers and smaller tributaries.

Mussel surveys report S. rugosus as an uncommon, widespread, Interior Basin species now believed extirpated from the Tennessee and Cumberland rivers but occurring in their tributary streams. Strophitus rugosus was found only in riffle and shoal areas with moderate- to fast-flowing currents and clean-swept rubble, gravel, and sand substrates. This species may be more common in the upper Clinch than records indicate since specimens were found only after considerable digging.

Actinonaias carinata and A. pectorosa were two of the most common mussels found in the Clinch. Actinonaias carinata was the more common of the two, occurring in both the upper and lower Clinch. It was reported from 103 sites between sites 65 and 202 in the upper Clinch and at 3 sites between sites 42 and 61 in the lower Clinch Figure 3, page 27; Figures 1 and 2, pages 12 and 13). Ortmann (1918) reported it from 13 sites throughout the Clinch and found it extremely abundant in the larger rivers. It was less common near the headwater of the Clinch where it disappears near Cedar Bluff, Virginia (site 202). While extremely common in the upper Clinch, only occasional old specimens were found in the lower Clinch.

Currently, A. carinata is a relatively common, widespread, Interior Basin species occurring in the Tennessee and Cumberland rivers and their tributaries. This mussel is becoming rare in the Tennessee River but remains common in its tributaries. Large, old specimens occur in the pools of the upper Clinch.

Actinonaias pectorosa is an extremely common species that inhabit only the upper Clinch in Tennessee and Virginia. It was reported from 100 sites between sites 65 and 202 (Figure 3, page 27; Figure 2, page 13). Both A. carinata and A. pectorosa have similar overlapping distributions in the upper Clinch; however, A. pectorosa becomes the dominant species in the headwaters while A. carinata remains more abundant in the larger river sections. Ortmann (1918) found it to occur at eight sites throughout the Clinch and observed that it was also more abundant than A. carinata north of the Virginia-Tennessee state line.

As a relatively common, Cumberlandian species, A. pectorosa occurs only in the tributary streams of the Tennessee and Cumberland rivers. It is now believed extirpated from the Tennessee, Cumberland, and lower Clinch rivers. Numerous, large specimens occur in the pools of the upper Clinch.

Conradilla caelata is an extremely rare species in the upper Clinch in Tennessee and Virginia. It was reported from 12 sites between sites 97 and 169 (Figure 3, page 27; Figure 2, page 13). Ortmann (1918) found it at two sites on the Clinch and commented that it was widespread in distribution but found nowhere in great numbers.

In June 1976, C. caelata was federally listed as an endangered species. This rare Cumberlandian species is presently found only in the upper Clinch, Powell, Duck, and Elk rivers (Ahlstedt 1983d). It occurs nowhere in great numbers except in the middle reaches of the Duck River below Lillard Mill dam. Conradilla caelata is generally a shallow riffle or shoal species found in moderate- to fast-flowing current in clean-swept rubble, gravel, and sand substrates. However, this species has also been observed in deeper pool areas with constant current, and hundreds of juveniles were found in the Duck River in mud, sand, and silt substrate in a slackwater area near water willow beds. This mussel spawns in October with both male and female specimens partially or totally exposed on the substrate. A previously undescribed small, black or dark grey bubble is present on the posterior margin of the females during spawning. The bubble is slit in half with equal portions on each valve of the shell. Slight movements of the bubble have been observed in flowing current which suggests it may serve as an attractor for potential fish host species. The host fish for C. caelata is Etheostoma zonale, the greenside darter (Jenkinson 1982).

Cyprogenia irrorata is a relatively common species in the upper Clinch in Tennessee and Virginia. It was reported from 31 sites between sites 77 and 147 (Figure 3, page 27; Figure 2, page 13). Ortmann (1918) found it at only nine sites in the lower (now impounded) portion of the Clinch, where he considered it to be abundant. Cyprogenia irrorata extends into the headwater of the upper Clinch in Virginia where it becomes rare.

Recent collections indicate C. irrorata as a widespread, but uncommon, Ohioan species that is becoming increasingly rare in the Tennessee and Cumberland rivers. The largest known concentrations probably occur only in the upper Clinch. Only old, eroded specimens have been observed from the Tennessee and Cumberland rivers.

Dromus dromas is a rare species found only in the upper Clinch in Tennessee and Virginia. It was reported from 16 sites between sites 77 and 108 (Figure 3, page 27; Figure 2, page 13). Recently, one live specimen was found in the Virginia portion of the Clinch at Pendleton Island (site 137) by Richard Neves (Virginia Polytechnic Institute, personal communication). This represents the only known record of D. dromas in the Virginia portion of the Clinch. Ortmann (1918) reported it at seven sites only in the lower (now impounded) Clinch and commented that it was abundant in the Holston River.

In June 1976, D. dromas was federally listed as an endangered species. This rare Cumberlandian species is presently found only in the upper Clinch, Powell, Tennessee, and Cumberland rivers (Ahlstedt 1983e). The largest concentrations occur in the upper Clinch and Powell rivers with occasional relict specimens reported from the upper Tennessee river below Watts Bar dam and the middle reaches of the Cumberland River below Cordell Hull dam. Dromus dromas is primarily a shallow riffle or shoal species found in moderate- to fast-flowing current in clean-swept rubble, gravel, and sand substrates. It never occurs in standing pools or slackwater.

This species has also been found at depths greater than 609 cm (20 feet) in both the Tennessee and Cumberland rivers. The continued survival of D. dromas in the Tennessee and Cumberland rivers is tenuous.

Ortmann (1918) reported nine species of the genus Epioblasma from the Clinch. Of these, three (E. triquetra, E. capsaeformis, and E. brevidens) were encountered during this study. Another Epioblasma species occurring in the Clinch (E. torulosa gubernaculum) was not found during this study but was collected in 1982 from the upper Clinch in Virginia by Richard Neves (Virginia Polytechnic Institute, personal communication). The remaining five species of Epioblasma (E. lenior, E. arcaeformis, E. haysiana, E. propinqua, and E. stewardsoni) were considered extinct by Stansbery (1971, 1973, 1976), Bates and Dennis (1978), Jenkinson (1981), and Bogan and Parmalee (1983). Ortmann (1918) found E. torulosa gubernaculum in the lower Clinch, as well as in the upper Clinch in Virginia. This species is precariously close to extinction where, prior to impoundment, it was considered by Ortmann to be locally abundant. Stansbery (1971) reported that all species of recent North American naiads believed to be extinct are members of the genus Epioblasma. Members of this genus, with few exceptions, are riverine species inhabiting areas with sandy gravel substrates and rapid currents. This type of habitat has nearly been eliminated by impounding rivers for flood control, power generation, and barge traffic. This is especially noticeable in the lower impounded Clinch where no Epioblasma species

were found. The remaining Epioblasma species in the upper Clinch are absent in some portions of the river. While pollution problems have occurred in the upper Clinch, their overall decline in other reaches suggests these species or their fish hosts are being killed by levels or types of impacts which do not appear detrimental to other mussel species occupying similar habitats.

Epioblasma capsaeformis is the most common of the three Epioblasma species in the Clinch. It was reported from 43 sites between sites 74 and 147 only in the upper Clinch in Tennessee and Virginia (Figure 3, page 27; Figure 2, page 13). Ortmann (1918) reported it from 14 sites throughout the Clinch and found it to extend into the extreme headwaters in Virginia; it was also noted to be abundant throughout the upper Tennessee region. This species was not found in the upper Clinch above Dungannon, Virginia (site 147), but was locally common farther downstream.

Currently, E. capsaeformis is becoming an increasingly rare Cumberlandian species, presently found only in the tributary streams of the Tennessee and Cumberland rivers. Fresh-dead specimens have also been observed by the author from Buck Creek, a headwater tributary to the Cumberland River. Epioblasma capsaeformis no longer occurs in the Tennessee, Cumberland, or lower Clinch rivers. The largest concentrations are found in the upper Clinch and Powell rivers. It is typically a riverine species present only in shallow riffle and shoal areas in moderate- to fast-flowing current. Specimens were found in clean-swept rubble, gravel, and sand substrates, and

never occurred in standing pools. It remains buried in the substrate except during spawning. Hundreds of live male and female specimens were observed totally exposed on the substrate while spawning in early May and June. Females have an iridescent blue mantle when spawning, which is easily observed for some distance during clear water and low flows.

Epioblasma brevidens is an uncommon species in the upper Clinch in Tennessee and Virginia. It was reported from 31 sites between sites 80 and 146 (Figure 3, page 27; Figure 2, page 13). Ortmann (1918) found it at only seven sites throughout the Clinch and commented that it was more common in medium- to larger-rivers.

As an increasingly rare Cumberlandian species, E. brevidens is presently found only in the Cumberland River and tributary streams of the Tennessee and Cumberland rivers. Fresh-dead specimens have also been observed by the author from Buck Creek, a headwater tributary to the Cumberland River, and relict specimens are reported from the Cumberland River by Parmalee et al. (1980) and Leroy Koch (Tennessee Valley Authority, personal communication). The largest concentrations occur in the upper Clinch and Powell rivers. Epioblasma brevidens is typically a riverine species present only in shallow riffle and shoal areas with moderate- to fast-flowing current. This mussel was found in clean-swept rubble, gravel, and sand substrates and never occurs in standing pools. It remains buried in the substrate except during spawning. Hundreds of live male and female specimens were observed totally exposed on the substrate while spawning in early May and June.

Epioblasma triquetra is a relatively common species that occurred only in the upper Clinch in Tennessee and Virginia. It was reported from 30 sites between sites 77 and 146 (Figure 3, page 27; Figure 2, page 13). Ortmann (1918) found it at nine sites throughout the Clinch and mentioned it as frequently occurring in both large and small rivers.

Recent collections indicate E. triquetra as an uncommon, widespread, Ohioan species that is becoming increasingly rare throughout its range. It is present but rare in the Cumberland River, but is no longer found in the Tennessee River. The largest concentrations are found in the upper Clinch and Powell rivers. This mussel was typically found in the transition zone between pools and riffles, in moderate current, and in shallow riffle and shoal areas in moderate- to fast-flowing current. Epioblasma triquetra remains buried in rubble, gravel, and sand substrates except during spawning. Hundreds of live male and female specimens were observed totally exposed on the substrate while spawning in early May and June.

Epioblasma torulosa gubernaculum is a federally listed, endangered, Cumberlandian species that occurs only in the upper Clinch River in Virginia (Ahlstedt 1983a). Although this species was not found during the present study, one live specimen was reported at Pendleton Island, Virginia (site 137). Based on the number of relict specimens observed from the upper Clinch between Gray's Island (site 144) and Pendleton Island, this mussel must have been locally common in this reach.

Ortmann (1918) reported three species of the genus Lampsilis (L. fasciola, L. ovata, and L. orbiculata) from the Clinch. All three species were found in this study.

Lampsilis fasciola is a common species in the upper Clinch in Tennessee and Virginia. It was reported from 73 sites between sites 66 and 202 (Figure 3, page 27; Figure 2, page 13). Ortmann (1918) reported it at 15 sites throughout the Clinch and commented that it occurs everywhere in the larger rivers and smaller streams.

Currently, L. fasciola is a widespread Interior Basin species believed extirpated from the Tennessee and Cumberland rivers but relatively common in their tributary streams. This mussel is extremely common in the upper Clinch and locally abundant in the lower North Fork Holston River near the Tennessee-Virginia state line.

Lampsilis ovata is a common species in the upper Clinch in Tennessee and Virginia. It was reported from 69 sites between sites 65 and 199 (Figure 3, page 27; Figure 2, page 13). Ortmann (1918) found it at 16 sites throughout the Clinch and indicated it to be more abundant in larger rivers.

Recent surveys report L. ovata as a widespread Interior Basin species occurring throughout the Tennessee and Cumberland rivers and their tributary streams. It is extremely common in the upper Clinch and locally abundant in the lower North Fork Holston River near the Tennessee-Virginia state line.

Lampsilis orbiculata is an extremely rare species in the Clinch River in Tennessee. It was found at only one site (site 100) in the upper Clinch, and at one site (site 27) in the lower Clinch, below Melton Hill dam (Figure 3, page 27; Figures 1 and 2, pages 12 and 13). Ortmann (1918) reported it from two sites in the lower (now impounded) portion of the Clinch. The presence of this species in the upper Clinch is unusual in that it is typically a medium- to large-river species.

In June 1976, L. orbiculata was federally listed as an endangered species. This widespread Interior Basin species is present throughout the Tennessee and Cumberland rivers and 14 additional streams (Ahlstedt 1983h). Lampsilis orbiculata is a riverine species that has been able to survive and reproduce in impoundments with river-lake conditions. This mussel was found in moderate- to fast-flowing currents in rubble, gravel, sand, and silt substrates and, never occurs in standing pools.

Two species of the genus Leptodea (L. fragilis and L. leptodon) have been reported from the Clinch River (Ortmann 1918), although L. fragilis is the only one still inhabiting the river. Ortmann considered L. leptodon a rare species, reporting it from only two sites in the lower Clinch. This species is now believed extirpated from the Clinch.

Leptodea fragilis is a relatively common species in the upper Clinch in Tennessee and Virginia. It was reported from 26 sites between sites 68 and 178 (Figure 3, page 27; Figure 2, page 13).

Ortmann (1918) only found it at three sites in the lower (now impounded) Clinch, but mentioned that it was not rare in the larger rivers. Leptodea fragilis occurs into the headwaters of the Clinch in Virginia where it disappears above Carbo (site 178).

A common, widespread, Ohioan species, L. fragilis occurs in the Tennessee and Cumberland rivers and their tributary streams. It is usually found in pools and slackwater areas where it lives in mud and sand.

Ligumia recta is a relatively common species in the upper Clinch in Tennessee and Virginia, but was found at only one locality (site 42) in the lower Clinch. It was reported from 31 sites between sites 71 and 170 in the upper Clinch (Figure 3, page 27; Figures 1 and 2, pages 12 and 13). Ortmann (1918) found it at 11 sites throughout the Clinch and considered it abundant in the larger rivers. Ligumia recta is more common in the Tennessee portion of the upper Clinch; however, it occurs into Virginia where it disappears near St. Paul (site 170).

Ligumia recta is a widespread Interior Basin species present in the Tennessee and Cumberland rivers and their tributary streams. It is primarily a big river species; however, it occurs with frequency in the upper Clinch and Powell rivers.

Medionidus conradicus is an extremely common species in the upper Clinch in Tennessee and Virginia. It was reported from 59 sites between sites 65 and 200 (Figure 3, page 27; Figure 2, page 13).

Ortmann (1918) reported it from 12 sites throughout the Clinch and commented that it was very abundant in the headwaters and small streams.

Recently, M. conradicus is reported as an extremely common Cumberlandian species found only in the tributary streams of the Tennessee and Cumberland rivers. It is one of the most common and widespread of all Cumberlandian species and is typically found in slow- to fast-flowing current, along stream banks, and in shallow riffle and shoal areas.

Ortmann (1918) reported five species of Villosa from the Clinch River. Three of these (V. nebulosa, V. vanuxemi, and V. perpurpurea) were present in the Clinch while two (V. fabalis and V. trabalis) were not found. Villosa fabalis was found by Ortmann to be a relatively rare species occurring primarily in the headwaters of streams. During this study, it may have been overlooked while sampling because of its small size and/or rarity. Only relict specimens were found in the upper Clinch. The only known recent records for V. fabalis in the Tennessee River system are from the middle reaches of the Duck River where two live specimens were found by the author in 1982. Bogan and Parmalee (1983) considers this species endangered. Villosa trabalis was not found during this study; it was reported by Ortmann (1918) as extremely rare. Ortmann found only one specimen in the Clinch River where it occurred with another closely related species, V. perpurpurea.

Villosa nebulosa is the most common Villosa in the Clinch. It was found at 49 sites between sites 71 and 202 in the upper Clinch in Tennessee and Virginia (Figure 3, page 27; Figure 2, page 13). Ortmann (1918) reported V. nebulosa from 12 sites throughout the Clinch and mentioned that it was widespread over all the upper Tennessee region where it favors smaller streams.

Currently, V. nebulosa is a Cumberlandian form believed extirpated from the Tennessee and Cumberland rivers but a common species in their tributary streams. Villosa nebulosa is typically found in gentle currents and slackwater pools along stream banks. It prefers soft mud, sand, and silt substrates.

Villosa perpurpurea is an extremely rare species present only in the Virginia portion of the upper Clinch. It was reported from 4 sites between sites 119 and 188 (Figure 3, page 27; Figure 2, page 13). Ortmann (1918) only found it at seven sites in the upper Clinch in Virginia, where it was considered not rare.

Currently, V. perpurpurea is an extremely rare Cumberlandian species, present only in the upper Clinch, Copper Creek (a tributary to the upper Clinch), and Beech Creek (a tributary to the Holston River) (Ahlstedt 1981). This species is restricted to small headwater streams and is found in moderate- to fast-flowing water in clean-swept rubble, gravel, and sand substrates, and under large flat rocks. It never occurs in pools or slackwater areas and typically remains buried in the substrate; however, numerous male and female specimens were observed in Beech Creek during January,

totally exposed on the substrate while spawning. Villosa perpurpurea is very similar to V. trabalis, a federally listed, endangered, Cumberlandian species reported by Ortmann (1918) from the upper Clinch. Villosa trabalis is now believed extirpated from the Clinch and is currently found only in the tributaries of the upper Cumberland River (Ahlstedt 1983f). These two species are separated only by nacre color and there are apparently no intergrades.

Villosa vanuxemi is a relatively uncommon species in the upper Clinch in Tennessee and Virginia. It was reported from 22 sites between sites 74 and 179 (Figure 3, page 27; Figure 2, page 13). Ortmann (1918) found it at only four sites in the Clinch, but commented that it was widespread in both the Tennessee and Cumberland rivers. Ortmann did not find V. vanuxemi in the Clinch above Speer's Ferry, Virginia (site 125), and indicated that it was probably overlooked while sampling. During recent studies, this species was found to extend into the headwaters of the upper Clinch in Virginia (site 199), where it becomes a rare species.

Recent collections indicate V. vanuxemi as an uncommon Cumberlandian species believed extirpated from the Tennessee and Cumberland rivers but occurring in their tributary streams. This mussel becomes locally abundant in smaller headwater streams and is typically found in shallow riffle and shoal areas in moderate- to fast-flowing current.

Proptera alata is a common species in the upper Clinch in Tennessee and Virginia, but rare in the lower Clinch. It was reported

from 65 sites between sites 64 and 183 in the upper Clinch and at 5 sites between sites 11 and 24 in the lower Clinch (Figure 3, page 27; Figures 1 and 2, pages 12 and 13). Ortmann (1918) mentioned this species as common in large rivers and collected it from 9 sites in the Clinch, of which 8 sites were in the lower (now impounded) portion. During this study, P. alata was found to extend into the headwaters of the upper Clinch in Virginia where it disappears near Cleveland (site 183).

A common, widespread, Interior Basin species, P. alata is present throughout the Tennessee and Cumberland rivers and their tributary streams. Proptera alata is common in the upper Clinch and easily adapts to impoundment (Pardue 1981). It was typically found in pools and along stream banks. It has great mobility and routinely leaves a trail through soft mud and sand substrates.

Two species of the genus Ptychobranchus (P. fasciolaris and P. subtentum) were reported by Ortmann (1918) from the Clinch and both were encountered during this study. Ptychobranchus fasciolaris is a common species in the upper Clinch in Tennessee and Virginia, but rare in the lower Clinch. It was reported from 72 sites between sites 67 and 202 in the upper Clinch and at 1 site (site 42) in the lower Clinch (Figure 3, page 27; Figures 1 and 2, pages 12 and 13). Ortmann (1918) found it at 13 sites throughout the Clinch and commented that it was widely distributed over the upper Tennessee region but found nowhere in large numbers. Ptychobranchus fasciolaris is especially common in the upper Clinch where it extends into the headwaters near Cedar Bluff (site 202).

Ptychobranchus fasciolaris is a widespread, Interior Basin species present in the Cumberland River but apparently extirpated from the Tennessee River. The largest concentrations probably occur in the upper Clinch and other tributaries to the Tennessee and Cumberland rivers. In the upper Clinch it prefers the fast-moving currents near boulders and bedrock.

Ptychobranchus subtentum is a common species in the upper Clinch in Tennessee and Virginia. It was reported from 80 sites between sites 65 and 202 (Figure 3, page 27; Figure 2, page 13). Ptychobranchus subtentum is almost identical in distribution to P. fasciolaris in the upper Clinch. Both species extend into the headwaters in Virginia. Ortmann (1918) reported it at 10 sites throughout the Clinch and mentioned it to be rare in big rivers but locally abundant in smaller streams.

Ptychobranchus subtentum, a Cumberlandian species, is present only in tributaries of the Tennessee and Cumberland rivers. It is now believed extirpated from the Tennessee and Cumberland rivers. The largest concentrations occur in the upper Clinch and the North Fork Holston river above Saltville, Virginia. It is typically found only in shallow riffle and shoal areas with moderate to swift current. This mussel prefers clean-swept rubble, gravel, and sand substrates, and is sometimes found buried along the sides of boulders. It never occurs in standing pools or slackwater.

Truncilla truncata is a relatively common species in the upper Clinch in Tennessee and Virginia. It was reported from 32

sites between sites 74 and 181 (Figure 3, page 27; Figure 2, page 13). Ortmann (1918) only found it at six sites in the lower (now impounded) Clinch and mentioned that it was an uncommon species and absent from headwater areas. During this study, T. truncata was found to occur upstream to near Cleveland, Virginia (site 181).

Currently, Truncilla truncata is a widespread Interior Basin species believed extirpated from the Tennessee River but present in the Cumberland River, and the tributary streams of both the Tennessee and Cumberland rivers. It was found to be locally abundant in pools near Brooks Island (site 97).

Two Anodonta species not recorded from the Clinch by Ortmann (1918) were found during this study. Anodonta grandis and A. suborbiculata were found only in the lower Clinch below Norris and Melton Hill dams. Anodonta grandis was the more abundant of the two species, occurring at 25 sites between sites 1 and 53 (Figure 3, page 27; Figure 1, page 12).

Recent collections indicate Anodonta grandis as a common, widespread, Ohioan species found throughout the Tennessee and Cumberland rivers, and their tributary streams. It occurs only in the lower Clinch and is characteristic of impoundments where it colonizes mud and silt substrates of the overbanks (Bates 1962).

Anodonta suborbiculata is very rare in the lower Clinch; only three specimens (sites 12, 21, and 25) were found (Figure 3, page 27; Figure 1, page 12). Presently, Anodonta suborbiculata is reported as an uncommon, Ohioan species occurring in the Tennessee

and lower Clinch rivers. It is extremely rare in the lower Clinch and is typically a big river species that colonizes the overbanks of impoundments.

Four additional mussel species previously reported from the Clinch by Ortmann (1918) were not found during this study. Three of these (Obliquaria reflexa, Obovaria retusa, and Plagiola lineolata) are primarily big river species that were present only in the lower reaches of the Clinch prior to impoundment. The fourth species (Toxolasma lividus) was found by Ortmann only in the upper Clinch at one site in Virginia. The three big river species were probably eliminated from the lower Clinch when the river was impounded. No reasons can be given for the absence of Toxolasma lividus from the upper Clinch, since it was reported by Ortmann as widespread in the upper Tennessee drainage. It may still be present in the upper Clinch; however, intensive sampling efforts have failed to find any evidence of this species.

Mussel Community Structure

The Clinch River was divided into 32-km reaches in both the lower and upper river to simplify community structure analysis (Table 4). Mussel species reported from the Clinch during recent surveys are listed in Table 3, page 41, and include Ortmann's (1918) mussel data. Cluster analysis was performed on these two data sets to help define the community structure (Figures 4 and 5).

Stream reaches in the upper Clinch River above Norris Reservoir from km 241 to 434 (CRM 150 to 270) formed a cluster indicating similar

TABLE 4. River Kilometer, Elevation, Gradient and Number of Mussel Species During Recent Sampling Including Ortmann's (1918) Survey in each 32-km Reach of the Clinch

Kilometer (mile)		Elevation m (ft.)	Gradient m/km (ft./mile)	Ahlstedt No. Species	Ortmann No. Species
16	(10)	226 (741.0)	.25 (1.3)	12	16
48	(30)	235 (770.0)	.26 (1.4)	3	NS
80	(50)	241 (792.0)	.23 (1.2)	13	42
113	(70)	257 (844.5)	.42 (2.2)	11	41
145	(90)	276 (905.5)	.53 (2.8)	NS	16
177	(110)	285 (935.0)	.36 (1.9)	NS	2
209	(130)	307 (1006.0)	.57 (3.0)	NS	42
241	(150)	339 (1111.0)	.85 (4.5)	23	NS
273	(170)	348 (1142.5)	.49 (2.6)	36	5
306	(190)	368 (1208.5)	.58 (3.1)	40	14
338	(210)	381 (1250.0)	.45 (2.4)	36	38
370	(230)	416 (1364.0)	.87 (4.6)	38	2
402	(250)	468 (1535.5)	1.38 (7.3)	25	26
434	(270)	489 (1604.0)	.89 (4.7)	23	24
466	(290)	594 (1950.0)	2.47 (13.1)	15	NS
499	(310)	599 (1966.0)	.93 (4.9)	5	19
531	(330)	714 (2341.5)	2.68 (14.2)	10	17

NS = Not Sampled.

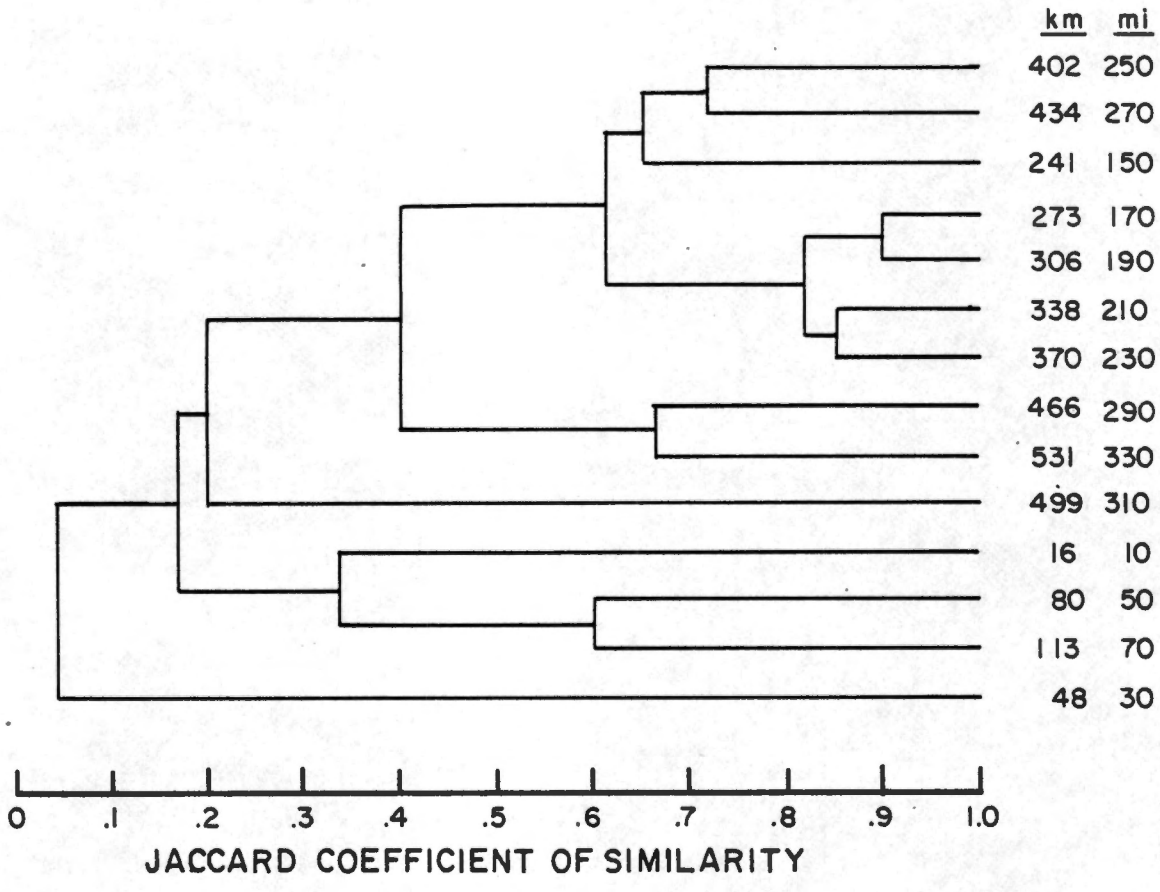


FIGURE 4. Cluster analysis showing recent mussel species associations in the Clinch River (Ahlstedt 1978 to 1983).

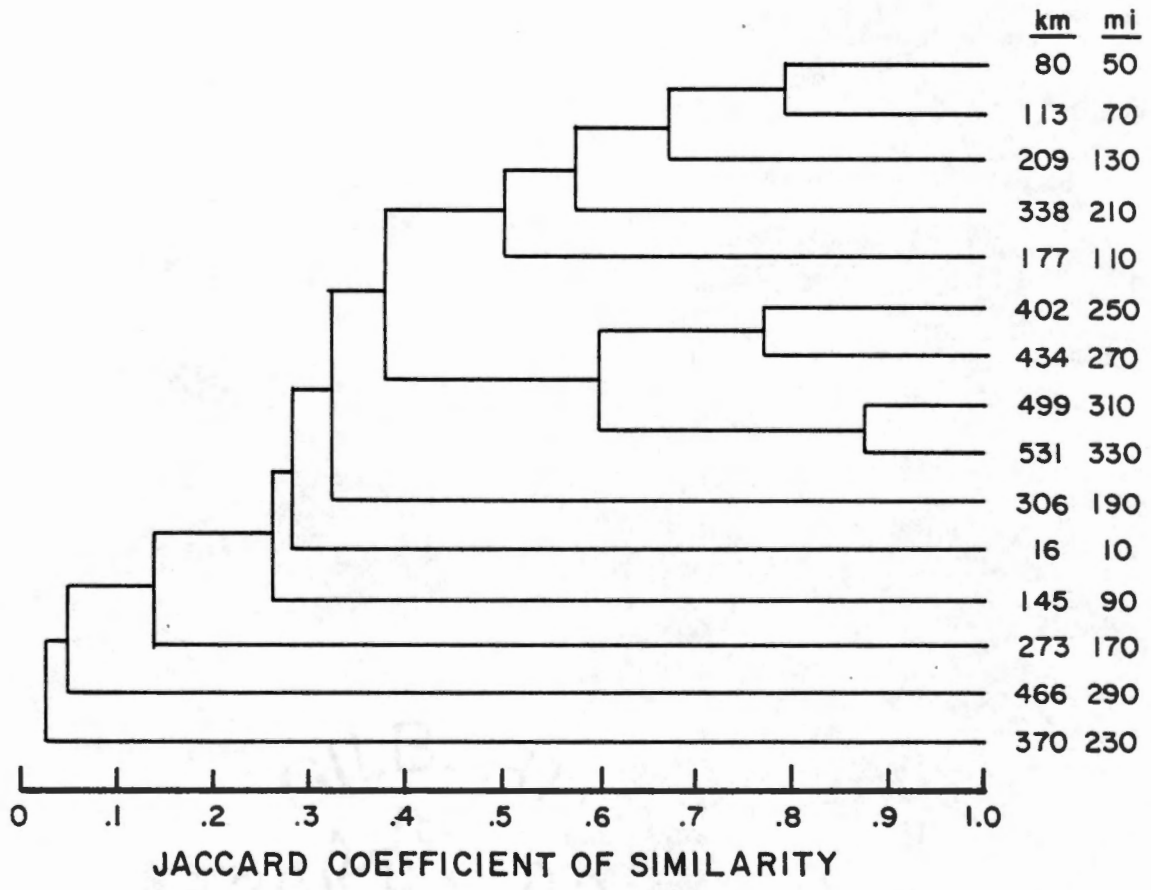


FIGURE 5. Cluster analysis showing mussel species associations in the Clinch River (Ortmann 1918).

species compositions (>60% similarity) occurring in this reach (Figure 4). An extremely tight cluster with 80% similarity formed from km 273 to 370 (CRM 170 to 230). This area contained the richest concentration of mussels found in the Clinch. Above 466 (CRM 290), species compositions are less similar because of habitat changes and small stream size typical of most headwater streams. Sampling reaches in the lower Clinch below Norris and Melton Hill dams were less similar to each other because most mussel species reported consisted of relict specimens.

Cluster analysis of Ortmann's (1918) mussel data did not exhibit patterns similar to the recent mussel data (Figure 4). Ortmann's data showed two groups of reaches having similarity of 50% or greater. Stream reaches below km 338 (CRM 210) formed one group, while reaches above this point formed the other. Six reaches were not grouped as would be expected, probably because of the small amount of time and effort spent in sampling these areas.

Longitudinal Zonation

In order to further assess the effect of longitudinal zonation on the freshwater mussel community, correlations were computed between the number of species in each 32-km reach and kilometers from above the mouth of the river to include elevation and gradient (Table 5). Since the lower Clinch is affected by impoundment and channelization, these reaches were excluded for this analysis. Correlations were computed for both recent studies and Ortmann's data. Correlations

TABLE 5. Correlation Coefficients Between the Number of Species in Each 32-km (20-mile) Reach and Three Physical Parameters for Both Ahlstedt 1978 to 1983 and Ortmann (1918)

	Elevation	Gradient	Mile
Ahlstedt 1978-1983			
No. Species	-.833**	-.649*	-.756*
Elevation		.835*	.958**
Gradient			.712*
Ortmann (1918)			
No. Species	-.292	-.239	-.429
Elevation		.877**	.945**
Gradient			.749**

*Significant at .05 level.

**Significant at .01 level.

between physical parameters differ in the two matrices because some reaches were not included in each survey.

Elevation showed the highest correlation with the number of mussel species found during recent sampling ($r = 0.833$; $V = 0.01$) (Figure 6). Stream reaches marked with a B are from the lower Clinch. These stream reaches were excluded from the correlation analysis. Stream reaches marked with an A are from the upper Clinch. Stream gradient and river kilometer were also significantly correlated with the number of mussel species found. None of these variables were significantly correlated with the number of mussel species reported by Ortmann (1918). This was probably due to the difficulty Ortmann had in sampling certain reaches of the Clinch. Ortmann typically traveled by train and sampled at river railroad crossings. Some of the largest mussel concentrations reported from the upper Clinch were largely missed by Ortmann because of inaccessibility.

Introduced Species

The introduced Asiatic clam *Corbicula cf. manilensis* has continued to spread throughout the southeastern United States since its discovery in the Tennessee River in 1959 (Sinclair and Ingram 1961). *Corbicula* was first reported from the Clinch River by Bates (1975). This species was not included in this study but was noted as widespread and extremely common throughout the Clinch. Based on the number of live specimens observed in the river and the number of fresh-dead specimens found in muskrat middens, *Corbicula*

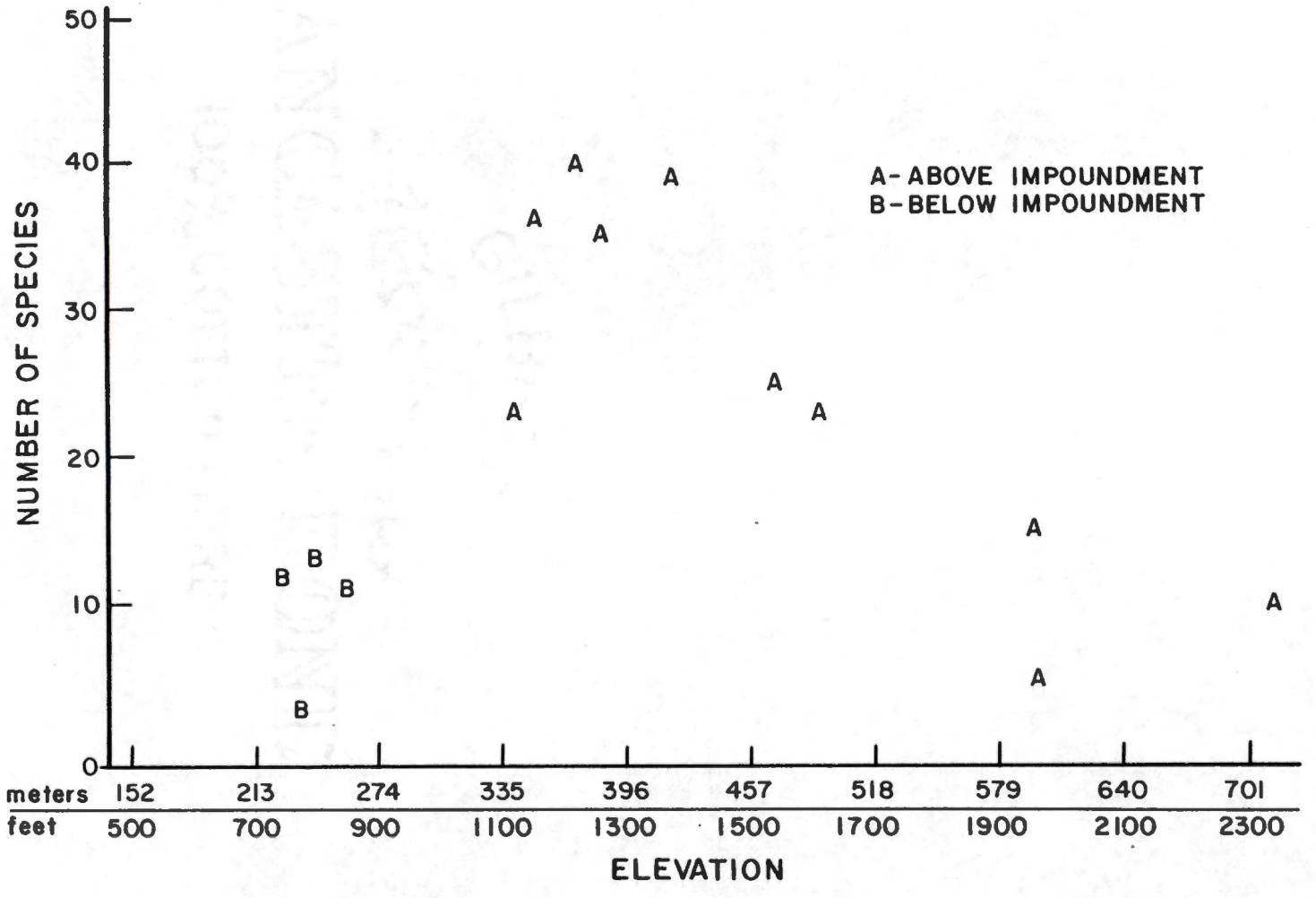


FIGURE 6. Plot showing elevation changes in meters and recent mussel distributions in the Clinch River (Ahlstedt 1978 to 1983).

is the most abundant mussel species in the Clinch. During the course of this study, muskrats appeared to be feeding more heavily on Corbicula than native mussel species. This may be due in part to large densities, availability, relative small size for easy opening, and its presence in all types of habitat. At the present time, it is doubtful that Corbicula is out-competing the native mussel fauna in the Clinch for food and/or habitat, and is possible that it is relieving the pressure on the native mussel fauna.

CHAPTER VI

DISCUSSION AND CONCLUSIONS

The Clinch River contains the richest assemblage of freshwater mussels (including Cumberlandian species) remaining in the upper Tennessee River. A total of 47 species of freshwater mussels were reported during recent surveys. Ortmann (1918) had previously reported 60 species of mussels prior to impoundment and major developments in the watershed (Table 1, page 17).

Impoundments have had the greatest impact on the mussel fauna in the Clinch River. Stream impoundments affect species compositions by eliminating those species not capable of adapting to reduced flows, altered temperature regimes, and anoxic conditions. Both Norris and Melton Hill dams draw water from the hypolimnion of their storage reservoirs. Water drawn from the hypolimnion causes the stream below the dam (reservoir tailwater) to differ significantly from preimpoundment conditions. The effects of hypolimnial discharges include: altered temperature regimes, extreme water level fluctuations, reduced turbidity, seasonal oxygen deficits, and high concentrations of certain heavy metals (Hynes 1970; Isom 1971; TVA 1980b). Biological responses attributable to these environmental changes typically include reductions of fish and macroinvertebrate communities (Isom 1971; Fuller 1980). Hickman (1937) predicted that Norris dam would have a deteriorating effect on the molluscan fauna in the Clinch River. Cahn (1936) reported 45 mussel species in the lower Clinch

prior to closure of Norris dam. In a return visit to the area four months later, not a single live specimen was found. During recent sampling in the lower Clinch, 20 species of freshwater mussels were found. Of these 20 species, 7 species (Amblema costata, Anodonta grandis, A. suborbiculata, Cyclonaias tuberculata, Lasmigona complanata, Proptera alata, and Quadrula pustulosa) are surviving impoundment and reproducing in limited numbers. Three of the species (Anodonta grandis, A. suborbiculata, and L. complanata) have recently colonized the lower Clinch River since being impounded. These species are typically found in the overbanks of impoundments (Bates 1962, 1975; Parmalee et al. 1982). The remaining 13 species, with the exception of Cumberlandia monodonta, were found in such low numbers and poor condition that their survival is tenuous. Cumberlandia monodonta was also found in extremely low numbers; however, evidence of reproduction (small, young specimens) was observed at one site below Norris dam.

Freshwater mussels were relatively widespread throughout most areas of the upper Clinch. During recent studies, 43 mussel species were found. Ortmann (1918) reported 42 mussel species from the same area.

Stream reaches immediately below the Appalachian Power Company's steam-electric generating plant at Carbo, Virginia, are apparently still affected by operations at this plant (Cairns et al. 1971). Freshwater mussels have failed to recolonize this reach of the Clinch below the plant site (Bates and Dennis 1978); and more recently,

experimental mussel transplants made below the plant site have failed (Richard Neves, personal communication). Tremendous amounts of fly ash are routinely deposited in holding pits along the banks of the Clinch adjacent to the plant site. The steep mountainous terrain in this reach of the Clinch and the close proximity of the fly ash to the river poses a serious problem in the event of a flood or the collapse of a holding pit during heavy rainfall. A large mine dump (tailings pond) is also located at Dump's Creek adjacent to the steam plant at Carbo. Freshwater mussels may be unable to recolonize this section of the Clinch because of fly ash leaching into the river or silt and coal fines entering the Clinch from Dump's Creek. This dump area is considered to be one of the major polluting sources impacting freshwater mussel communities in the river.

Freshwater mussels in the upper Clinch exhibited longitudinal distribution throughout the river. Masnik (1974), while studying fish distributions in the Clinch, observed similar faunal changes with regard to increases in stream gradient. Bogan and Starnes (1983) and Starnes and Bogan (1982) made similar observations for mussel populations in the Little River and Little South Fork Cumberland River. Species diversity and abundance generally became less at collecting sites in the upper headwaters of the Clinch. The number of species varies according to the size of the drainage area, flows, stream gradient, and elevations (Hynes 1970; Hawkes 1975; Strayer 1983).

Abrupt changes in stream gradient are apparently a major physical barrier to mussel species distributions in the headwaters of the Clinch. Freshwater mussels were unable to colonize some of these areas because of changes in the fish fauna (lack of suitable host species), boulder and bedrock substrates, nutrient loss, or scouring action during periods of heavy rainfall. Usually near the end of a steep gradient change there was a long, deep pool not conducive for riverine mussel species.

CHAPTER VII

SUMMARY

1. From 1978 to 1983, 47 species of freshwater mussels (naiads) were reported from the Clinch River. Ortmann (1918) reported 60 mussel species from the Clinch River.

2. Four mussel species are new to the Clinch River fauna since Ortmann. Three of these (Anodonta grandis, Anodonta suborbiculata, and Lasmigona complanata) have colonized the lower Clinch since impoundment. Quadrula sparsa was also found and occurs only in the upper Clinch.

3. Reservoirs have greatly reduced the freshwater mussel fauna in the Clinch River and are largely responsible for the extirpation of eight species previously reported from the lower Clinch.

4. Freshwater mussels have been unable to recolonize the upper Clinch River below the Appalachian Power Company's steam-electric plant at Carbo, Virginia.

5. This study showed a distinct longitudinal distribution of freshwater mussels in the upper Clinch with an increase in the number of species downstream with increasing stream size.

6. Abrupt changes in stream gradient are effective physical barriers for mussel distributions in the upper Clinch.

CHAPTER VIII

RECOMMENDATIONS

The Clinch River contains the richest and most diverse mussel fauna remaining in the southeastern United States. In order for this fauna to survive the next century it is essential that careful management decisions are made to protect the resource at risk. An educational program must first be established to point out the basic problems, uniqueness of the river system, rarity of the resource, the river's potential value both aesthically and economically, and the penalities or future consequences for its abuse. A program such as this may help to eliminate some of the misconceptions about the value of preserving species and their habitat. Secondly, negative impacts occurring in the watershed (i.e., fly ash, active and abandoned mines, and coal washing) must be identified and corrected before additional damage is done. Local, state and federal agencies presently have sufficient laws and regulations to protect the river system; however, the support of these agencies and greater law enforcement power are crucial for protecting the resource. Third, the Clinch River should be investigated for scenic river status under the National Wild and Scenic Rivers Act program. Finally, a clearing-house must be established to review all proposed projects or developments in the Clinch River watershed. This would help to eliminate most problems before they arise instead of after-the-fact.

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VITA

Steven Albin Ahlstedt was born in Jamestown, New York on September 29, 1946. He attended various schools in the Jamestown area and graduated from Southwestern Central High School in June 1964. Mr. Ahlstedt entered the United States Air Force in December 1965, and was released from active duty in March 1969. While in the Air Force, he worked in military intelligence and is a Viet Nam veteran. He attended Alfred University in Alfred, New York, and graduated in 1973 with a Bachelor of Science degree in Biology/Geology/Environmental studies.

In September 1975, he was accepted as a graduate student at The University of Tennessee, Knoxville. In June 1984, requirements for the Master of Science degree with a major in Wildlife and Fisheries were completed.

From October 1974 to present, Mr. Ahlstedt has been employed by the Tennessee Valley Authority in Norris, Tennessee as a fisheries biologist. He married the former Linda Esther Carlson on June 25, 1970.