ALAN C. BUCHANAN

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**CONTENTS**

## EDITORS' NOTE

After a lengthy hiatus, STERKIANA is back in circulation. The editors are now using their own desktop publishing equipment which will greatly facilitate production of future issues. We plan to publish one or two numbers per year, depending on the availability of material.

The purpose of STERKIANA was well stated by long time editor, Aurele La Rocque, in his first issue, printed in November, 1959.

> The purpose of STERKIANA is to serve malacologists and paleontologists interested in the living and fossil non-marine Mollusca of North and South America by disseminating information in that special field.

In keeping with the original intent of the journal, we continue to welcome papers on distribution and ecology of non-marine molluscs. While we will consider papers on any aspect of non-marine molluscan biology, we prefer not to publish species descriptions. As in the past, all papers published in STERKIANA will be subjected to peer review prior to publication.

The cost of subscription will be included in a future mailing.

Please address all correspondence to:

Sally Dennis
Biology Department
Radford University
Radford, VA 24142

Phone: (703) 831-5645 (University)
(703) 268-5960 (home)

# Distribution and Banding Patterns of *Cepaea hortensis* and *C. nemoralis* at Cape Ann, Massachusetts

**Ralph W. Dexter**
Department of Biological Sciences
Kent State University, Kent, Ohio 44242I

## I. INTRODUCTION: Origin of Cepaea hortensis in North America

There are three schools of thought concerning the origin of *C. hortensis* in North America. Amos Binney (1837) published the first New World record (as *Helix subglobosa*) from Cape Ann, Mass., noting it was especially abundant on Salt Island. It was assumed to be an introduced species. Gould (1841) also believed it was introduced by commerce. He wrote, "*Helix* [i.e. *Cepaea*] *hortensis* is as yet confined to some limited parts of the sea-coast, as the extremities of Cape Ann and Cape Cod." The Gould-Binney report (1870) stated that it "has been undoubtedly imported to this continent, and has not as yet made great advances into the interior". W. G. Binney (1885) later placed this species in the genus *Tachea*, and still believed it was introduced by commerce, although by then he had some question on the matter. Pilsbury (1890) disagreed with Cockrell who regarded it as a native species. Johnson (1906) reviewed all records to-date including those from Cape Ann, and believed it was an introduced species. Nylander (1908) thought it was introduced by early French settlers in Canada. In more recent times, Lindroth (1957) reviewed the problem of origin and banding patterns carefully and concluded that the original population must have been heterozygous and not ancient. He still maintained this belief in a chapter he later published in a volume by Love & Love (1963). In that same volume Walden (1963) also reviewed the problem and also concluded "there is no doubt that part of the population is of a recent anthropochorous nature."

On the other hand, Morse (1867) questioned whether this snail was introduced by commerce, and Bolles (1871) stated "we cannot suppose the hand of man placed them there," especially on islands uninhabited and seldom visited, but like Walden he suggested that possibly some European specimens were introduced which mingled with native specimens. Cockrell (1890) received specimens from Cape Ann, Mass., and believed they were a native species. Tryon (1894) pointed out that since *C. hortensis* was found in pre-Columbian shell-heaps it "cannot be regarded as a recent immigrant." By 1896 Morse was convinced (Morse, 1896) that from his own collections from shell-heaps on islands of Casco Bay it must be a native species confirming his earlier doubts about an artificial introduction. Winkley (1904) believed *C. hortensis* came from Europe by natural migration rather than by human agency. He believed it is a survivor on the edge of the continental glacier and now found largely on outlying islands. Later, (Winkley, 1916) he called attention to collections from Indian shell-heaps on Martha's Vineyard. Johnson (1915), from specimens associated with the bones of extinct mink on an island in Penobscot Bay, was convinced they lived locally before colonization. Wurtemberg (1919) also reported specimens from pre-historic shell-heaps. However, Ingram (1944) later called attention to land snails being carried into shell-heaps by shrews, which may possibly explain some of the collections of *C. hortensis* from that source.

In that connection it is interesting to note a letter sent by Manly Hardy to F. W. Putnam at the Peabody Museum of American Archeology and Ethnology 12 February 1878, "one thing which greatly perplexes me, was the abundance of whole land-snail shells everywhere to be found among the remains [shell-heap]. If eaten for food they would have been broken. If used for ornament they would have holes where they were strung. I found plenty of whole but no broken ones." It is possible such land snails were buried by shrews as shown by Ingram, and might explain the presence of shells of *C. hortensis* in shell-heaps.

Pilsbury (1939) summarized all of the North american records to-date and reviewed the theories of origin in North America presenting arguments both pro and con, and de Beaufort (1951) also reviewed the opposing points of view. Recent geological and biogeographical studies support the possibilities of a natural introduction since "until the early Tertiary, there seems to have been a land connection between North America and Eurasia" (Dansereau, 1957).

It is possible that the North American populations may be a mixture of a native population with others introduced after colonization by man, and the writer is in agreement with that conclusion. There is some good evidence for a native population. Clarke and Erskine (1961) have shown a carbon-14 age of 700+ 225 yr. B. P. based on marine snails collected with *C. hortensis* from a shell-heap, but there is also a strong possibility that some individuals have also been introduced from Europe by human agency. The restricted distribution along the North Atlantic coast of North America could possibly be explained by the fact that salt-spray is not carried very far inland, because of the prevailing winds from the west, whereas in Europe salt-spray can be carried much farther inland by the prevailing winds. *C. hortensis* seems to be related to the presence of salt-spray, at least on North American shores.

## II. Distributions of C. hortensis at Cape Ann, Mass.

The first collection of *C. hortensis* from Cape Ann, also the first from North America, was made by Dr. Amos Binney in 1837 (Binney, 1837, 1851). Subsequently, records or reviews of records have been published by Gould (1841), Morse (1867), Gould-Binney (1870), Anon (1887), Cockrell (1890, 1899), Pilsbury (1897), Johnson (1906, 1913, 1915), Pilsbury (1939), and Lindroth (1957). In addition, records have been published from nearby localities by Russell (1852), Tufts (1856) and Anon (1864). In 1951 I began to collect specimens of *C. hortensis* at Cape Ann. During 1954-60, after two dry summers, I made an intensive effort to locate colonies of this land snail throughout the Cape Ann area. Information from local field naturalists and responses I received from a request in the Gloucester Daily Times led to the location of 15 colonies (two of them, Nos. 5 and 13, were added the last year of the survey). Figure 1 shows the location of these 15 colonies around the perimeter of Cape ann. The habitat in most cases was a grassy, weedy, or shrubby field, or over-grown garden. Usually large boulders, stone walls, or a ledge were present, and often the snails were found on whetstone following a rain (see appendix for details). It has been well known that this snail seldom gets far away from salt-water, and the presence of salt-spray may be the limiting factor. My study was concerned with local distribution, the banding patterns found in this area, and changes from one year to another in abundance and banding patterns.

*C. Nemoralis* has been reported from Cape Ann, but the records are somewhat dubious. Reve (1863) stated "*Helix nemoralis...* has been transported to the U.S. and keeps to the eastern parts near the sea, especially the lower extremity of Cape Cod and Cape Ann." Without much question this was an error in which *nemoralis* was inadvertently substituted for *hortensis*. In the Mollusk Department at the Museum of Comparative Zoology there are two shells (no.125863) of *C. nemoralis* received in August, 1940, from the Grand Rapids Public Museum in Michigan and labeled "from Cape Ann, Mass." It is believed that these might be the source of a report from Taylor (1914) that this species was "reported from cape Ann, Mass., by Mr. Bryant Walker." Reed (1964) listed *C. nemoralis* from Gloucester, Mass., collected by Roper in 1980 (specimens in the Carnegie Museum, Pittsburgh), but no mention is made of the specimens at M.C.Z. I have never found this species on Cape Ann, and if it ever did occur naturally it is likely the population has died out. In 1959-60, I was given a large collection of *C. nemoralis* from Lynn, some 20 miles southwest of Cape Ann, on which a detailed report has already been published (Dexter, 1966). Attempts were made to establish colonies of *C. nemoralis* on Cape Ann from specimens collected at Lynn. Details are given below.

## III. Banding patterns of C. hortensis at Cape Ann, Mass.

Table 1 gives an analysis of 6208 snails, including 20 varieties, collected from 14 colonies (station 15 is not included because of the small sample taken there). Unbanded snails (00000) were taken in greatest number (47.8%) and were found in all but three stations. Five-banded snails (12345) were nearly as common (47.0%) and were found in all but one station. The third largest collection (2.0%) consisted of four bands with band #2 missing (10345).

Two comparable islands (Stations 1 and 10) had opposite results. Kettle Is. had all but one snail with formula 12345, while Salt Is. had nothing but 00000. Also, the closest station to

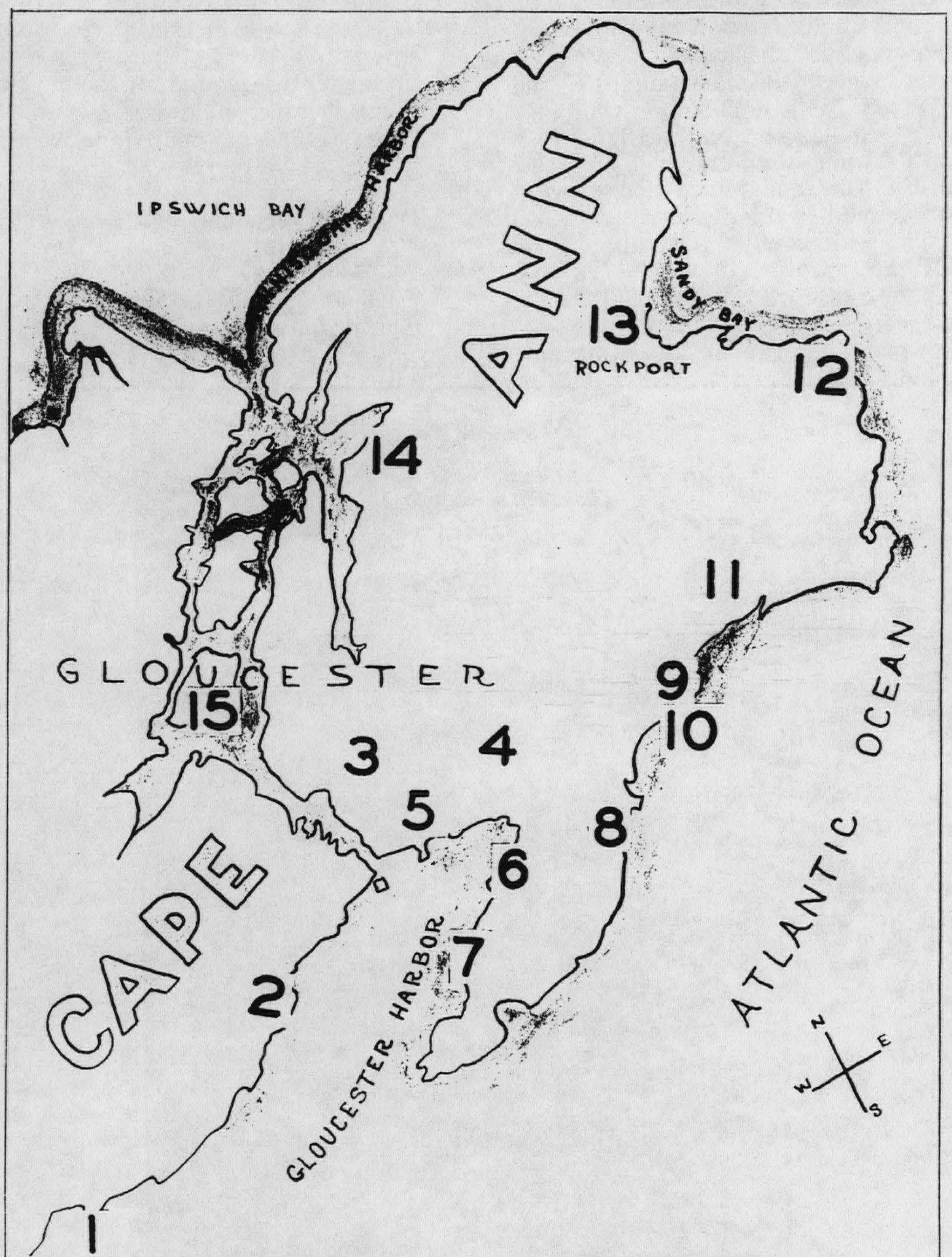


**Figure 1.** Location of *Cepaea hortensis* colonies, Cape Ann, Massachusetts.

Salt Is. (no. 9) likewise had the opposite result with nearly all snails having the formula 12345.

Two of the stations farthest away from salt water (stations 3 and 4) had the greatest variety of banding patterns (15 and 8), but the station farthest from saltwater (station 13) had almost nothing but unbanded snails.

The two smallest collecting stations (7 and 8) had relatively small populations with only two varieties, but station 7 had nearly all five-banded snails while station 8 had an equal number of five-banded and unbanded forms.

Stations 2 and 6, similar in many ways, had an equal number of varieties, but station 2 had a preponderance of form 12345 while station 6 had a preponderance of form 00000. On the other hand, stations 9 and 14, on opposite sides of the Cape had a very similar ratio of banding patterns. Station 3 yielded five unique specimens, three other stations (2, 6, and 12) had one unique specimen, but the remaining ten stations did not have any.

Surprisingly, station 11, consisting largely of loose sand, had the third largest total count. The snails were found for the most part on the wooden walks following a rain. Typically, ledges, boulders, and stone walls were the favored background.

## IV. Local Variations and Temporal Changes

Bolles (1871) pointed out that while in England banded shells were more numerous than plain, specimens collected in the United

Table I

Analysis of Color Patterns of *Cepaea hortensis* from Cape Ann, Mass., 1951, 1954-60

| | Station No. | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stripe Pattern | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | No. Snails | No. |
| 12345 | 52 | 304 | 411 | 241 | 19 | 434 | 53 | 31 | 86 | - | 351 | 9 | 2 | 926 | 2919 | 13(1)(2) |
| (12)345 | - | 13 | 9 | 1 | - | 1 | 2 | - | - | - | - | 3 | - | - | 29 | 6(4)(6) |
| 12(34)5 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| 123(45) | - | - | 7 | 6 | - | - | - | - | - | - | - | - | - | - | 13 | 2(7)(7) |
| (12)3(45) | - | 3 | 5 | - | - | - | - | - | - | - | - | - | - | - | 8 | 2 |
| 1(23)(45) | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| (123)45 | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | 1 |
| (12345) | - | - | 2 | - | - | - | - | - | - | - | - | - | 1 | - | 3 | 2 |
| 1234a4b5 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | 2 | 2 |
| 1234a(4b5) | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| 10345 | - | - | 1 | - | - | 53 | - | - | 3 | - | 43 | - | - | 29 | 129 | 5(5)(3) |
| 12045 | - | 6 | 5 | 3 | 1 | 15 | - | - | 2 | - | 20 | - | - | 25 | 77 | 8(3)(4) |
| 12305 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| 120(45) | - | - | 1 | 1 | - | - | - | - | - | - | - | - | - | - | 2 | 2 |
| (12)0(45) | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | 2 | 2 |
| 02305 | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| 10045 | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 | 1 |
| 00340 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| 00300 | - | 1 | 6 | 12 | - | 29 | - | - | - | - | - | - | - | - | 48 | 4(6)(5) |
| 00000 | 1 | 133 | 297 | 563 | 37 | 881 | - | 31 | - | 43 | 499 | 322 | 161 | - | 2968 | 11(2)(1) |
| Totals: No. snails | 53 | 461 | 749 | 828 | 57 | 1414 | 55 | 62 | 91 | 43 | 913 | 336 | 164 | 982 | 6208 | |
| No. varieties | 2 | 7 | 15 | 8 | 3 | 7 | 2 | 2 | 3 | 1 | 4 | 5 | 3 | 5 | | |

Note: 12345 indicates presence of five stripes, 00000 indicates absence of all stripes. The numbers in parenthesis in the last column give, first the rank for the number of stations with a certain stripe pattern, and second, the rank for stations based on total snails collected.

**Table II**

Annual Collections of *Cepaea hortensis* at Dolliver's Neck, Magnolia, Mass., 1951-60 (Station 2)

| | Year Sampled: | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 51 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
| Stripe Pattern* | | | | | | | | |
| 12345 | 44 | 8 | 60 | 80 | 28 | 51 | 22 | 11 |
| (12)345 | 1 | - | 4 | 5 | - | 3 | - | - |
| (12)3(45) | - | - | - | 2 | - | 1 | - | - |
| 12045 | - | - | 1 | - | 1 | 4 | - | - |
| 02305 | 1 | - | - | - | - | - | - | - |
| 00300 | 1 | - | - | - | - | - | - | - |
| 00000 | 22 | 5 | 19 | 40 | 18 | 17 | 9 | 3 |

States up to that time were mostly all-yellow, and that banded shells were scarce. On the other hand, Hanham (1893) later found that the plain form was least abundant in the Gaspe Region, but Cockerell (1899), reporting on a collection made by G. H. Clapp from Rockport Mass. (on Cape Ann), found the bandless variety most common. Johnson (1904) found only bandless forms in a collection he made on Cape Cod, but Clapp (1907) found the banded varieties to predominate on Bass Island off the coast of Maine, but at Bar Harbor, and on Bar Island in Frenchman's Bay, they were all unbanded. William F. Clapp wrote to Victor Sterki on 1 August 1912, "I am sending a few *Tachea hortensis* [*Cepaea hortensis*] alive from High Plains, Duxbury, Mass. They are all of the unbanded variety in this place. In 10,000 specimens not one showing any bands."

Binney (1851) noted changes in abundance and banding patterns on Salt Island and at a later date Johnson (1913) wrote that *C. hortensis* "seems to undergo a considerable change from time to time. When I first visited Salt Island [Cape Ann] ten years ago it was impossible to find a single specimen with bands. At the present time banded varieties are said not to be uncommon. "However, on a subsequent visit Johnson did not find any banded specimens. Lindroth (1957) reported that *C. hortensis* collected from Salt Island in 1837 were all unbanded, but in 1851 banded varieties were not uncommon. However, I failed to find any banded forms in my collections during 1956-60.

In a study of *C. nemoralis*, McConnell (1935) found that the proportion of unbanded snails increased five-fold over a period of 32 years in a colony at Lexington, Virginia, whereas the five-banded variety was found less than one-half in 1930 compared to 1898. Shells with band no. 3 only, however, increased between two and three fold. Schilder (1949) pointed out that

**Table III**

Annual Collections of *Cepaea hortensis* at Madison Square, Gloucester, Mass., 1956-60 (Station No. 3)

| | Year Sampled: | | | | |
|---|---|---|---|---|---|
| Stripe Patterns* | 56 | 57 | 58 | 59 | 60 |
| 12345 | 109 | 113 | 88 | 58 | 43 |
| (12)345 | 2 | 1 | 2 | 3 | 1 |
| 12(34)5 | 1 | - | - | - | - |
| 123(45) | 1 | 1 | 4 | 1 | - |
| (12)3(45) | 3 | - | 2 | - | - |
| 1(23)(45) | - | - | 1 | - | - |
| (1-2-3-4-5) | - | - | - | - | 2 |
| 1234(45) | - | - | - | - | 1 |
| 10345 | 1 | 1 | - | - | - |
| 12045 | - | - | 3 | 1 | 1 |
| 12305 | - | - | - | - | 1 |
| 120(45) | - | - | 1 | - | - |
| 00340 | 1 | - | - | - | - |
| 00300 | 5 | - | 1 | - | - |
| 00000 | 40 | 88 | 71 | 45 | 23 |

Table IV

Annual Collections of *Cepaea hortensis* at Barberry Shore, E. Gloucester, Mass., 1956-60 (Station No. 6)

| | Year Sampled | | | | |
|---|---|---|---|---|---|
| Stripe Pattern* | 56 | 57 | 58 | 59 | 60 |
| 12345 | 47 | 113 | 116 | 41 | 117 |
| (12)345 | - | - | - | - | 1 |
| 10345 | 1 | 12 | 16 | 6 | 19 |
| 12045 | 1 | 3 | 6 | 1 | 4 |
| 10045 | - | - | 1 | - | - |
| 00300 | 25 | - | 1 | 3 | - |
| 00000 | 83 | 235 | 296 | 84 | 183 |

* 12345 indicates presence of five stripes; 00000 indicates absence of all stripes.

theoretically there are 89 possible combinations of banding and all have been found in Europe theoretically there are 89 possible combinations of banding and all have been found in Europe for *C. nemoralis*, but only 60 combinations have been found in *C. hortensis*. On Cape Ann I found only 21 banding patterns. Tables 2-4 show changes in banding patterns collected from three stations during 1951 and 1954-60. Stations 2 and 3 showed a degree of homogeneity over the years sampled, but station 6 did not. Also, at station 2, the five-banded form was often about twice the number of the unbanded form, while at station 6 the reverse was true - about twice as many unbanded snails were collected each year as the five-banded form.

Bengston et al. (1976) found unbanded *C. hortensis* in Iceland to be more frequent in open habitats than in darker habitats, and the latter also had a greater frequency of fused bands. From a study of the effects of density on polymorphic land snails Owen (1965) suggested that polymorphism in land snails should be re-examined in terms of population density.

Cain and Sheppard (1950) concluded that "selection through the agency of predators hunting by sight, acting upon a stable polymorphic situation was shown to be the most important factor determining the general appearance of different populations." Clarke (1960) showed that "colonies in woodlands tend to have a high proportion of banded shells with the bands fused together - a condition that gives an overall brown appearance which matches the background of brown leaf litter. Colonies from grasslands... a high percentage of unbanded forms which more closely resemble the uniform green background of grass."

Much research has been done over a long time, especially in England, on the survival value of color and banding morphs found in *Cepaea*. Diver (1940) early concluded that there is "no indication that the different color and band forms confer any advantage, not that the interspecific differences are in anyway adaptive." Similarly, Cain and Sheppard (1954) concluded that "although polymorphism in this [*C. nemoralis*] and other species is controlled by selection, there is no evidence that it is adaptive and contributes to the persistence or ecological expansion of the species." This writer and probably many investigators would agree with Jones, Leith, and Rawlings (1977) that the problem of polymorphism is "complex and perhaps unique explanations are needed for almost every *Cepaea* population."

## V. Abnormal Shells of C. hortensis

Occasionally, snails are found with reversed symmetry. Daniels (1912) reported that "the reversed specimens [of *Helix*] known do not exceed 10 or 12." Dexter (1958) reported a sinistral shell of *C. hortensis* found at Cape Ann. (this specimen was donated to the Museum of Comparative Zoology). From a study of 50,000 adult specimens of *C. hortensis*, Bantock et al. (1973) found only two sinistral shells. They concluded that such reversed symmetry is "unlikely to be genetic in origin."

## VI. Additional Collecting Records for C. hortensis at Cape Ann (1961-69)

Between 1961-69 brief visits were made to most of the established collecting stations. In 1961 collections were relatively small for the most part, and results were not very different from previous years except for two new records. At station 2 a snail was collected with banding formula 10345 which was new for that station Also, at station 5 a snail was found to have the formula 00045 which was new for the Cape Ann colonies. During 1962-65, the summers were very dry and *Cepaea* snails were either not collected or were very scarce.

In the summers of 1966-69 relatively small numbers were collected which may have been the results of the dry summers from the previous four years. Only one new record was made. At station no. 2 a snail was collected in 1967 which had the formula 123(45) which had not been found previously at that station.

## VII. Attempts to establish colonies of C. hortensis and C. nemoralis at Cape Ann

In 1958 numerous specimens of *C. hortensis* were released in a low land pasture on Riggs Point and in a highland pasture on Wheeler's Point. In 1959 about 90 *C. nemoralis* from Lynn, Mass., were released on the upland of Riggs Point. In 1960, some specimens of *C. nemoralis* from Lynn were given to Mrs. Otis Dana of Rockport to attempt colonization. A brief report of subsequent observations over two years is given in Dexter (1966:42). Also, in 1960, I scattered 667 live specimens of *C.*

*hortensis* on the upland of Riggs Point. In 1966, 108 live specimens of *C. nemoralis* from Lynn were released in a weed patch on Cherry St. at the edge of Dogtown Common, and in 1967, 266 were released on the lowland pasture of Riggs Point, and 120 were released in a pasture on Dogtown Common.

In the summer of 1961, I collected 26 *C. hortensis* from the introduced colony on the upland at Riggs Point. Most of them were plain yellow, but seven were banded. Five had the formula 12345 and two with the formula 00345. During the dry summers of 1962-65 none were seen on Riggs Point.

In 1966, after a night of soaking rain on 22 September, one yellow *C. hortensis* was found on the upland of Riggs Point and another yellow one found in the pasture on Wheeler's Point. At the same time a single snail of *C. nemoralis* with five-bands was observed at the point of recent release in a weed-patch at the edge of Dogtown Common. In the summer of 1967 one plain and one five-banded snail of *C. nemoralis* were found at the same place. These were the only ones recovered that season from the introduced colonies.

In the summer of 1968, a single five-banded *C. hortensis* snail was found on the upland at Riggs Point, and three snails of *C. nemoralis*, two five-banded and one with the second band missing, were found in the weed-patch at the edge of Dogtown Common. In 1969, a single unbanded specimen of *C. hortensis* was found in the pasture at Wheeler's Point which was the only one collected from the introduced colonies that year. However, in 1970, a large colony of *C. nemoralis* was flourishing in the weed-patch at the edge of Dogtown Common. Over 500 were plain yellow, 95 were five-banded, and two had the formula 12045. A house was then constructed on the site of this colony and snails were never collected there again.

On 12 July 1975 a single five-banded *C. hortensis* was collected on the upland of Riggs Point, and on 26 June 1977 four snails of *C. nemoralis* were found in the lowland pasture at Riggs Point. These were the last to be collected from sites where these snails had been introduced. It would appear that the artificial introduction of these gastropods is not a simple matter.

## SUMMARY


1. Some malacologists have long considered *Cepaea hortensis* to be an introduced species in North America, but others considered it to be a native population, which seems a very reasonable conclusion.

2. Fifteen colonies of *C. hortensis* have been found around the perimeter of Cape Ann, Mass., never far from salt water. The first published record for North America was made from Cape Ann in 1837.

3. The former occurrence of *C. nemoralis* at Cape Ann is questionable. No recent records are known, however, the species was introduced during 1959-1966 in an effort to establish colonies, but they did not persist long.

4. A total of 20 banding patterns of *C. hortensis* were collected from 14 sizeable colonies between 1951-60 around the margin of Cape Ann. Unbanded snails were most numerous (47.8%) while five banded snails were nearly as common (47.0%).5. The proportion of different banding patterns varied from place to place and from time to time, even though the environments were often similar. There is no simple explanation for these differences.

6. One sinistral shell of *C. hortensis* was collected.

7. Between 1961-69 samples were small because of dry weather, especially during 1962-65, but one new banding type was found for the first time for the Cape Ann colonies.

8. Attempts were made to establish colonies of *C. hortensis* and *C. nemoralis*. Only one of the latter flourished, and that was destroyed during subsequent construction of a building.


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## Appendix

Brief Description of Environments and Size of
Collecting Stations in Square Meters

| Station No. | Location | General Nature | Proximity to Salt Water | Approx. Size of Coll. Area |
|---|---|---|---|---|
| 1 | Kettle Is. | Weeds and Shrub | 25 m | 200 $m^2$ |
| 2 | Dolliver's Neck | Grasses, weeds, and stone walls | 25 m | 250 $m^2$ |
| 3 | Madison Sq. | Weedy Garden and glacial boulders | 600 m | 50 $m^2$ |
| 4 | Portugese Hill | Weeds, shrubs, exposed granite ledges | 480 m | 400 $m^2$ |
| 5 | Shoreline of Inner Gloucester Harbor | Grasses, weeds and gardens | 150 m | 200 $m^2$ |
| 6 | Barberry Shore of Gloucester Harbor | Grasses, weeds, compost pile and garden | 30 m | 250 $m^2$ |
| 7 | Rocky Neck | Flower Garden and granite ledge | 30 m | 15 $m^2$ |
| 8 | Bass Rocks | Weeds on a rocky shore | 10 m | 20 $m^2$ |
| 9 | Brier Neck | Grasses and weeds in sandy soil along stone stairs | 20 m | 25 $m^2$ |
| 10 | Salt Is. | Weeds and shrubs with exposed ledge | 15 m | 100 $m^2$ |
| 11 | Long Beach | Grasses and weeds in sand along wooden walkway | 40 m | 30 $m^2$ |
| 12 | Straiths-mouth Neck | Grasses, weeds, and compost pile | 120 m | 30 $m^2$ |
| 13 | Poole Hill | Grasses, weeds, shurbs and stone walls | 780 m | 250 $m^2$ |
| 14 | Goose Cove | Grasses, weeds, garden with stone walls and ledge | 25 m | 225 $m^2$ |
| 15 | Rust Is. | Grasses, weeds, granite | 50 m | 15 $m^2$ |

# Freshwater Mussels (Unionidae) of The Hatchie River, a Tributary of the Mississippi River, in West Tennessee

**Don Manning**
Rt. 2, Box 81A
Buchanon, Tennessee, 38222

## ABSTRACT

A brief survey of the Hatchie River, a West Tennessee stream draining directly into the Mississippi River, during the summers of 1980 through 1983 revealed 33 taxa of unionacean mussels and the Asian clam, *Corbicula fluminea* (Muller, 1774). Three of these species, *Uniomerus declivis* (Say, 1831), *Obovaria jacksoniana* (Frierson, 1912) and *Villosa vibex* (Conrad, 1834), have not been previously reported as occurring in the State of Tennessee. The mussel assemblage of the Hatchie River shows a definite southern or Gulf Coastal affinity.

## INTRODUCTION

Several surveys of the freshwater bivalves of western Tennessee have been reported Ortmann (1925) surveyed the Tennessee River below Walden Gorge. This survey was later supplemented by van der Schalie (1938) with emphasis on that portion of the river bordering West Tennessee. Scruggs (1960), Bates (1962), Isom (1969) and Yokley (1972) have all done post-impoundment studies of the lower Tennessee River. Brown and Pardue (1980) recently reported the occurrence of *Uniomerus tetralasmus* in the lower Tennessee River drainage. Ortmann (1926) published the most recent survey of the mussels of West Tennessee, from rivers draining directly into the Mississippi River. An earlier report (Pilsbry and Rhoads, 1896) was incorporated into Ortmann's survey as was Lea's record from "Horn Lake Creek, Shelby Co., Tenn." Superficial recent surveys of the benthic organisms in the Obion, Forked Deer and Hatchie Rivers by the Corps of Engineers show *Corbicula fluminea (manilensis)* as the only bivalve inhabiting any of the three rivers (Anon., 1982). No other published report of the mussels from tributaries of the Mississippi in West Tennessee has come to the attention of the author. This survey was done in conjunction with the Tennessee Wildlife Resources Agency to establish a baseline from which to compare the Hatchie River, a relatively undisturbed river, with the Obion and Forked Deer Rivers which have undergone channel "improvement" and are essentially drainage ditches.

## STUDY AREA

The Hatchie River is located on the Mississippi Embayment of the Gulf Coastal Plain in southwestern Tennessee and northern Mississippi. The river arises in Northern Mississippi and is joined near the Mississippi-Tennessee state line by the Tuscumbia River and Cypress and Muddy Creeks. From there it flows northwesterly across Tennessee to it's outlet at Mississippi River mile 773, about 35 miles north of Memphis. The drainage basin is about 110 miles long. The river meanders within this basin and is considerably longer. The eastern one third of the basin lies within the physiographic region known as the West Tennessee Uplands, which is characterized as hilly with bands of rolling topography. The remainder of the basin falls within that region known as the West Tennessee Plain which has gently rolling typography with small ridges and drainage divides. The flood plain in the main stem of the river is quite wide and flat in the downstream section of the basin and narrows to a ridge and valley type in a fan-patterned area upstream. The main channel of the river has not been physically manipulated to any appreciable extent by man. However, a major portion of the main channel in Mississippi has been altered by stream excavation and realignment as has the main channel of the Tuscumbia River and fifty per cent of the other fifteen major tributaries (USDA 1970). That section of the Hatchie River from the Mississippi-Tennessee state line (Hatchie River mile 191.3) to its confluence with the Mississippi River has been designated a Class I State Scenic River by the 1970 amendment to the Tennessee Scenic Rivers Act of 1968 (Tenn. Dept of Public Health, 1976).

**Table I**

COLLECTING STATIONS

| Station Number* | Description |
|---|---|
| 1 | From Hwy 64 bridge upstream approx. 1 mile. East of Bolivar, Hardeman Co., TN |
| 2 | Ditch entering the Hatchie R. approx 1 mile above Hwy 76 bridge south of Brownsville, Haywood Co., TN |
| 3 | Bluff approx. 1/2 mile upstream from Hwy 76 bridge, south of Brownsville, Haywood, Co., TN |
| 4 | From Hwy 76 bridge downstream approx. 200 yds. South of Brownsville, Haywood Co., TN |
| 5 | From Interstate 40 bridge upstream to approx. 200 yds. below Hwy 76 bridge. South of Brownsville, Haywood Co., TN |
| 6 | Borrow pit along road in Hatchie National Wildlife Refuge, parallel to river between Hwy 76 and I-40 bridges, South of Brownsville, Haywood Co., TN |
| 7 | Borrow pit (McCool Lake) south of Hatchie R. and west of I-40 in Haywood Co., TN |
| 8 | Three mile section of Bear Cr., a cypress slough running through the Hatchie Nat. Wildlife Refuge, South of Brownsville, Haywood Co., TN |
| 9 | From Hwy 70 bridge upstream for approx. 1 mile. South of Brownsville, Haywood Co., TN |
| 10 | From Hwy 54 bridge west of Brownsville, to a point approx. 1 mile upstream. Haywood and Tipton Co.,TN |
| 11 | From Hwy 54 bridge west of Brownsville, to a point approx. 1/2 mile upstream. Haywood and Tipton Co., TN |
| 12 | From Hwy 51 bridge north of Covington to a point approx 1 1/2 mile upstream. Tipton Co., TN |

* listed in order from uppermost station downstream

Collecting for this survey was concentrated in the lower half of the basin. The river in this area winds slowly over a wide flood plain and has a slow but steady current. The only areas of slack current were encountered on the inside of the river bends and below sand bars. The river ranges from 20 to 30 meters in width and varies from 1 to 5 meters in depth. The substrate is primarily sandy silt or shifting sand in the faster current changing to silt along the edges and in areas of slack current. Limited reaches of the river have a firm pebbly or clay substrate, particularly where the river runs along low sandstone or clay bluffs. The majority of shells were found in the shoal-like areas associated with these bluffs or in the stable silt deposits along the stream edges. The ox-bow lakes, sloughs and borrow pits found on the flood plain and subject to flooding by the river were surveyed and the records collected from these sites have been included in this report as belonging to the Hatchie River Basin fauna.

River sections were surveyed during the low flow conditions encountered during the summers of 1980 through 1983. Collections were made by hand picking and looking for muskrat middens along the river while some collection was done with a four foot crowfoot brail.

Distinctions are drawn, in this report, between dead, relic and live shells. Dead shells were those found with no soft parts but with a lustre to the nacre, an intact hinge ligament and no erosion of the edges of the shell. Relic shells exhibited a soft and lusterless nacre and erosion of the periphery of the shell. Live mussels were found with the soft parts intact. Examples of all taxa collected are listed in this report as occurring in the Hatchie River Basin although they may be represented by only relic or dead specimens (Table II).

A complete set of voucher specimens has been deposited in the Harvard Museum of Comparative Zoology, Harvard University, with most taxa represented in a set deposited in the Ohio State Museum, Ohio State University. The remainder of the shells are in the author's personal collection.

## DISCUSSION

The brief survey work done in the summers of 1980 through 1983 on the Hatchie River revealed 33 taxa of unionids and the Asiatic clam, *Corbicula fluminea*, living in the river basin. All species previously reported from the direct drainage of the Mississippi River in western Tennessee were found in the Hatchie River. In addition, eleven species were found which have not previously been reported as occurring in this drainage (Table III). These species are: *Fusconaia ebenus, Quadrula nodulata, Plethobasus cyphyus, Pleurobema cordatum, Uniomerus tetralasmus, Uniomerus declivis, Leptodea laevissima, Obovaria jacksoniana, Villosa vibex, Obliquaria reflexa* and *Corbicula fluminea*. H. and A. van der Schalie (1950) considered *ebenus, nodulata, cyphyus, cordatum, laevissima* and *reflexa* part of the Mississippi River fauna, so their occurrence in the Hatchie is to be expected. *Uniomerus tetralasmus* is widespread in the lower Mississippi basin (Johnson, 1970), was recently reported from the lower Tennessee drainage (Brown and Pardue, 1980), and is common in all drainages in western Tennessee. *Uniomerus declivis* is found in the Gulf drainages from the Rio Grande drainage in Texas to the Coosa River system in Alabama and could have entered from the Mississippi River (Morrison, 1977). *Obovaria jacksoniana* and *Villosa vibex* are found in rivers to the south which now have no direct link to the Hatchie although only a low ridge separates the headwaters of the Hatchie and the Tombigbee River near Bonneville, Mississippi. The occurrence of *Corbicula fluminea* in the Hatchie is to be expected in light of the spread of this introduced clam (MaMahon, 1982).

The identification of *Uniomerus declivis* has been confirmed by Dr. David H. Stansbery (pers. Comm.) although Richard I. Johnson (1970) considered *declivis* an ecophenotype of *tetralasmus*. Morrison (1977) later gave cogent reasons for maintaining *declivis* as a distinct species. It has been included in this report because two isolated populations were found which differed markedly from the dominant type found in the western Tennessee drainages. Individuals from these populations differ from the dominant type by being smaller, much more arcuate, having a rough periostracum, having a distinct point at the posterior base and having no concentric bands of color. Examples of the dominant type (*tetralasmus*) were found nearby with no evidence of intergrading.

Burch (1973) lists *Anodonta grandis grandis* and *Anodonta grandis corpulenta* for the two forms found in the Hatchie River. H. and A. van der Schalie (1950) treat these two forms as species while noting the complexity of the *grandis* group. The examples from the Hatchie River are readily separable although existing in the same habitat so they are listed in this report as separate species. Richard I. Johnson and David H. Stansbery have confirmed the identifications of these two taxa.

Ortmann (1926) separated his examples of *Carunculina* from West Tennessee into *parva* and *texasensis* and noted that they were distinct. Since two forms were found in the Hatchie basin, the distinctions have been maintained in this report despite the opinion of Johnson (1976), shared by Burch (1973), that only *parva* is found west of the Appalachian Mountains.

*Lampsilis anodontoides anodontoides* and *L. anodontoides fallaciosa* are included in this report because examples fitting the description of both forms were found along with numerous intergrades. Ortmann (1926) treated all West Tennessee records as *fallaciosa* while van der Schalie (1950) lists both forms as occurring in the Mississippi River. Burch (1973), probably correctly, lists only *anodontoides*. The distinctions have been maintained in this report only to show that both "forms" are present.

Considerable controversy surrounds the identification of the *Lampsilis ovata-ventricosa* group from the Hatchie. Johnson (pers. comm) assigns *Lampsilis satur* to this group. Ortmann (1926) assigned *Lampsilis ovata satura* to his example from the Obion River while noting that it represented *ventricosa* in the south and intergraded with *ventricosa* in northern Arkansas. Most malacologists who have examined the Hatchie series assign *ventricosa* to the series.

The *Obovaria jacksoniana* and *Villosa vibex* identifications have been confirmed by Johnson and Stansbery.

Several species of mussels are rare in the Hatchie River (Table II). *Corbicula fluminea* is the most common shell encountered. *Quadrula pustulosa* and *Lampsilis anodontoides* are the most common and widespread of the unionids. Despite the silt load increase caused by tributary channelization and the pollution caused by

**Table II**
**MUSSEL SPECIES DISTRIBUTION HATCHIE RIVER**

| Mussel Species | Station Number 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Status* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Amblema costata | - | - | L** | L | L | - | - | - | L | L | L | L | C |
| *Fusconaia ebenus* | - | - | R | - | - | - | - | - | D | R | - | - | UC |
| *Fusconaia flava* | - | - | L | - | - | - | - | - | - | - | - | - | R |
| *Plectomerus dombeyanus* | L | - | L | - | - | - | - | - | - | L | L | L | C |
| *Quadrula nodulata* | - | - | - | - | - | - | - | - | - | - | - | L | R |
| *Quadrula pustulosa* | L | - | L | L | L | - | D | - | L | L | L | L | A |
| *Quadrula quadrula* | - | - | L | L | L | - | - | - | L | L | L | L | C |
| *Tritogonia verrucosa* | L | - | L | L | L | - | - | - | - | L | L | L | C |
| *Megalonaias gigantea* | - | - | L | L | L | - | - | - | - | L | L | L | C |
| *Plethobasus cyphyus* | - | - | R | - | - | - | - | - | - | R | - | D | R |
| *Pleurobema cordatum* | - | - | L | - | - | - | - | - | - | - | - | - | R |
| *Uniomerus tetralasmus* | - | - | - | - | - | L | L | L | - | - | - | L | C |
| *Uniomerus declivis* | - | - | - | - | - | - | - | L | - | - | - | - | R |
| *Anodonta grandis* | L | L | L | L | - | L | L | L | - | L | L | L | C |
| *Anodonta corpulenta* | - | L | - | - | - | L | L | L | - | L | L | - | C |
| *Anodonta suborbiculata* | - | - | D | - | - | L | L | - | - | - | L | L | UC |
| *Anodonta imbecillis* | - | - | - | - | - | L | L | L | - | - | L | - | UC |
| *Arcidens confragosus* | - | - | - | - | - | - | - | - | - | - | L | L | UC |
| *Lasmigona complanata* | - | - | - | - | - | - | - | - | - | - | L | L | UC |
| *Strophitus undulatus* | - | - | R | - | - | - | - | - | - | - | L | - | R |
| *Carunculina parva* | - | - | - | - | - | - | L | L | - | - | - | - | C |
| *Carunculina texasensis* | - | - | - | - | - | - | L | L | - | - | - | - | C |
| *Lampsilis anodontoides f. fallaciosa* | L | - | L | L | L | - | L | - | - | L | L | L | A |
| *Lampsilis anodontoides f. anodontoides* | - | - | - | - | L | - | L | - | - | - | L | - | C |
| *Lampsilis satur* | - | - | L | L | - | - | - | - | L | L | L | L | C |
| *Leptodea fragilis* | - | - | L | L | L | L | - | L | - | L | L | L | C |
| *Leptodea laevissima* | - | - | - | - | - | - | D | - | - | - | - | - | R |
| *Ligumia subrostrata* | - | L | - | - | - | L | L | L | - | - | - | - | C |
| *Obovaria jacksoniana* | - | - | - | - | - | - | - | - | D | - | - | L | R |
| *Proptera purpurata* | - | - | L | L | L | - | - | - | L | L | L | L | C |
| *Truncilla truncata* | - | - | L | - | - | - | - | - | - | - | - | - | R |
| *Villosa lienosa* | L | L | L | L | L | - | - | - | L | L | L | L | C |
| *Villosa vibex* | - | - | - | - | - | - | - | - | L | L | L | L | C |
| *Obliquaria reflexa* | - | - | R | - | - | - | - | - | - | - | - | - | R |
| *Corbicula fluminea* | L | - | L | L | L | - | - | - | L | L | L | L | A |
| Totals: | 7 | 4 | 21 | 12 | 11 | 7 | 12 | 9 | 10 | 17 | 21 | 21 | |

Total taxa represented = 34

* A- large numbers observed at most suitable stations
UC- found at less than half of suitable stations
C- small numbers observed at most suitable stations
R- found at only one station or represented by only one or two specimens

** L- live D- dead R- relic

inadequate sewage treatment, there still exists in the Hatchie River a remarkable mussel fauna with a definite southern or Gulf coastal affinity. The presence of *Plectomerus dombeanus, Uniomerus declivis, Carunculina texasensis, Lampsilis satur, Obovaria jacksoniana, Proptera purpurata* and *Villosa vibex* clearly demonstrates this affinity. Six of these species (*Plectomerus dombeyanus, Uniomerus declivis, Lampsilis satur, Obovaria jacksoniana, Proptera purpurata* and *Villosa vibex*) are not found in any other stream in Tennessee although *Plectomerus dombeyanus* has been found in the Kentucky portion of Kentucky Lake (Pharris et al., 1982).

*Obovaria jacksoniana* seems to be rare within its historic range. It is listed as endangered in Alabama (Stansbery, 1976) and Strecker (1931) listed the shell as "exceedingly rare" in Texas. The Texas listing is under *Obovaria castanea* (Lea, 1831) which Stansbery (1976) has pointed out is preoccupied by *Unio castaneus* (Raf., 1831). *Obovaria jacksoniana* should be listed as endangered in Tennessee because of its rarity and restriction to one river.

*Proptera purpurata* and *Villosa vibex*, while common within their ranges, should be listed as threatened in Tennessee because of their restriction to one river with a history of catastrophic pollution spills (Tenn. Dept of Public Health, 1976).

In most cases the nomenclature used in this paper is that suggested by Ortmann and Walker (1922) and used by Burch (1973). The problems associated with having two or three Linnaean names appearing in various publications for the same species of mussel has been discussed by van der Schalie (1952, 1981). The taxonomic list (Table III) used in this paper includes all available records from the West Tennessee drainages, with common synonyms.

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Table III

**MUSSEL SPECIES RECORDS FOR MISSISSIPPI DRAINAGE IN WEST TENNESSEE**
**Recent and Historic records**

| Species | Locality Record* | | | | |
|---|---|---|---|---|---|
| | Hatchie River | Obion River | Reelfoot Lake | Horn Lake Creek | Wolf River |
| *Amblema* (Crenodonta) *costata* (Raf. 1820) | X | O | - | - | - |
| incl. *Amblema peruviana* (Lamarck 1819) | - | - | - | - | - |
| as *Unio plicatus* Say 1817 | - | - | P | - | - |
| *Amblema plicata* (Say 1817) | - | - | - | - | - |
| *Fusconaia ebenus* (Lea 1831) | X | - | - | - | - |
| *Fusconaia flava* (Raf. 1820) | X | - | - | - | - |
| incl. *flava trigona* (Lea 1831) | - | O | - | - | - |
| *Plectomerous dombeyanus* (Val. 1833) | X | - | - | - | - |
| as *Plectomerus trapezoides* (Lea 1831) | - | O | P | - | - |
| *Quadrula nodulata* Raf. 1820 | X | - | - | - | - |
| *Quadrula pustulosa* (Lea 1831) | X | - | P | - | - |
| incl. *pustulosa mortoni* (Conrad 1836) | - | O | - | - | - |
| as *Unio turgidus* Lea 1831 | - | - | - | - | P |
| *Quadrula quadrula* (Raf. 1820) | X | - | O | - | - |
| as *Unio asperrimus* Lea 1831 | - | - | P | - | - |
| *Tritogonia verrucosa* (Raf. 1820) | X | - | - | - | - |
| as *Quadrula verrucosa* | - | O | - | - | P |
| *Megalonaias gigantea* (Barnes 1823) incl. *Megalonaias nervosa (Raf. 1820)* | X | O | - | - | - |
| *Plethobasus cyphyus* (Raf. 1820) | X | - | - | - | - |
| *Pleurobema cordatum* (Raf. 1820) | X | - | - | - | - |
| *Uniomerus tetralasmus* (Say 1831) | X | - | - | - | - |
| *Uniomerus declivis* (Say 1831) | X | - | - | - | - |
| *Anodonta grandis* Say 1829 incl. *grandis grandis* | X | - | P | - | - |
| *Anodonta corpulenta* Cooper 1834 | X | - | - | - | - |
| as *grandis gigantea* Lea 1838 incl. *grandis corpulenta* | - | - | O | - | - |
| *Anodonta imbecillis* Say 1829 incl. *Anodonta ohiensis* Raf. 1820 | X | - | O,P | - | - |
| *Anodonta suborbiculata* Say 1831 | X | - | O,P | - | - |
| *Arcidens confragosus* (Say 1829) | X | O | P | - | - |
| *Lasmigona complanata* (Barnes 1823) | X | O | - | - | - |
| *Strophitus undulatus* (Say 1817) | X | - | - | - | - |
| as *Anodonta shaefferiana* (Lea 1852) incl. *rugosus* (Swainson 1822) | - | - | - | L | - |
| *Carunculina* (Toxalasma) *parva* (Barnes 1823) | X | - | O,P | - | - |

**Table** III (Continued)

| Species | Locality Record* Hatchie River | Obion River | Reelfoot Lake | Horn Lake Creek | Wolf River |
|---|---|---|---|---|---|
| *Carunculina* (Toxalasma) *texasensis* (Lea 1859) | X | - | O,P | - | - |
| *Lampsilis anodontoides anodontoides* (Lea 1834) | X | - | - | - | - |
| as *Unio anodontoides* | - | - | - | - | - |
| incl. *teres anodontoides* | | | | | |
| *Lampsilis anodontoides fallaciosa* (Smith 1899) | X | O | - | - | - |
| incl. *teres teres* (Raf. 1820) | | | | | |
| *Lampsilis satur* (Lea 1852) | X | - | - | - | - |
| as *ovata satura* | - | O | - | - | - |
| *Leptodea fragilis* (Raf. 1820) | X | O | - | - | - |
| as *Unio gracilis* Barnes 1823 | - | - | - | - | P |
| *Leptodea laevissima* (Lea 1829) | X | - | - | - | - |
| incl. *Potamilus ohiensis* (Raf. 1820) | | | | | |
| *Ligumia subrostrata* (Say 1831) | X | - | O.P | - | - |
| *Obovaria jacksoniana* Frierson 1912 | X | - | - | - | - |
| incl. *Unio castaneus* Lea 1831 | | | | | |
| *Proptera* (Potamilus) *purpurata* (Lamarck 1819) | X | - | - | - | P |
| *Truncilla truncata* Raf. 1820 | X | - | - | - | - |
| as *Unio elegans* Lea 1831 | - | - | P | - | - |
| *Villosa* (Micromya) *lienosa* (Conrad 1834) | X | O | - | - | - |
| *Villosa* (Micromya) *vibex* (Conrad 1834) | X | - | - | - | - |
| *Obliquaria reflexa* Raf. 1820 | X | - | - | - | - |
| *Corbicula fluminea* (Muller 1774) | X | - | - | - | - |
| incl. *manilensis* (Philippi 1841) | | | | | |
| *leana* (Prime 1864) | | | | | |

* X- Present study; O- Ortmann, 1926; P- Pilsbry and Rhodes, 1896; L- Lea

# Status of the Freshwater Mussel Fauna Pendleton Island Mussel Preserve, Clinch River Virginia

**Sally D. Dennis**
Biology Department, Radford, University
Radford, Virginia 24142

## INTRODUCTION

During August of 1987, at the request of the Virginia Nature Conservancy, I instituted an evaluation of the freshwater mussel fauna of The Nature Conservancy Preserve in the Clinch River at Pendleton Island (CRM 226), Scott County, Virginia. The purpose of this evaluation was to provide background data which would be useful in monitoring the condition of the mussel fauna of this river reach. While it is the particular aim of the Conservancy to keep track of rare and endangered mussel species inhabiting this preserve, most of these species do not occur in sufficient abundance to allow reliable monitoring of their status. Rare species are not easily sampled quantitatively (Kovalak et al., 1986) and, therefore, population parameters such as age-class structure cannot be determined with any degree of reliability for them. For this reason, a sampling program was designed to evaluate community structure. Changes in percent composition of species and in age-class structure of the more abundant species can, it is hoped, be used to detect changes in habitat quality.

## ACKNOWLEDGEMENTS

The Virginia Chapter of The Nature Conservancy provided expense money and personnel to aid in the sampling at Pendleton Island. I am grateful for the support and assistance of Faye Cooper and Ann Lewis of the Nature Conservancy and Michael Lipford, now of the Department of Conservation and Historic Resources Natural Heritage Program. I also wish to thank John Bates, Ecological Consultants, Inc., for his help with field work and for keeping a photographic record of the sampling efforts. Mr. Don Manning, Buchannon Tennessee, also volunteered assistance in sampling.

## METHODS

During the August, 1987, sampling period, one full day was spent in qualitative sampling of the Pendleton Island area, and two days were spent collecting quantitative data using a quadrat sampling technique described by Dennis (1985). A one-half meter square frame was placed randomly within predetermined areas, and all mussels were removed by hand (by three to four persons). The substrate within the sampler was carefully examined for small specimens, and all mussels were identified, enumerated, aged and the data recorded. Gravel removed from the quadrat during sampling was replaced and all live mussels carefully replaced in the substrate in the same area from which they had been removed. Care was taken to keep habitat disturbance to a minimum. Five persons were involved in collecting and recording data from 22 quadrat samples. The site was revisited in September of 1988, when limited sampling was carried out for comparative purposes.

For sampling purposes, four separate river reaches were defined as indicated on the site sketch (Figure 1). Reaches A and B, which were the most productive, were sampled quantitatively. Quadrat samples 1-14 were taken from reach A; samples 14a-21 from reach B. Reach C includes the narrower (north) side of the island, and reach D the lower end.

## RESULTS

Table I lists all mussel species found during the 1987 sampling period. A total of 30 living species were collected, with records of two additional species represented by dead shells only. Of these, *Dysnomia brevidens* may exist in low abundance at the site; *D. torulosa gubernaculum* is probably extinct, and *D. capsaeformis* is near extinction. Table II summarizes species

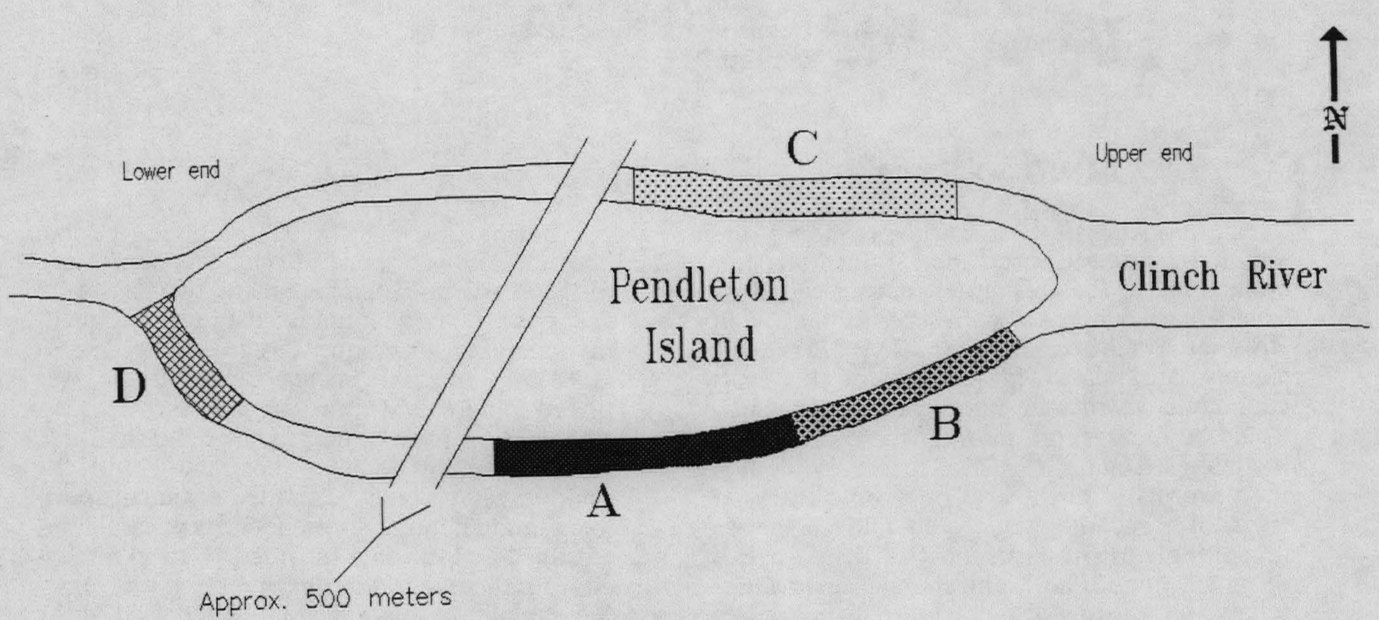


**Figure 1**. Sketch of river reaches sampled at Pendleton Island, Clinch River (not to scale). Dimensions of Island: 804 m long by 193 m wide.

taken in 1987 from 22 quadrat samples (note: two samples numbered 14 are listed as 14 and 14a). The average density of mussels was 18.7 per $M^2$ sampled. This compares favorably with densities found at other sites in the Clinch River. Quantitative sampling in 1986, revealed mussel densities of approximately 30 per $M^2$ at Kyles Ford, TN. Comparative samples taken at Speers Ferry VA in 1987 yielded only 3.7 mussels per $M^2$.

In Table III mussel species taken from quadrat samples are listed in order of relative abundance with the percent occurrence given for each species. It can be seen that only 5 species accounted for more than 70% of the specimens collected. Many of the species were represented by only one specimen. This is characteristic of the pattern observed in other mussel communities (Dennis, 1985). Of the 5 dominant species, one (*Fusconaia cuneolus*) is listed as Federally Endangered. The two species of *Actinonaias* (*A. pectorosa*, and *A. carinata*) have been found among the dominant species at other locations in the Clinch and Powell Rivers.

Results of analysis of age-class structure of the mussels sampled are presented graphically in Figure 2. In this histogram, age is plotted against number for all mussel species combined. Results indicate that few young specimens were collected in quadrat samples.

## DISCUSSION

The best historical account of the fauna of the Clinch River is given by Ortmann (1918). Since then, there have been a number of mussel surveys of this river (Ahlstedt, 1984; Bates and Dennis, 1978; Jenkinson and Ahlstedt, 1988; Neves, et al., 1980; Stansbery, 1973). Additional unpublished reports on various aspects of water quality as well as several master's thesis dealing with mussel life histories (as cited by Kosztarab, 1987) make this one of the most studies rivers in the Upper Tennessee System. Despite the tremendous effort and expense that has gone into producing these studies, we know almost nothing as to the cause of the obvious decline in the native unionid fauna of this and other rivers in the system. Distributional data col

**Table I**

Mussel Species collected at Pendleton Island, Clinch River, September, 1987

| Species | Live | Dead only |
|---|---|---|
| *Actinonaias carinata* | X | |
| *Actinonaias pectorosa* | X | |
| *Amblema costata* | X | |
| *Conradilla caelata* | X | |
| *Cyclonaias tuberculata* | X | |
| *Cyprogenia irrorata* | X | |
| *Dysnomia brevidens* | | X |
| *Dysnomia capsaeformis* | | X |
| *Dysnomia triquetra* | X | |
| *Dysnomia torulosa gubernaculum* | | X (relic) |
| *Elliptio dilatatus* | X | |
| *Fusconaia barnesiana* | X | |
| *Fusconaia cuneolus* | X | |
| *Fusconaia edgariana* | X | |
| *Fusconaia pilaris* | X | |
| *Lampsilis fasciola* | X | |
| *Lampsilis ventricosa* | X | |
| *Lasmigona costata* | X | |
| *Leptodea fragilis* | X | |
| *Lexingtonia dolabelloides* | X | |
| *Ligumia recta latissima* | X | |
| *Medionidus conradicus* | X | |
| *Plethobasus cyphyus* | X | |
| *Pleurobema cordatum* | X | |
| *Pleurobema oviforme* | X | |
| *Proptera alata* | X | |
| *Ptychobranchus fasciolaris* | X | |
| *Ptychobranchus subtentum* | X | |
| *Quadrula cylindrica* | X | |
| *Quadrula pustulosa* | X | |
| *Truncilla truncata* | X | |
| *Villosa trabalis* | X | |
| *Villosa nebulosa* (complex) | X | |
| Totals: (Grand = 33) | 30 | 3 |

lected over the past ten years do indicate, however, that significant changes in the mussel fauna of the Upper Tennessee River Drainage have been underway. There has been an alarming reduction in the amount of suitable mussel habitat, and several sensitive species appear to be on the decline. Most members of the genus *Dysnomia* have been extirpated from this region (Dennis, 1987). At present, the mussel fauna at the Pendleton Island Site in the Clinch River represents one of the richest in mussel density and diversity remaining in the State of Virginia.

Unfortunately we do not have historic records of mussel populations at Pendleton Island, which would allow us to determine the extent of recent water quality changes on this community. This is undoubtedly owing to the inaccessibility of the site. We can, however, compare this site to two others in the Clinch River (Speers Ferry, VA and Kyles Ford, TN) for which we do have historical records. The result of quantitative sampling at these sites during the period 1973-1975 was reported by Dennis (1985). During this period, Kyles Ford supported a rich and diverse mussel fauna of 36 species averaging 29.7 mussels per $M^2$. This community appears to have remained stable in terms of mussel density over the past 10 years, although there has been a shift in species composition. Speers Ferry, approximately 20 miles upstream supported approximately 28 species at this time, averaging only 7.7 mussels per $M^2$ (Dennis, 1985). The Speer's Ferry community has declined in density to 3.7 mussels per $M^2$ over the past 10 years. If this decline continues, this community may disappear.

At both sites, there has been a dramatic shift in species dominance within the past decade. *Dysnomia capsaeformis* which was among the dominant species in 1973-75, comprising more than 34% of mussels sampled at Speers Ferry and 17.7% at Kyles Ford, is all but extirpated from both areas.

Pendleton Island is approximately 20 miles upstream from Speers Ferry in an area which has not been sampled in the past. This area appears intermediate between the other two in terms of mussel diversity and abundance. In recent collections, 30 species were reported at a density of 18.7 mussels per $M^2$. No living specimens of *Dysnomia capsaeformis* were found here indicating that this species is at least very rare at Pendleton Island and may be extirpated from this site. This species may have been more abundant here in the past and is probably undergoing the same decline throughout its range.

## Table II

**Mussels Collected in Quadrat samples, Clinch River
Pendelton Island, August, 1987**

| Species: Quadrat # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 14a | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number collected: | | | | | | | | | | | | | | | | | | | | | |
| Actinonaias carinata | 2 | 2 | - | 1 | 5 | - | 4 | 2 | - | 1 | 2 | 3 | 3 | 1 | 2 | 1 | 4 | 1 | 3 | 2 | - | 3 |
| Actinonaias pectorosa | 2 | - | - | - | - | 1 | 3 | 4 | 1 | 2 | - | 1 | 4 | - | 5 | 2 | 7 | 3 | 4 | 2 | 3 | 3 |
| Amblema costata | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | - | - | 1 | - |
| Conradilla caelata | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Cyclonaias tuberculata | - | - | - | - | 1 | - | - | - | - | - | - | 1 | - | - | - | - | 2 | 1 | - | 1 | - | 1 |
| Dysnomia triquetra | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Elliptio dilatatus | 3 | 2 | 3 | 1 | 3 | - | 1 | 2 | 1 | 2 | - | 3 | 7 | 1 | - | - | - | - | - | - | - | - |
| Fusconaias barnesiana | 1 | - | - | - | - | 1 | - | 2 | - | 2 | - | - | - | - | - | - | - | - | 1 | 5 | 2 | - |
| Fusconaia cuneolus | 2 | 1 | - | - | - | 2 | 1 | 2 | - | 1 | - | 3 | 1 | - | 3 | - | 4 | - | - | 4 | 1 | - |
| Fusconaia pilaris | 1 | - | 1 | - | - | 1 | - | - | - | - | 1 | 2 | 1 | 3 | - | - | 1 | - | - | - | - | - |
| Lampsilis fasciola | - | - | - | - | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - |
| Lampsilis ventricosa | - | - | - | - | - | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Lasmigona costata | - | - | - | - | - | 1 | - | - | - | - | 1 | - | - | 2 | - | - | - | - | 1 | 2 | - | 2 |
| Ligumia recta latissima | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Plethobasus cyphyus | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Pleurobema cordatum | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Ptychobranchus fasciolaris | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - |
| Ptychobranchus subtentum | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Quadrula cylindrica | - | - | 1 | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Villosa trabalis | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - |
| Villosa nebulosa | - | - | - | - | 1 | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| Totals: | 11 | 7 | 7 | 3 | 12 | 9 | 10 | 13 | 3 | 9 | 4 | 13 | 17 | 8 | 11 | 3 | 18 | 5 | 11 | 16 | 7 | 9 |

Grand total= 206

Average Number per $m^2$ = 18.7

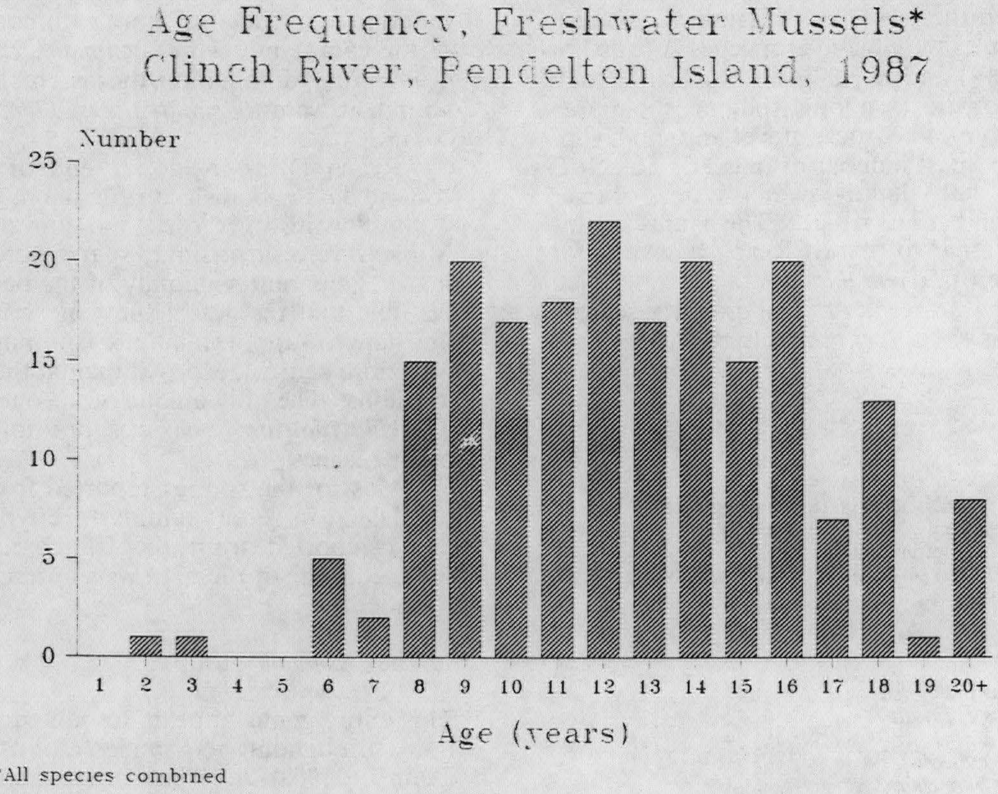


**Figure 2.** Age Frequency of mussels collected from the Clinch River at Pendleton Island, 1987.

The other river in the upper Tennessee drainage which has supported many of the endemic Cumberlandian species found in the Clinch is the Powell River. Recent collections from this river indicate that the fauna here is also declining. The richest site on the Powell River in 1975 was at McDowell Shoal, Tennessee. In a recent visit to this site, only three live mussels (*Actinonaias carinata*) were found. The mussel community here has been completely destroyed by unknown causes. The only remaining remnants of the Powell River fauna now reside in the State of Virginia. The rapid disappearance of endemic species throughout the Cumberlandian region makes preservation of the fauna at Pendleton Island all the more important.

The Pendleton Island Fauna:

Of the 30 species reported from Pendleton Island during 1987, three (*Conradilla caelata, Fusconaia cuneolus,* and *F. edgariana*) are presently listed as Endangered nationally, and several others are deserving of Endangered status. The three day effort undoubtedly did not turn up every species present at this site. Some very rare species require repeated efforts to collect. Future sampling efforts may, therefore, add species to this list. Some species which were not collected live but which can be expected to occur in this area include *Dysnomia brevidens* and *Lastena lata*.

For the purpose of discussion, the site has been subdivided into four separate reaches, as indicated on the site sketch (Figure 1). Quantitative samples were taken at reaches A (quadrat samples 1-14) and B (samples 14a-21). Reach A, which consists of a long, shallow, shoal area with substrate of bedrock, gravel and mud, supports the greatest number of mussels. Reach B is an area with slightly swifter water, coarser substrate, and more riffles. The fauna in this area was similar to that of Reach A except for the absence of *Elliptio dilatatus*, a species which was abundant in reach A. The dramatic segregation of this species is probably related to distribution of the fish host which may prefer quiet shoals to turbulent riffle areas.

**Table III**

Numbers and Species of Mussels Collected from 22 Quadrat Samples
Pendleton Island, Clinch River
(Listed in Order of Abundance)

| Species | Total | Percent |
|---|---|---|
| 1. *Actinonaias pectorosa* | 47 | 21.9 |
| 2. *Actinonaias carinata* | 42 | 19.5 |
| 3. *Elliptio dilatatus* | 29 | 13.5 |
| 4. *Fusconaia cuneolus* | 25 | 11.6 |
| 5. *Fusconaia barnesiana* | 14 | 6.5 |
| 6. *Fusconaia pilaris* | 11 | 5.1 |
| 7. *Lasmigona costata* | 9 | 4.2 |
| 8. *Cyclonaias tuberculata* | 7 | 3.3 |
| 9. *Amblema costata* | 4 | 1.9 |
| 10. *Lampsilis fasciola* | 3 | 1.4 |
| 11. *Lampsilis ventricosa* | 2 | 0.9 |
| 12. *Ptychobranchus fasciolaris* | 2 | 0.9 |
| 13. *Quadrula cylindrica* | 2 | 0.9 |
| 14. *Villosa nebulosa* | 2 | 0.9 |
| 15. *Ptychobranchus subtentum* | 1 | 0.5 |
| 16. *Dysnomia triquetra* | 1 | 0.5 |
| 17. *Plethobasus cyphyus* | 1 | 0.5 |
| 18. *Pleurobema cordatum* | 1 | 0.5 |
| 19. *Villosa trabalis* | 1 | 0.5 |
| 20. *Ligumia recta latissima* | 1 | 0.5 |
| 21. *Conradilla caelata* | 1 | 0.5 |
| Totals: | 206 | 100.0 |
| Ave No./$M^2$ 18.7 | | |

Reaches C and D supported fewer mussels and were sampled qualitatively only. Reach C, which occupies the narrower side of the island, maintains a lower flow than the other reaches, and, consequently, more silt was observed on the surface of the substrate in this region. The river here also receives more shade from trees along the bank on both sides. There was not as much shallow shoal and riffle habitat. Species found here include the more common members of the community with *Actinonaias carinata* and *A. pectorosa* dominating the assemblage. Also abundant were *Elliptio dilatatus*, *Lampsilis ventricosa*.

Reach D, at the lower end of the island consisted of a good sized riffle habitat with swift water flowing over rock and gravel substrate. Mussels were surprisingly sparse here considering the apparent suitability of the habitat. It is possible that the gravel substrate was too shallow here to support a mature community; there was more bedrock exposed than at the upstream locations. The only unique occurrence here was *Truncilla truncata*, a species not found at the other reaches.

Most of the species reported from Pendleton Island in recent samples are typical of the fauna reported from the Clinch and Powell Rivers. Some of these, however, deserve special comment.

1. The *Dysnomia* group.

This entire genus appears to be nearing extinction throughout its range (Johnson, 1978; Dennis, 1988). The once abundant *D. capsaeformis* is now all but extinct. No specimens were found at Pendleton Island in quadrat samples, only one freshly dead male specimen was found in qualitative samples. Likewise, *D. torulosa gubernaculum* appears to be extinct. This headwater form of *D. torulosa* has always been rare in the Clinch River. While collecting quadrats at Pendleton Island, however, an unusually high number of relic shells of this species were observed. Many of the specimens were buried in the substrate where they had apparently died in place. The age of these specimens cannot be determined with accuracy, but it is likely that they had been dead for ten years or more. Many relic shells were observed on the river bottom, but none that appeared recent (within the past 2 years). Since many more shells of *D. torulosa gubernaculum* were found than shells of *D. capsaeformis* it is possible that this species once occupied the niche held by *D. capsaeformis* at other sites. Another member of this genus which appears to be on the decline is *D. brevidens*. While it occurs in low abundance at other sites in the Clinch it is becoming increasingly rare. No live specimens were found at Pendleton Island. *Dysnomia triquetra*, a widespread species inhabiting the

Ohio River Drainage as well as the Tennessee, is the only member of this genus which seems to be holding its own.

2. The *Fusconaia* species complex.

This genus is represented by four species, two of which are listed as Federally Endangered. Of these, *Fusconaia cuneolus* was one of the more abundant species found (11.6 % of the sample) while *F. edgariana* (= *F. cor*) was extremely rare. The former species is relatively abundant at other sites in the Clinch River, while *F. edgariana* is becoming increasingly difficult to find anywhere. This species may be declining and should be given special attention.

*Fusconaia barnesiana* was once widespread and locally abundant within the headwaters of the Tennessee River system but is becoming increasingly rare. *Fusconaia pilaris* (form *bursa pastoris*) was recognized by Ortmann (1918) as the headwater form of *Fusconaia subrotunda* which occurs in the Tennessee and Cumberland Rivers, and these two taxa should be regarded as synonyms.

3. Other species of concern.

Several endemic species not currently listed as Endangered appear to be declining in abundance and should be offered protection. These include: *Ptychobranchus subtentum, Medionidus conradicus, Lexingtonia dolabelloides, Pleurobema oviforme*, and *Dysnomia brevidens* (previously mentioned). The relative absence of *Pleurobema subtentum* from this site (1 specimen found) is particularly disturbing since this Cumberlandian endemic was once abundant at both Kyles Ford and Speers Ferry. It still occurs in fair abundance at Kyles Ford, but its absence in other areas indicates that the species may be in trouble. Likewise, I expected to find *Medionidus conradicus* in much greater abundance than was observed. It appears that all of the endemic species in this faunal assemblage are becoming increasingly rare in areas where they were once abundant.

In addition, the entire *Pleurobema cordatum* complex appears to be in danger of extirpation. A number of forms of this species complex have been reported in the literature, one of these, *P. plenum*, is listed as Federally Endangered. *Pleurobema cordatum* once abundant in the Tennessee River is now found only in relic populations below dams. The headwater representatives of this complex referred to variously as *P. pyramidatum* and *P. rubrum*, are also increasingly rare. The taxonomic status of these two forms is at present not clear; they may represent two color variations of the same taxon.

One living specimen of a rare species *Villosa trabalis* was found during the study. This is the first record of this species from the upper Clinch River. The specimen was carefully examined, photographed, and returned to the river. This species is closely related to another, somewhat more common species, *Villosa perpurpurea*, which has been reported from tributary streams. It is distinguished from the later species primarily by nacre color. While the specimen collected at Pendleton Island was not sacrificed to confirm its identification, my determination is based on examination of specimens of both species housed in the University of Michigan Museum of Zoology Mussel collections. The status of this species in the Cinch River is presently unknown due to its rarity.

Age Class data:

In examining population and community structure of freshwater mussels, I prefer to use age class structure rather than the easier to measure length class structure which is now popular with many workers in the field of malacology. While ages are more difficult to determine, especially for older specimens (which are, therefore, often lumped), it is the critical younger age classes that are most important in determining the status of a community. Since mussels grow more rapidly when they are younger, exhibiting increasingly smaller growth increments as they get older, length measurements of older specimens, suffer from some of the same inaccuracies. Since length measurements are species specific, lengths of one species cannot be directly compared to those of another species as can age, which is independent of growth rate. Using age has the distinct advantage of allowing all species to be combined in an analysis of community age class structure. Since most communities consist of a few abundant species and many species of low occurrence, lumping is the only way to include rare species in this type of community analysis. Length frequencies have the added disadvantage of exhibiting inconsistencies at a given site due to differences in habitat (water depth, current velocity, patterns of flow, etc). This problem will be addressed in greater detail in another publication.

The age-class structure of the mussel community at Pendleton is skewed towards the older age-classes. When compared to earlier samples taken at Kyles Ford and Speers Ferry in the Clinch River, the number of young mussels collected is far below what was expected. During the period of 1973-75, I found that approximately 25% of the mussels at Kyles ford and 50% of those collected at Speers Ferry were less than 4 years old. Another 20% of the mussels from these sites were in the 4-5 year class. The percentage of young mussels (1-5 years) collected at Pendleton Island was very low by comparison (less than 1.0%), which may indicate a general decline in recruitment of all mussel species at this site.

Conclusions:

In light of the recent observed decline in the range and species abundance of the Cumberlandian mussel fauna, it is clear that protected areas such as that at Pendleton Island are needed to conserve this fauna. It is hoped that such areas can not only serve to shelter species from overt disturbance, but will serve as a base for research aimed at answering questions as to why so many species are declining. The most likely cause for the recent disappearance of a number of species is deteriorating water quality. Despite the plethora of studies conducted on the Clinch River fauna to date, we are not close to a solution to this problem. If this deterioration is not identified and stopped, many more species may follow in the footsteps of the *Dysnomias* which are near extinction.

The mussel preserve at Pendleton Island is precariously located in a river reach which has been subjected to severe pollution problems in the past (Dennis, 1985). There have been two documented spills from a power plant at Carbo, Virginia, and other industries are being developed within the watershed. The mussel community at Pendleton Island should continue to be monitored on an annual basis, with follow-up quantitative sampling at two year intervals to discern subsequent shifts in community structure. Conservancy efforts should be aimed at working with State and Federal regulatory agencies to identify potential threats to the habitat. If possible, a mussel preserve should be established in an upstream river reach which would provide a greater degree of protectability. A preserve is also needed within the Powell River watershed to monitor the status of Cumberlandian species which do not occur at Pendleton Island (i.e. *Quadrula intermedia, Dromus dromas*).

The emphasis in fresh water mussel studies over the past 20 years has been on distribution, only recently focusing on community structure as a means of monitoring the status of this fauna. It is clear that if we wish to preserve this faunal assemblage, future research should focus on the biology and ecology of these organisms. Otherwise, we can do little more than document their extinction.

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# The Status of Freshwater Mussels (Unionidae) of Virginia

Michael L. Lipford
Virginia Natural Heritage Program
Department of Conservation and Historic Resources
203 Governor Street, Suite 402
Richmond, Virginia 23219

The Virginia Natural Heritage Program (VANHP) was established through the joint efforts of The Nature Conservancy and the Commonwealth of Virginia. The VANHP, through inventory technique, maintains a continuously updated database that reflects the current status of biological diversity in Virginia.

The Nature Conservancy is a major, private conservation organization that specializes in ecological data management for the preservation of natural lands. For over a decade this organization, in partnership with state governments, has pursued biological inventory in a unique and systematic manner. Called State Natural Heritage Programs, these biological inventories collect and disseminate information on the existence, status, and precise locations of rare plants and animals and unique or exemplary natural communities. The data are assembled into an integrated system of databases that serve many purposes and are used by various State and Federal land-management agencies and private users. Heritage Programs have been established in forty-nine states, in Canada, and several of the Latin American countries. The success of Heritage methodology is reflected in state acceptance and recognition that a centralized, continually updated inventory that details specific locality information is critical to successful long-term planning and management. The Natural Heritage Network has made disparate information within and among states comprehensible and, hopefully, consistent, and has facilitated the sharing of ecological data across state and national boundaries.

The VANHP was established in Richmond in November of 1986 and was operated as a Nature Conservancy program under contract with the Commonwealth until 1988, when it was made a fully funded state program under the Natural Resources Secretariat. Administered by the Department of Conservation and Historic Resources, the VANHP is a section within the Department's Division of Natural Areas Conservation. The Division is responsible for preserving the Commonwealth's biological diversity through identification of high priority natural areas to be protected and managed as Virginia Natural Area Preserves.

The methods of data collection and management are consistent among all Natural Heritage Programs. The initial step is to decide which elements of natural diversity (species, natural communities, and other features) need to be inventoried. Natural Heritage Programs rely heavily upon the input of state experts in developing lists of rare species. Through every phase of the inventory the lists remain flexible and elements are added or deleted as the growing body of knowledge dictates. Once the list of elements in each category is compiled, each element is ranked in order of its overall priority for inventory and protection efforts. A scale of 1 to 5 is utilized and species are ranked from both a state (S) and a global (G) perspective (Table I).

For example, the James spinymussel (*Pleurobema collina*), known only from a few headwater tributaries of the James River, has a rank of G1/S1 and consequently receives a very high priority for inventory and protection. Although the black sandshell (*Ligumia recta latissima*) is also very rare in Virginia (ranked S1), it is apparently secure over its entire range (G4) and receives somewhat lower priority. Some species, such as the Eastern Elliptio (*Elliptio complanata*) are demonstrably secure throughout most of their known range (G5/S5) and consequently are not actively monitored by the program. Giving first priority to the species that rank the highest, the staff accumulates and processes information on the rarest freshwater mussel species of Virginia. In addition, these ranks are used for setting preservation priorities, planning status survey work, and the preparation of listing packages for State or Federal Endangered species.

The central unit of data in the Natural Heritage Program is termed the "element occurrence", a specific locality that supports one of the listed elements (Table I). For example, the population of the rare Powell River mussel *Quadrula intermedia* Conrad (Cumberland monkeyface) is an element occurrence. Sources for such site-specific information include specimen labels, the scientific literature, personal communications from experts, and field surveys.

For each element occurrence a manual and computerized record (the Element Occurrence Record) is completed. This includes, in addition to the scientific and common names of the element, such information as the element's location, notes on the status of the population, a site description, threats to the site, the date of observation or collection, the name of the source supplying that record, and ownership information. Given the importance of site-specific information, the Element Occurrence Record includes fields for recording latitude and longitude, the USGS quadrangle, county, physiographic province, watershed, etc. Because these records are computerized, data can be sorted and retrieved by any of the numerous fields on the Element Occurrence Record. Any combination of information on these records can be used to search and order the database. This information can be reported in a format tailored to fit a specific need or request. In addition to this computerized file, the Heritage Program also maintains a complete set of USGS 7.5-minute topographic maps for Virginia on which the exact location of each element occurrence is marked.

One of the keys to the success of Natural Heritage Programs is the hoped for impartiality of their data and the ease with which this information can be retrieved. Because these data can be used to help avert environmental conflicts before they arise, the VANHP is appreciated by both commercial and environmental interests. For these reasons, state agencies and organizations routinely choose to consult Heritage Programs for environmental reviews in the state. Natural Heritage Programs have Memoranda of Agreement with many Federal and State agencies, and private organizations. The U.S. Congressional Office of Technology Assessment recently cited the Heritage network to Congress as the leading effort in biodiversity data management. The National Office of The Nature Conservancy has cited the Virginia Natural Heritage Program as a model program, incorporating and testing the improvements in database management that are now applied by Natural Heritage Programs across the nation.

The purpose of this paper is to make available the freshwater Unionid list (Table II) established by the Virginia Natural Heritage Program. Comments or suggestions on ranks and/or species contained in the list are welcomed and should be addressed to the author.

## Acknowledgements

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## TABLE I

### Definition of Abbreviations used on element lists of the Virginia Natural Heritage Program Department of Conservation and Historic Resources

The following ranks are used by the Virginia Natural Heritage Program to set protection priorities. The primary criterion for ranking species is the number of occurrences, i.e. the number of known distinct populations. For the purpose of recording mussel distributional data and establishing ranks, the term "occurrence" is used to designate a conservation unit rather than an individual record. Closely spaced species records may, therefore, be merged into one "occurrence". Also of great importance is the number of individuals in existence for each occurrence. Other considerations may include the condition of the occurrences, the number of protected occurrences, and threats to each occurrence. However, the emphasis remains on the number of occurrences such that ranks will be an index of rarity.

S1 Extremely rare; usually 5 or fewer occurrences in the state; or may be a few remaining individuals; often especially vulnerable to extirpation.

S2 Very rare; usually between 5 and 20 occurrences; or with many individuals in fewer occurrences; often susceptible to becoming endangered.

S3 Rare to uncommon; usually between 20 and 100 occurrences; may have fewer occurrences, but with a large number of individuals in some populations; may be susceptible to large- scale disturbances.

S4 Common; usually >100 occurrences, but may be fewer with many large populations; may be restricted to only a portion of the state; usually not susceptible to immediate threats.

S5 Very common; demonstrably secure under present conditions.

SH Historically known from the state, but not verified for an extended period, usually >15 years; this rank is used primarily when inventory has been attempted recently.

SU Status uncertain, often because of low search effort or cryptic nature of the element.

SX Apparently extirpated from the state.

Global ranks are similar, but refer to a species' rarity throughout its total range. Global ranks are denoted with a "G" followed by a character; GX means apparently extinct. A "Q" in a rank indicates that a taxonomic question concerning that species exists. Ranks for subspecies are denoted with a "T". The global and state ranks combined (e.g. G2/S1) give an instant grasp of a species' known rarity.

These ranks should not be interpreted as legal designations.

<u>Federal Status</u>

The Virginia Natural Heritage Program uses the standard abbreviations for Federal endangerment developed by the U.S. Fish and Wildlife Service, Division of Endangered Species and Habitat Conservation.

LE - Listed Endangered
LT - Listed Threatened
PE - Proposed Endangered
PT - Proposed Threatened
C1 - Candidate, category 1
C2 - Candidate, category 2

3A - Former candidate - presumed extinct
3B - Former candidate - not a valid species under current taxonomic understanding
3C - Former candidate - common or well protected

<u>State Status</u>

The Virginia Natural Heritage Program uses similar abbreviations for State endangerment, as developed by the Department of Game and Inland Fisheries.

LE - Listed Endangered

LT - Listed Threatened

**TABLE II**

**VIRGINIA NATURAL HERITAGE PROGRAM
COMPLETE LIST OF
VIRGINIA FRESHWATER UNIONID MUSSELS[1]**

| SCIENTIFIC NAME | COMMON NAME | GLOBAL RANK | STATE RANK | FEDERAL LEGAL STATUS | STATE LEGAL STATUS |
|---|---|---|---|---|---|
| *Actinonaias carinata* | MUCKET | G5 | S4 | | |
| *Actinonaias pectorosa* | PHEASANTSHELL | G4 | S4 | | |
| *Alasmidonta heterodon** | DWARF WEDGEMUSSEL | G1 | SH | C1 | |
| *Alasmidonta marginata* | ELKTOE | G5 | S4 | | |
| *Alasmidonta undulata** | TRIANGLE FLOATER | G5 | S4 | | |
| *Alasmidonta varicosa** | BROOK FLOATER | G3 | S3 | | |
| *Alasmidonta viridis* | SLIPPERSHELL | G4 | S3 | | |
| *Amblema costata* | THREERIDGE | G5 | S5 | | |
| *Anodonta cataracta* * | EASTERN FLOATER | G5 | S5 | | |
| *Anodonta imbecillis* | PAPER PONDSHELL | G5 | S4 | | |
| *Anodonta implicata* * | ALEWIFE FLOATER | G5 | S4 | | |
| *Carunculina lividus* | PURPLE LILIPUT | G2 | SU | C2 | |
| *Conradilla caelata* | BIRDWING PEARLYMUSSEL | G2 | S1 | LE | LE |
| *Cumberlandia monodonta* | SPECTACLE CASE | G2G3 | S1 | C2 | |
| *Cyclonaias tuberculata* | PURPLE WARTYBACK | G5 | S4 | | |
| *Cyprogenia irrorata* | FANSHELL | G3 | S1 | C2 | |
| *Dromus dromas* | DROMEDARY PEARLYMUSSEL | G2 | S1 | LE | LE |
| *Dysnomia arcaeformis* | SUGARSPOON | GX | SX | | |
| *Dysnomia brevidens* | CUMBERLAND COMBSHELL | G2 | S1 | C2 | LE |
| *Dysnomia capsaeformis* | OYSTER MUSSEL | G1 | S1 | C2 | LE |
| *Dysnomia florentina florentina* | YELLOW-BLOSSOM | GX | SX | LE | |
| *Dysnomia florentina walkeri* | TAN RIFFLESHELL | G1T1 | S1 | LE | LE |
| *Dysnomia haysiana* | ACORNSHELL | GH | SX | 3A | |
| *Dysnomia lenior* | NARROW CATSPAW | GX | SX | 3A | |
| *Dysnomia lewisii* | FORKSHELL | GXQ | | SX | 3A |
| *Dysnomia stewardsoni* | CUMBERLAND LEAFSHELL | GX | SX | 3A | |
| *Dysnomia torulosa gubernaculum* | GREEN-BLOSSOM | G2T1 | S1 | LE | LE |
| *Dysnomia triquetra* | SNUFFBOX | G4 | S1 | | LE |
| *Elliptio complanata** | EASTERN ELLIPTIO | G5 | S5 | | |
| *Elliptio crassidens* | ELEPHANT EAR | G4 | S1 | | |
| *Elliptio crassidens incrassatus** | SOUTHERN ELEPHANT EAR | G4T? | S4 | | |
| *Elliptio dilatata* | SPIKE | G5 | S5 | | |
| *Elliptio fisheriana** | NORTHERN LANCE | G3G4 | S3S4 | | |
| *Elliptio lanceolata** | YELLOW LANCE | G4 | S3S4 | | |
| *Elliptio producta** | ATLANTIC SPIKE | G3Q | S3S4 | | |
| *Fusconaia barnesiana* | TENNESSEE PIGTOE | G3 | S3 | | |
| *Fusconaia cuneolus* | FINE-RAYED PIGTOE | G1 | S1 | LE | LE |
| *Fusconaia edgariana* | SHINY PIGTOE | G1 | S1 | LE | LE |
| *Fusconaia masoni** | ATLANTIC PIGTOE | G3 | S1 | | |
| *Fusconaia subrotunda* | LONG SOLID | G4 | S4 | | |
| *Lampsilis cariosa** | YELLOW LAMPMUSSEL | G4 | S3 | | |
| *Lampsilis fasciola* | WAVY-RAYED LAMPMUSSEL | G4 | S4 | | |
| *Lampsilis ochracea** | TIDEWATER MUCKET | G4 | S4 | | |
| *Lampsilis ovata* | POCKETBOOK | G5 | S5 | | |
| *Lampsilis radiata** | EASTERN LAMPMUSSEL | G5 | S4 | | |
| *Lasmigona complanata* | WHITE HEELSPLITTER | G5 | S3 | | |
| *Lasmigona costata* | FLUTED SHELL | G5 | S5 | | |
| *Lasmigona holstonia* | TENNESSEE HEELSPLITTER | G3 | S2 | C2 | |
| *Lasmigona subviridis** | GREEN FLOATER | G4 | S3 | | |
| *Lastena lata* | CRACKING PEARLYMUSSEL | G2 | S1 | C2 | |
| *Leptodea fragilis* | FRAGILE PAPERSHELL | G5 | S4 | | |
| *Lexingtonia dolabelloides* | SLABSID PEARLYMUSSEL | G2 | S1 | C2 | |
| *Lexingtonia subplana** | VIRGINIA PIGTOE | G1Q | SH | | |
| *Ligumia nasuta** | EASTERN PONDMUSSEL | G4 | S4 | | |

TABLE II (Continued)

| SCIENTIFIC NAME | COMMON NAME | GLOBAL RANK | STATE RANK | FEDERAL LEGAL STATUS | STATE LEGAL STATUS |
|---|---|---|---|---|---|
| *Ligumia recta latissima* | BLACK SANDSHELL | G5 | S2 | | |
| *Medionidus conradicus* | CUMBERLAND MOCCASIN | G4 | S3S4 | | |
| *Pegias fabula* | LITTLE-WINGED PEARLY-MUSSEL | G1 | S1 | LE | LE |
| *Plethobasus cyphyus* | SHEEPSNOSE | G3 | S1 | | |
| *Pleurobema collina** | JAMES SPINYMUSSEL | G1 | S1 | LE | LE |
| *Pleurobema cordatum* | OHIO PIGTOE | G4 | S2 | | |
| *Pleurobema oviforme* | TENNESSEE CLUBSHELL | G3 | S3 | C2 | |
| *Pleurobema plenum* | ROUGH PIGTOE | G1 | S1 | LE | LE |
| *Pleurobema pyramidatum* | PYRAMID PIGTOE | G2G3 | S2 | C2 | |
| *Proptera alata* | PINK HEELSPLITTER | G5 | S4 | | |
| *Ptychobranchus fasciolaris* | KIDNEYSHELL | G4 | S3 | | |
| *Ptychobranchus subtentum* | FLUTED KIDNEYSHELL | G3 | S3 | | |
| *Quadrula cylindrica* | RABBITS FOOT | G3 | S2 | C2 | |
| *Quadrula intermedia* | CUMBERLAND MONKEYFACE | G1 | S1 | LE | LE |
| *Quadrula pustulosa* | PIMPLE BACK | G5 | S3 | | |
| *Quadrula sparsa* | APPALACHIAN MONKEYFACE | G1Q | S1 | LE | LE |
| *Strophitus rugosus* | INTERIOR SQUAWFOOT | G5 | S3 | | |
| *Strophitus undulatus** | SQUAWFOOT | G5 | S4 | | |
| *Tritogonia verrucosa* | PISTOLGRIP | G4 | S2 | | |
| *Truncilla truncata* | DEERTOE | G4 | S1 | | |
| *Uniomerus obesus** | SOUTHERN PONDHORN | G2 | S2 | | |
| *Uniomerus tetralasmus* | PONDHORN | G3 | SU | | |
| *Villosa constricta** | NOTCHED RAINBOW | G3 | S3S4 | | |
| *Villosa fabalis* | RAYED BEAN | G2 | S1 | C2 | |
| *Villosa nebulosa* | ALABAMA RAINBOW | G3 | S3S4 | | |
| *Villosa perpurpurea* | PURPLE BEAN | G2Q | S2 | C2 | |
| *Villosa trabalis* | CUMBERLAND BEAN MUSSEL | G2 | S1 | LE | LE |
| *Villosa vanuxemensis* | MOUNTAIN CREEKSHELL | G3 | S3S4 | | |

* - Restricted to the Atlantic Slope drainage in Virginia.

1 - Scientific names are those listed by the VANHP as "state names" in the Heritage database
- Common names are in general conformance with those listed in the publication Common and Scientific Names of Aquatic Invertebrates from the United States and Canada: Mollusks. American Fisheries Society Special Publication 16, Bethesda, Maryland. 1988.