was generally acceptable and that the reservoir could be filled if the program proved to be successful.

The general goal of the Cumberlandian Mollusk Conservation Program (CMCP) is to improve conditions for the survival of endangered and other stream dwelling mollusks that exist only in the headwaters of the Tennessee and Cumberland river systems. The general approach of the program is to obtain new data to substantiate or expand published information and then to use this data base to characterize species and faunal requirements and to evaluate mussel habitat in selected river reaches in the Tennessee River basin.

In its simplest organization the CMCP involves a number of activities separated into two consecutive phases. The first or research phase of the program consists of eight activity leaders assigned the responsibility for development and implementation of nine interrelated activities designed to answer questions about the Cumberlandian mussel fauna and present or potential habitats. Specifically these activities include float surveys of several rivers to update distribution records; field and laboratory studies intended to identify fish hosts for several mussel species; laboratory studies designed to perfect an artificial culture medium for mussel glochidia; and several concurrent studies to describe the physical, chemical, and biological components of 15 actual or potential Cumberlandian mussel habitats scattered throughout the Tennessee River basin. The final activity in this phase of the program will consist of analyzing all of the accumulated data to produce characterizations of the habitat of certain Cumberlandian species and to select transplant sites for mussel specimens now living in the impoundment area of Columbia Reservoir.

The second or conservation phase of the program is designed to apply the foundation of information produced in the research phase. An important activity in this phase will be the actual moving and monitoring of mussel transplants. Other activities, all directed toward maintaining or improving habitat conditions in areas where Cumberlandian species occur naturally, will include various approaches to reducing the amounts of silt and other materials that are carried into streams, stabilizing and safeguarding gravel beds, and developing and implementing procedures to minimize impacts of present and future human uses of selected watercourses. Additional activities also may be indicated based on the analyses or observations made during the research phase of the program.

Implementation of this program began with a few mollusk and fish surveys that were conducted in 1979. By July 1980 all of the research activities had started field or laboratory work. Completion of the research phase is scheduled for fall 1982, by which time the analysis of data and the selection of transplant sites will have occurred. Conservation phase activities are scheduled to begin after the research analysis has been completed. Transplantation of Duck River mussels is presently scheduled to occur in late fall 1982 and anticipated stream restoration work is proposed to begin in 1983. Monitoring of the transplants and completion of restoration activities may continue for a number of years.

Although this wide-ranging program was proposed and, largely, will be carried out by TVA, representatives of several Federal agencies and three affected states are involved in monitoring its progress and in judging whether it has accomplished its goal. These governmental agencies are represented on a coordination committee which has been charged by the FWS with establishing biological criteria for this program and then evaluating the results of the various activities. If TVA can meet the biological criteria established by the interagency committee, more than likely the FWS will remove the endangered species obstacles to the completion of Columbia Reservoir.

At this point, this program represents an effort of Federal and State agencies to try to resolve an endangered species problem through cooperation instead of confrontation. The next several years will demonstrate how well this effort succeeds. In the interim malacology will gain significant quantities of information about the life history and ecology of the Cumberlandian mollusk fauna.

COMPARISON OF MOLLUSKS RETRIEVED BY CROWFOOT DREDGE AND PONAR GRAB SAMPLER FROM THE WHITE RIVER AT ST. CHARLES, ARKANSAS WITH COMMENT ON POPULATION STRUCTURE OF *CORBICULA FLUMINEA* *(BIVALVIA: SPHAERIACEA)*

Louise Russert Kraemer and Mark Gordon
Department of Zoology, University of Arkansas
Fayetteville 72701

Indigenous molluscan inhabitants of benthic communities in U.S. rivers exhibit a wide size range. The largest animals are the mussels (Unionidae) which may commonly attain a length of more than 12 cm. The smallest animals include gastropods, fingernail clams, and various juvenile molusks, all within a size range of one to 30 mm. When benthic communities of large rivers are studied, however, collecting gear is not selected with the objective of obtaining samples of all animals, both large and small.

Investigators have compared the composition of benthic samples obtained with various kinds of gear (Baker, et al. 1977 and others). A number of workers have analyzed efficacy of collecting gear in such freshwater habitat as shallow streams, deep rivers, lakes, and reservoirs (Wefring and Teed, 1980; Rabeni and Gibbs, 1978; Paterson and Fernando, 1971; and others). Benthic sampling gear effectiveness has been studied in marine habitat from shallow coastal waters and bays to deep sea. Gear effectiveness in substrates such as soft mud bottoms, hard bottoms and artificial substrates has been evaluated. One study (Radford and Hartland-Rowe, 1971) was a comparison of surface and subsurface sampling techniques. In the literature reviewed, however, no record was found of a study which deliberately set out to sample all animals, regardless of size, on a river bottom.

In November, 1979, plans for a large bridge and approaches to span the White River at St. Charles, (Arkansas County) Arkansas, required a site study to determine presence or absence of the mussel, *Proptera (=Potamilus) capax*, now listed as an endangered species in the Federal Register. Collections of *Proptera capax* near the proposed bridge site housed in several museums include specimens from: (1) Devalls Bluff, Arkansas, in 1966 (U.A.M.); (2) lower White River in the migratory waterfowl refuge, date unknown, (U.S.M.N.H.); and (3) one mile north of Devalls Bluff, in 1939 (U.M.M.Z.). The White River in Arkansas has been the locale of one of the richer unionid mussel faunas in the world, including at least 58 species (Gordon, et al., 1979). However, no previous data on the benthos of the proposed bridge site at St. Charles existed and seasonal sampling for this study was precluded by time constraints.

Table 1. Location of the four ponar grab sampling transects and number of collection sites and samples from each transect of the White River at St. Charles, Arkansas, November 21 and 26, 1979.

Transect Number	Location of transect in relation to centerline of proposed bridge	No. of collection sites	No. of samples
1	75 feet downstream from centerline	10	30
2	25 feet downstream from centerline	10	30
3	25 feet upstream from centerline	11	33
4	75 feet upstream from centerline	10	30

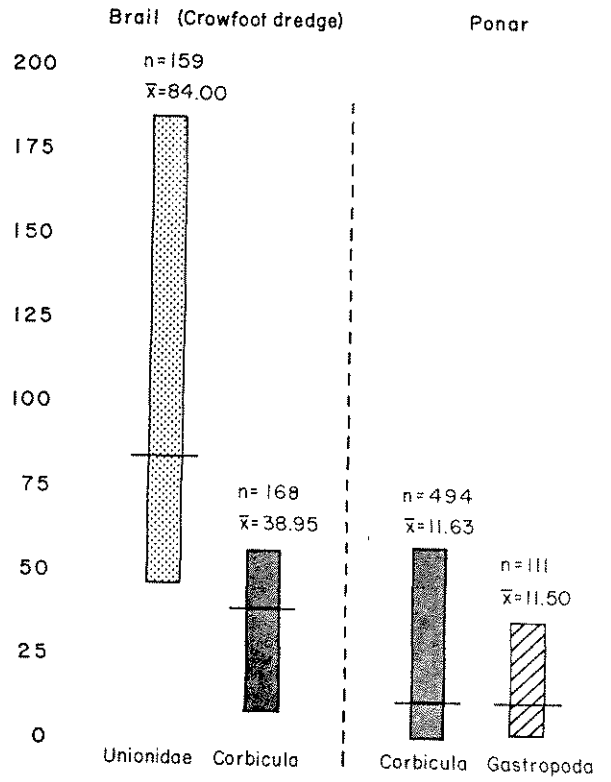

Figure 1. Comparative size dispersal and size range of Mollusca sampled by crowfoot dredge and ponar grab. X represents mean length in mm. Note: occurrence of gastropods in crowfoot dredge samples (indicated in Table 2) was accidental and insignificant and thus is not shown here.

Consequently, a one-time, intensive, overlapping sampling process was undertaken which not only supplied the evidence immediately required concerning *P. capax*, but which also produced substantial baseline data on extant White River biota.

In this paper we present evidence to show: (1) that overlapping collection methods used in this study (crowfoot dredge and ponar grab) allow community structure of benthic mollusk populations to be fully characterized; (2) that the White River bottom study site is inhabited by an essentially molluscan fauna, until recently comprised of indigenous gastropods and mussels, but now conspicuously including the introduced Asian clam, *Corbicula fluminea*; (3) that the successful colonization of the site by *C. fluminea* is associated with disturbance of the substrate and with a diminution of the indigenous fauna; and (4) that *C. fluminea* presently comprises a substantial portion of the small animals (retrieved by ponar grab) and of large animals (retrieved by crowfoot dredge). We note that the size range of local populations of *C. fluminea* now greatly exceeds that of autochthonous mollusks, a feature which is traceable to developmental, behavioral, reproductive and neurobiological peculiarities of the introduced species. We suggest it may be that *C. fluminea* owes a portion of its "success" to this peculiar population characteristic.

MATERIALS AND METHODS

Crowfoot dredge samples were taken in three complete transects of the river bottom at the bridge site on November 21 and 26, 1979. A fourth complete transect series by crowfoot dredge was taken November 26, 1979 at a point 5600 feet downstream from the bridge site. All the mollusks retrieved were relaxed in Nembutal and subsequently fixed in Bouins' fluid or formalin before being saved in ethanol.

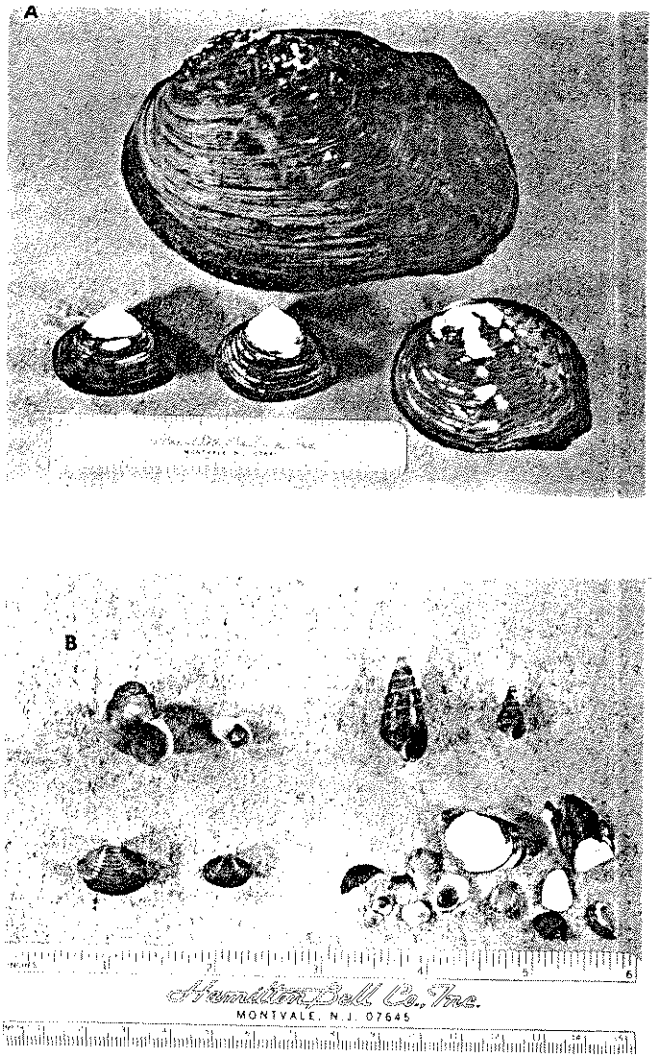

Figure 2. Photographs showing typical molluscan assemblage in samples retrieved from the White River at St. Charles, Arkansas, by means of crowfoot dredge (A) and by means of ponar grab (B).

Ponar grab samples were taken in four complete river transects at the bridge site using a ponar grab with a 9.5 cm^2 "bite", (Table 2). In each of the transects the first sampling site was within 50 feet of the southwest bank and subsequent sampling sites were located 50 feet apart, the last sampling site of each transect occurring within 50 feet of the northeast bank. Average river depth at the first sampling site in each series was 8 feet, at mid-river sampling sites 15 feet, and at last sampling site, 15 feet. All grab samples were taken in replicates of three. Replicated samples were combined, sieved through a 30-mesh sieve (openings of 520 um), and preserved in ethanol.

Animals in the crowfoot dredge samples were identified. Length, width, height and number of annual growth lines were tabulated for each animal. Dimorphic species were sexed. All of each of the ponar grab samples was examined using a Luxo-10X Magnifier Lamp and tech-

TABLE 2
COMPOSITION OF CROWFOOT DREDGE SAMPLES, WHITE RIVER, ARKANSAS 1979-1980

Bivalvia: Unionidae	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	Total Specimens
Fusconaia ebena (Lea, 1831)	7	1	6	2	6	4	6	4	2	-	-	-	38
Megalonaias gigantea (Barnes, 1823)	1	-	-	-	-	-	-	-	1	1	-	1	4
Amblema plicata (Say, 1817)	-	-	-	-	-	-	-	-	-	-	-	1	1
Quadrula pustulosa (Lea, 1831)	6	2	7	6	4	1	6	-	1	4	3	3	43
Quadrula nodulata (Rafinesque, 1820)	-	-	-	1	-	-	2	-	-	-	-	-	3
Quadrula cylindrica (Say, 1817)	-	-	-	-	-	-	-	-	1	-	-	-	1
Quadrula quadrula (Rafinesque, 1820)	4	2	2	3	5	1	2	3	3	1	3	-	29
Tritogonia verrucosa (Rafinesque, 1820)	-	-	-	-	-	-	-	-	-	-	3	-	3
Plectomerus dombeyanus (Valenciennes, 1833)	-	-	-	-	-	-	-	-	-	-	1	1	2
Elliptio dilatatus Rafinesque (1820)	-	-	-	-	-	-	-	-	-	2	-	-	2
Anodonta grandis Say (1829)	-	-	-	-	-	1	-	-	1	1	-	-	3
Obliquaria reflexa Rafinesque (1820)	-	-	-	-	-	-	-	-	1	1	-	-	2
Obovaria olivaria (Rafinesque, 1820)	-	-	-	-	-	-	1	-	2	-	-	-	3
Truncilla truncata Rafinesque (1820)	-	-	-	-	-	-	-	-	-	-	1	-	1
Leptodea fragilis (Rafinesque, 1820)	-	-	-	2	1	3	2	1	6	-	-	-	15
Lampsilis anodontoides (Lea, 1831)	-	-	-	1	-	-	-	-	-	-	2	-	3
Lampsilis ovata ventricosa (Barnes, 1823)	-	-	-	-	-	2	-	1	1	-	2	-	6
Lampsilis radiata siliquoidea (Barnes, 1823)													
Total number of specimens:	18	5	15	15	16	12	19	9	19	10	15	6	159
Total number of species:	4	3	3	6	4	6	6	4	10	6	7	4	17
Bivalvia: Corbiculidae													
Corbicula cf. *fluminea* (Müller)	27	81	2	4	2	1	15	1	-	-	1	34	168
Gastropoda: Viviparidae													
Campeloma sp. (probably *subsolidum*)	-	-	-	-	-	-	2	-	-	-	-	4	6
Viviparus subpurpureus (Say, 1829)	-	-	-	-	-	-	-	-	-	-	-	23	23
Total number of all mollusk specimens:	45	86	17	19	18	13	36	10	19	10	16	67	356
Total number of all mollusk species:	5	4	4	7	5	7	8	5	10	6	8	7	20

niques described elsewhere (Kraemer, 1976). Substrate particle size using the Wentworth scale (Wentworth, 1922), artifacts and shell fragments encountered in the substrate were tabulated for each lot of the samples. All visible organisms, many only 1-2 mm long, were saved. Specific determinations of the mollusks were made insofar as possible. Other organisms, because of their lesser value to the limited aims of this study, were seldom evaluated beyond family or order.

All items retrieved from crowfoot dredge and ponar grab samples were accessioned into the University of Arkansas Museum Collections.

RESULTS

Crowfoot dredge samples

Table 2 summarizes most of the findings from study of the 12 sample series. Though *Proptera capax* was not found, a diverse fauna of other mussel species was present. The mussels included 17 species, six of which are in the same subfamily as *P. capax: Obliquaria reflexa, Obovaria olivaria, Truncilla truncata, Leptodea fragilis, Lampsilis anodontoides* and *Lampsilis ovata ventricosa*. Mussels from the crowfoot dredge samples represented a mature, long-established group of animals, ranging in age from six to more than 25 years.

A substantial biomass of the introduced bivalve, *Corbicula fluminea* (Sphaeriacea: Corbiculidae), also appeared in the crowfoot dredge samples. The animals were at the upper limit of their known size range, from 8.7 - 56.3 mm long, with a mean of 39.0 mm. From two of the 12 sample series the gastropods *Campeloma* (probably *C. subsolidum*) and *Viviparus subpurpureus* were recovered.

Ponar grab samples

Numbers and kinds of animals recovered from the 47 stations and 77 lots of ponar grab samples from the four river transects at the bridge site are shown in Table 3. A preponderance of mollusks was found, but insect forms, mostly larvae of Chironomidae and Trichoptera, and occasional specimens of other animal groups were also present.

C. fluminea was the most common bivalve mollusk found in the ponar samples. This species was represented by adults, juveniles (1-4 mm long), and by abundant shell fragments. Indigenous relatives of *C. fluminea* included *Musculium transversum* (Sphaericea: Sphaeriidae) and were found in only five of the samples, mostly near shore. Unionid bivalves were represented by occasional shell fragments, a few of which could be identified as *Quadrula pustulosa, Q. quadrula* and *Leptodea fragilis*. The only identifiable whole juvenile mussel specimen found was *Quadrula cylindrica*.

Gastropods were a prevalent component of the ponar samples. At 23 of the 47 stations, *Viviparus subpurpureus* was present. Thirteen of the ponar sampling sites yielded specimens of *Pleurocera canaliculatum*; and 9 stations included *Campeloma subsolidum*. Both *V. subpurpureus* and *C. subsolidum* were present as large adult snails (2 cm+ tall) and less frequently as juveniles. Rarely encountered were *Somatogyrus*,

TABLE 3

ORGANISMS COLLECTED BY PONAR GRAB
FROM FOUR BENTHIC TRANSECTS OF THE WHITE RIVER, ST. CHARLES, ARKANSAS, NOVEMBER 21 AND 26, 1979

Transect 1

Station	A	B	C	D	E	F	G	H	I	J	K	Total
Corbicula cf. *fluminea* (Müller)	30	66	19	2		2	1					120
Unidentified juvenile Unionidae						1						1
Juvenile *Quadrula cylindrica* (Say)		1										1
Viviparus subpurpureus (Say)	6	10	2		1	1						20
Pleurocera canaliculatum (Say)	1	1	1									3
Chironomidae		22	61	1	4	5	1	1				95
Trichoptera	2											2
Coleoptera			1									1
Oligochaeta	3	115	1		1							120
Nematoda	2											2
Number of specimens	44	215	85	3	6	9	2	1	0	0		365
Number of taxa	6	6	6	2	3	4	2	1	0	0		13

Transect 2

Corbicula cf. *fluminea* (Müller)	32	27		40	2	4		2	10	12		129
Unidentified Sphaeriidae					2							2
Viviparus subpurpureus (Say)	24	2		14	3			1	4	13		61
Campeloma (probably *subsolidum*)	2								3	4		9
Somatogyrus sp.					1							1
Pleurocera canaliculatum (Say)	6	1		2					1			10
Goniobasis potosiensis plebeius (Anthony)					1							1
Chironomidae	1			3	4	11		5	6			30
Trichoptera	12					1						13
Plecoptera	2											2
Ephemeroptera		1										1
Amphipoda	5											5
Oligochaeta	1											1
Nematoda						1						1
Number of specimens	85	31	0	59	13	17	0	8	24	29		266
Number of taxa	9	4	0	4	6	3	0	3	5	3		14

Transect 3

Corbicula cf. *fluminea* (Müller)	13	5	53	5	7	2			5	3	57	150
Musculium transversum (Say)	1								1	1		3
Viviparus subpurpureus (Say)		2	8	1	1				3		11	26
Campeloma (probably *subsolidum*)	6		1	1							1	9
Somatogyrus sp.			1		1							2
Unidentified Hydrobiidae			1									1
Pleurocera canaliculatum (Say)	1	2	4								1	8
Chironomidae	1		8	3		1		2		5		20
Trichoptera		5										5
Palaemonetes kadiakensis		1										1
Amphipoda	1	5	1									7
Oligochaeta	4	5	16		1	1					3	32
Nematoda			3					2	1			6
Number of specimens	27	25	96	10	10	6	0	4	10	9	73	270
Number of taxa	7	7	10	4	4	3	0	2	4	3	5	13

Transect 4

Corbicula cf. *fluminea* (Müller)	10	21	122	5	6	6	1		1	7	179
Musculium transversum (Say)			1								1
Quadrula pustulosa (Lea)									1		1
Quadrula quadrula (Rafinesque)									1		1
Leptodea fragilis (Rafinesque)		1									1
Unionidae fragments									4		4
Viviparus subpurpurens (Say)	2	4	14			3			4	1	28
Campeloma (probably *subsolidum*)									1		1
Pleurocera canaliculatum (Say)	1	3	9								13
Physa sp.							1				1
Chironomidae	2	3	17	21	9	2	5	6	2	1	68
Trichoptera	4								2		6
Dytiscidae									3		3
Oligochaeta		2			3	1					6
Hirudinea	1	1									2
Nematoda					2	5					7
Turbellaria									3		3
Number of specimens	20	35	163	26	20	17	7	6	22	9	325
Number of taxa	6	7	5	2	4	5	3	1	10	3	17

Goniobasis and a hydrobiid snail. Larger average size and lesser numbers of gastropods approached but did not equal the biomass of *C. fluminea* in the ponar samples.

Samples comprised of just fine and medium sand substrate usually yielded nothing more than juvenile *C. fluminea* and a few midge larvae (Chironomidae); substrate samples comprised of very coarse sand, granules and cobbles frequently contained species of insect larvae, gastropods, and *C. fluminea.*

Simple, graphic comparison of the mollusk communities sampled by means of crowfoot dredge and ponar grab, is shown in Figure 1.

DISCUSSION

Combined results of crowfoot dredge and ponar grab sample studies allow us to characterize the community structure of the river bottom. Major components of the benthos are not mollusks and arthropods, as found for the Arkansas River (Kraemer, 1976), and characterized as typical for many rivers (Hynes, 1972). The White River benthos proved in this study to be comprised primarily of two groups of mollusks: (1) bivalves, especially indigenous mussels (Unionidae) and the introduced Asian clam *Corbicula fluminea* (Corbiculidae); ;and (2) gastropods, especially *Viviparus subpurpureus, Pleurocera canaliculatum* and *Campeloma subsolidum.* Indigenous mussels recovered in this study (nearly all by crowfoot dredge) were almost all more than six years old. Since seasonal sampling was not done, we are not sure that younger mussels are not now present, though it seems unlikely.

Prior to 1966, chief molluscan inhabitants of the river bottom most likely were indigenous mussels, including *Proptera capax,* and indigenous snails such as the species mentioned above. Several large commercial shell heaps near the White River at Devalls Bluff, about 20 miles upstream from the bridge site at St. Charles were inspected in 1966. While *P. capax* was present, there was no evidence of *C. fluminea.* Since 1966, the introduced *C. fluminea* has established itself among the long-lived, large benthic animals (retrieved in crowfoot dredge samples) and among the small benthic animals (retrieved in ponar grab samples).

Evidence presented here indicates that the size of *Corbicula,* both as a juvenile and as a relatively long-lived adult, may be a factor in its phenomenal "success" as it populates U.S. river bottoms. Previous studies have indicated that mature *C. fluminea* has peculiar structural, functional and behavioral characteristics (Kraemer, 1979b, 1978a, 1978b, 1977a) which suit it for life on a disturbed river bottom among indigenous mussels. Less attention has been given to the role of immature *C. fluminea* among indigenous small benthic animals (Kraemer, 1979a, 1977b). Went (1968) reminds us that extremes of size impose very different living conditions on organisms. *C. fluminea* seems to have met successfully the living conditions imposed on both of its size extremes and thereby to have outclassed the capabilities of its indigenous benthic molluscan neighbors, both large and small.

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A NEW AID TO TAXONOMIC RESEARCH ON MOLLUSKS

Joseph Rosewater
Department of Invertebrate Zoology, Division of Mollusks
National Museum of Natural History, Smithsonian Institution
Washington, D.C. 20560

Taxonomic studies on mollusks are impeded by a major problem concerning the literature of the latter half of the 19th Century. There are virtually no exhaustive indices to the literature of the period 1850-1870. Sherborn's magnificent "Index Animalium" (1902-1933) covers years 1758-1850. The Zoological Record began abstracting literature in 1864 and continues to date, although the latter was rather incomplete during its