RICHARD [illegible]

Dr. Neves Dunn 1989

RECEIVED
NOV 5 1990
ENVIRONMENTAL DIV.

ECOLOGICAL SPECIALISTS, INC.

November 2, 1990

Heidi L. Dunn
Rt 1 Box 155BA
Elsberry, MO 63343
314-898-3111

Mr. Bill Beuter
Virginia Department of Transportation
1201 E. Broad
Richmond, Virginia 23219

Dear Bill:

As we discussed on the phone, I was involved with a relocation project in 1987. We relocated over 5000 mussels. Since then I have sampled the relocated mussels yearly. I have attached last years report for your information. I am currently compiling the 1990 data. I am also working on a comparison of results between years. Both reports should be finished by early 1991.

If you have any questions or require further information, please contact me and I would be happy to be of further assistance.

Sincerely,

Heidi L. Dunn
President

CC: Alan Gaulke, Mussel Mitigation Trust Fund Committee

HLL

REPORT OF THE 1989 MONITORING STUDY OF RELOCATED MUSSELS NEAR RIPLEY, OHIO (Contract #104)

Submitted to:

MUSSEL MITIGATION TRUST FUND COMMITTEE
Columbus, Ohio

Submitted by:

HUNTER/ESE, INC.
St. Louis, Missouri

Hunter/ESE No. 590-1020-0400

February 23, 1990

HUNTER / ESE
ENVIRONMENTAL SERVICES, INC.

EXECUTIVE SUMMARY

Hunter/ESE monitored unionid mollusks in August 1989, two years after relocation. Tagged mussels were located with coordinates recorded during previous monitoring efforts. Approximately 24 percent of the transect was sampled to estimate survival, growth, and reproductive status of relocated clams. Data indicate:

1. Survival of tagged unionid mollusks, as calculated by direct enumeration was 29.8 to 37.4 percent;
2. Survival based on direct comparison averaged 32.1 percent (21.3 to 42.9 confidence interval);
3. Survival based on the number of live versus dead tagged mussels recovered averaged 83 percent;
4. Survival, movement, and growth of mussels appears to be related to substrate type;
5. High discharge in 1989 may have contributed to low recovery of tagged mussels;
6. Most species continue to survive, although *Quadrula quadrula* and *Truncilla truncata* continue to exhibit high mortality;
7. Growth was apparent in 11 of the 18 species recovered, primarily in young individuals;
8. Few native or tagged mollusks were gravid during the monitoring effort;
9. Movement of recovered mussels was minimal, with 90 percent of live mussels collected in their original locations; and
10. Most movement was less than 5 feet in distance, but a few individuals were collected up to 70 feet downstream of initial placement.

Survival was lower than the previous monitoring efforts, presumably due to mussels being dislodged and transported away from the transect. However, trends with respect to species, substrate, and area of transect in survival, growth, and movement were similar in 1988 and 1989.

TABLE OF CONTENTS

LIST OF TABLES
(Page 1 of 2)

LIST OF TABLES
(Page 2 of 2)

LIST OF FIGURES

1.0 INTRODUCTION

Hunter/ESE was contracted by the Mussel Mitigation Trust Fund to sample unionid mollusks along a transect near Ripley, Ohio during August 1989. The primary purpose of the study was to determine survival, growth, movement, and reproductive condition of mussels relocated to this site in May 1987. This report describes the background and objectives, methods, and results of the study.

American Electric Power Service Corporation (AEPSC) is the Project Manager for a project to convert a power plant from a nuclear facility to a coal-fired facility. The facility being converted, Wm.H. Zimmer Plant, is located on the Ohio River near River Mile 443.0. A barge fleeting and coal unloading facility will need to be constructed to accommodate coal delivery to the new power plant. The fleeting and unloading facility will require the dredging of about 1.5 miles of the Ohio River. Under Section 10 of the 1899 Rivers and Harbors Act and Section 404 of the Clean Waters Act, permits are required for dredging and construction in navigable waters. The U.S. Army Corps of Engineers is responsible for reviewing potential impacts of the proposed action and issuing the permits.

A large, diverse mussel bed is known to occur between River Miles 443.4 and 447.5 (Williams and Schuster, 1982 unpublished data). To determine the extent of the bed in the area affected by dredging and fleeting, mussels were sampled between River Miles 442.6 and 445.6 (Stansbery and Cooney, 1985). Three beds were located in the study area. Bed 1 extended from River Mile 443.0 to about 443.6, Bed 2 extended from River Mile 443.8 to about 445.0, and Bed 3 extended from River Mile 445.2 to about 445.6.

Since a portion of Bed 1 would be impacted by the construction of the coal unloading facility, the U.S. Army Corps of Engineers stipulated in their permit conditions that the potential loss of mussels, via dredging, be mitigated. As a mitigative measure AEPSC was required to:

1. collect, tag and relocate 5,000 mussels from the area to be affected; and

2. set up a trust fund to be used in monitoring the relocated mussels and fund other research on Ohio River unionid mollusks.

Few large scale mussel relocation projects have been attempted to date (Miller and Nelson, 1983). Of the efforts completed, few have been monitored to determine the success or failure of the effort. A few studies from which results have been reported include a relocation effort on the Mississippi River and an effort on Duck River in Tennessee. NUS Corporation (a consultant from Pittsburgh, Pennsylvania) relocated mussels from Sylvan Slough on the Mississippi River near Rock Island, Illinois. Mussels relocated were in the area of new bridge construction. Of the 7,096 mussels collected and relocated, three *Lampsilis higginsi* and 16 *Cumberlandia monodonta* were tagged with plastic tags and 50 *Megalonaias nervosa* and 50 *Amblema plicata* were marked with fluorescent paint. Relocated mussels were checked 1 year after initial relocation. The effort appeared to be successful as all three *L. higginsi*, 69 percent of the *C. monodonta*, 60 percent of the *M. nervosa*, and 20 percent of the *A. plicata* were recovered during the follow-up survey (Oblad, 1979).

In 1982, Tennessee Valley Authority tagged and relocated 1,000 *Conradilla caelata* from the Duck River where reservoir construction was underway (Jenkinson, 1980). Mussels were relocated to four streams. An average of 35 percent survived 1 year after the transplant. After 5 years of monitoring only 15 percent of the relocated population was recovered (Jenkinson, 1987 personal communication).

Two other relocation efforts are currently being monitored, but results are preliminary. The Wisconsin Department of Natural Resources in conjunction with the U.S. Fish and Wildlife Service and Wisconsin Department of Transportation relocated mussels from a bridge construction area on the St. Croix River in late 1988. Monitoring will not be conducted until bridge construction is complete (David Heath, 1989 personal communication). The Illinois Natural History Survey relocated unionid mollusks from a bridge site on the Kankakee River. Mollusks were measured, weighed, marked, and relocated to a known area (INHS 1989, personal communication). Relocated, as well as resident, unionid mollusk populations have been monitored for the past 2 years.

In May 1987, Hunter/ESE collected, tagged and relocated 5,160 mussels representing 22 species from the Wm.H. Zimmer Plant site (Table 1-1). Mussels were tagged by drilling small holes (3/32 inches) just anterior to the posterior ridge, between the pallial line and the outer margin. A pre-numbered floy spaghetti tag was inserted and drawn tight after the clam was closed. Excess monofilament line was trimmed off the tag. Mussels were relocated to a 500-foot transect near Ripley, Ohio (Figure 1-1). The transect was marked with a line knotted every 10 feet and weighted with cinder blocks every 50 feet. Mussels were placed along the transect and their position recorded using the knots and cinder blocks as landmarks.

Each 10-foot interval was designated with an alpha-numeric code for the purpose of recording the position of tagged mussels. The zero point was designated 0-A, 10-foot point 0-B, 20-foot point 0-C, 50-foot point 1-A, etc., to the 490-foot point of 9-E (Figure 1-2). The sides of the transect were designated as L (left--looking downstream) and R (right--looking downstream). For example, if a mussel was placed between the 90 and 100 foot knot on the shoreward side of the line, its position would be recorded as 1-E-R.

In October 1987, Hunter/ESE monitored mussels to determine mortality, mobility, reproductive condition, and growth of relocated mussels. Tag condition and response of mussels to tagging was noted. Results of the first monitoring effort (ESE, 1988) indicate:

1. Survival of tagged mussels, as calculated from a population estimate of 2,086 to 2,398, was between 40.4 and 46.5 percent;
2. Survival based on a comparison of the number of mussels placed in each transect to the number recollected from each section was between 34.9 and 53.0 percent;
3. Few mussels moved from the area of initial placement except in one portion of the line, where movement of up to 40 feet was documented;
4. Growth was not detectable between May and October 1987;
5. A few tagged *Ellipsaria lineolata* and *Potamilus alatus* were gravid, indicating that reproductive activity was taking place; and
6. Tags were not inhibiting burrowing and animals were attaching mantle tissue, and in some cases, nacre over the tag holes.

Table 1-1. Mussel Species Collected Near the Wm.H. Zimmer Plant and Relocated to the Ripley, Ohio Transect, May 1987

Lasmigona costata
Megalonaias nervosa
Tritogonia verrucosa
Quadrula quadrula
Quadrula metanevra
Quadrula nodulata
Quadrula pustulosa
Amblema plicata
Fusconaia ebena
Fusconaia flava
Cyclonaias tuberculata
Plethobasus cyphyus
Pleurobema cordatum complex
Elliptio crassidens crassidens
Elliptio dilatata
Obliquaria reflexa
Actinonaias ligamentina carinata
Ellipsaria lineolata
Truncilla truncata
Potamilus alatus
Ligumia recta
Lampsilis ventricosa

Source: Hunter/ESE, 1989.

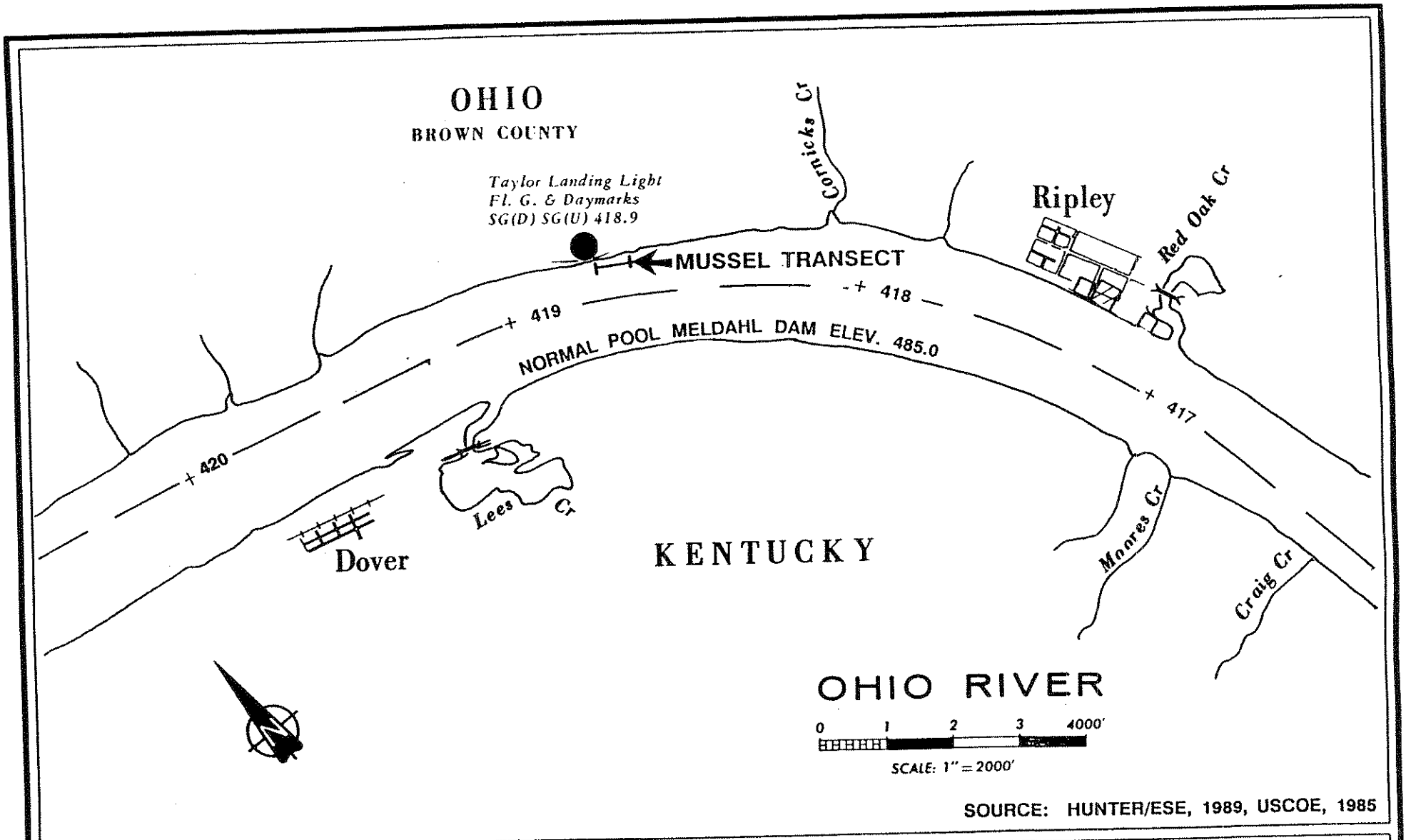


Figure 1-1
LOCATION OF MUSSEL RELOCATION TRANSECT

HUNTER/ESE
ENVIRONMENTAL SERVICES, INC.

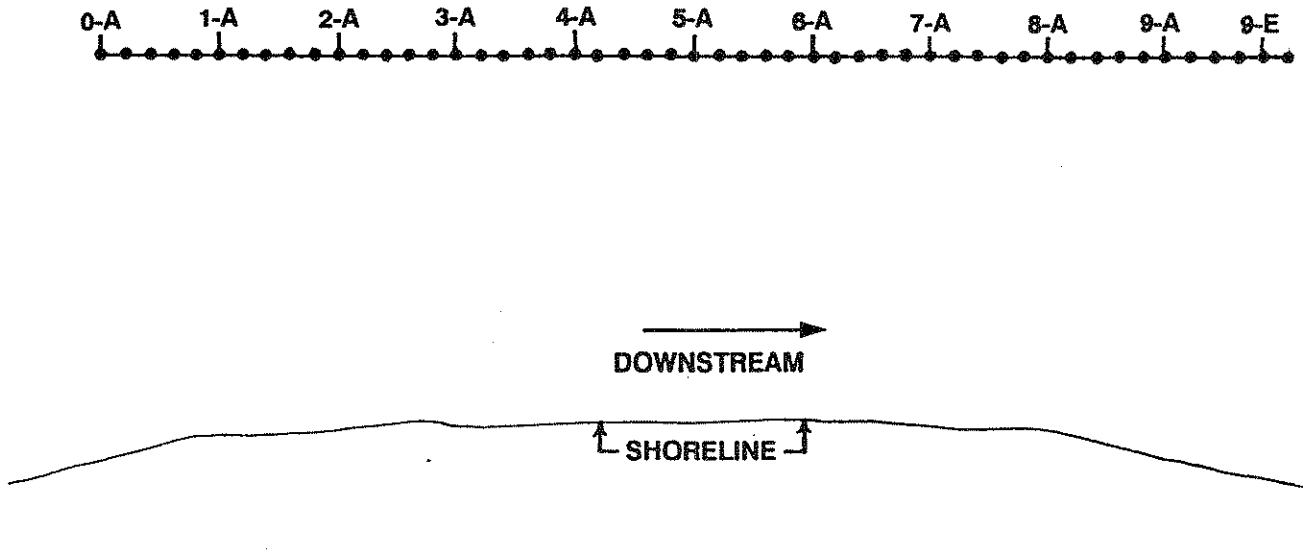


Figure 1-2
ORIGINAL TRANSECT DEMARCATIONS

HUNTER/ESE
ENVIRONMENTAL SERVICES, INC.

A second monitoring effort was conducted in August 1989 (Hunter/ESE, 1989a). Results indicate:

1. Survival of tagged unionid mussels, as calculated by direct enumeration, was 51.9 to 58.9 percent;
2. Survival based on direct comparison averaged 50.3 percent (39.4 to 61.2 confidence interval;
3. Substrates near Point 33 apparently inhibited tagged animals from burrowing, resulting in lower survival, lower percent growth, and more movement by individuals than in other areas of the transect;
4. Survival rate of most species was similar except *Quadrula quadrula* which exhibited high mortality;
5. Individuals collected during both monitoring efforts appear to have survived continued disturbance;
6. Growth was apparent in 8 of the 20 species collected;
7. Primarily young individuals exhibited growth;
8. Few native or tagged unionids were gravid during the monitoring effort and only one juvenile was collected near the transect; and
9. Most tagged mussels (82 percent) remained in the area they were placed, and detected movement was generally less than 5 feet either riverward, downstream, or upstream.

High survival, evidence of growth, and little movement suggested that relocated unionid mollusks were adapting to their new environment.

A third monitoring study was conducted in August 1989. Objectives of the study, as in past years, were to:

1. locate the transect;
2. estimate mussel survival;
3. determine if individuals have grown since May 1987;
4. determine if individuals moved from the position of initial placement;
5. determine reproductive condition of relocated mussels; and
6. locate dislodged tagged mussels by brailing.

2.0 MATERIALS AND METHODS

The relocation transect was found and the unionid mollusk population along the line was sampled August 1-6, 1989.

2.1 TRANSECT LOCATION AND RECONNAISSANCE

In May 1987, a 500-foot lead-core line was placed parallel to the current near River Mile 418.8. The position of the transect was recorded with a theotolite/ Electronic Distance Meter (EDM). Prior to removal of floats along the line in October 1987 and August 1988, the angle and distance to each float (100-foot interval) was recorded. The transect area was located in August 1989 using the recorded angles and distances from the prior efforts.

In August 1989, a cinder block and float was dropped at each recorded 100-foot interval. A diver conducted a reconnaissance near each point to determine the presence or absence of tagged mussels. If no tagged individuals were located, the diver swam a search pattern around the block until tagged animals were located. The block was placed in the center of the tagged mussel corridor. A pre-measured, lead core line with knots every 10-feet was stretched between blocks. In this manner, a sampling line within the tagged mussel corridor was created. After establishing a line, divers noted the presence or absence of tagged mussels along the line.

The position of points along the recreated line did not necessarily correspond to the original 10-foot point positions. To avoid confusion, the sampled points were numbered 0 to 49. The side of the line sampled was designated as shoreward (S) or riverward (R).

All lines and floats were removed at the termination of the study. Prior to detaching floats, each 100-foot interval was again recorded with the theotolite/EDM.

2.2 FIELD COLLECTION

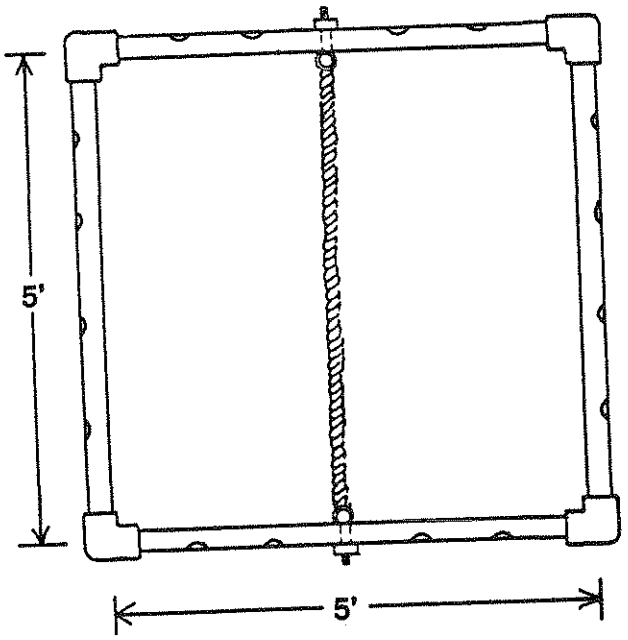
2.2.1 Adult Unionid Mollusks

A 5-foot by 5-foot quadrat divided into two subsections (5-foot by 2.5-foot) was utilized for the 1989 monitoring effort (Figure 2-1). Each diver collected from two quadrats placed adjacently within a section (10-foot by 5-foot area) of transect. Mussels collected in each subquadrat were placed in separate collection buckets and treated as separate samples.

Sampling points along the transect were selected by a random number generator. Points used for this effort were 8, 18, 30, 40, and 47. Adjacent sections were sampled to detect upstream and downstream movement of tagged mussels. At Point 8, one section was sampled on each side of the line, whereas, at Point 18, two sections were sampled on each side. At Point 30, 40 and 47, three sections were sampled on each side of the line. At each sampling point, two quadrat distances were sampled on each side of the line to determine shoreward or riverward movement. The configuration of quadrats sampled along the line is illustrated in Figure 2-2.

Malacologists sorted mussels collected by divers into four groups by species: (1) tagged live, (2) tagged dead, (3) untagged live, and (4) untagged dead. Malacologists worked from a boat next to the dive support boat to reduce the amount of time mussels were out of the water. Tagged mussels were measured (height and length) to the nearest millimeter and weighed to the nearest gram. Measurements were recorded along with tag number. Untagged live mussels were also measured and weighed. The reproductive condition of all live mussels was determined by slightly separating valves with modified reversible pliers and examining gill sacs. The collection location was recorded for each mussel.

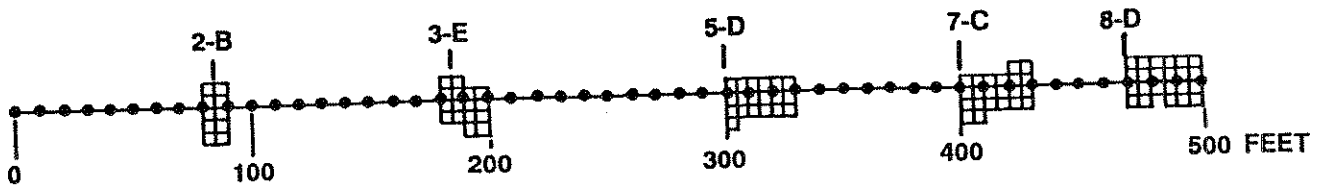
After data were recorded, the collected location of tagged mussels was compared to the original placement location. In most cases, the location of recollection was the same or very near the original position of placement. All live mussels were returned to the frame section from which they were collected. Notes were recorded on the tag condition and tissue growth near the tag hole from all tagged specimens.



SOURCE: HUNTER/ESE

Figure 2-1
QUADRAT USED FOR MUSSEL
MONITORING STUDY

HUNTER/ESE
ENVIRONMENTAL SERVICES, INC.



100 POINTS AS DETERMINED BY THEOTOLITE/EDM AND RECONNAISSANCE

2-B ORIGINAL TRANSECT DESIGNATION AS DETERMINED BY TAGGED MOLLUSKS

▫ ADJACENT QUADRATS SAMPLED DURING 1989 MONITORING STUDY

NOTE:

STARTING LOCATION OF SAMPLE QUADRATS WAS DETERMINED BY A RANDOM NUMBER GENERATOR.

Figure 2-2
PLACEMENT OF SAMPLING QUADRATS ALONG RELOCATION TRANSECT

HUNTER/ESE
ENVIRONMENTAL SERVICES, INC.

A shoreline survey was conducted in an effort to locate any tagged shells that may have died and washed to the bank. A boat was driven slowly as close to the bank as possible. An observer on the bow visually searched the shoreline and shallow water area for shells. The search was initiated approximately 50 yards upstream of the transect and continued for about 50 yards downstream of the transect. Although the visual search was conducted as thoroughly as possible, shells lodged below or between rocks may have been missed due to the riprap on the river bank.

2.2.2 Brail Survey

An intensive brail survey was conducted near the transect. The area 500 feet upstream to 500 feet downstream, 200 feet riverward, and 200 feet shoreward of the line was sampled by brail. Most of the area was sampled two or more times to gather as much data as possible. The brail was pulled slowly along the bottom while the boat drifted or was slowly powered downstream. After each run (approximately 500 feet upstream and downstream of the line and 100 feet riverward and shoreward of the line), the brail was lifted and all clams and debris removed. All clams were measured, weighed, and checked for tags and reproductive condition.

2.3 WATER QUALITY AND PHYSICAL MEASUREMENTS

Prior to each sampling day, dissolved oxygen, temperature, and current velocity were collected near the transect, at surface and near bottom depths.

Dissolved oxygen and temperature were measured with a YSI dissolved oxygen meter. Current velocity was measured with a Teledyne Gurley current meter. A qualitative estimate of substrate composite was recorded at each collection point.

2.4 DATA ANALYSIS

Data were analyzed to determine survival, growth, reproduction and mobility of the relocated unionid mollusk population.

2.4.1 Survival

Survival was calculated using two methods. The first method, direct enumeration (Bagenal, 1978), calculates a total population based on the number of mussels

collected within each area. The second method compares the number collected in each section to the actual number placed in each section of line.

Direct enumeration is applicable to situations that allow the number of animals to be accurately counted within a given area. The area occupied by the population is divided into units and a selected number of units are sampled. The population over the entire area is calculated using the formula:

$$\hat{N} = \frac{A}{a} \sum N_i$$

where: $\hat{N}$ = population estimate in August,
A = possible number of sections,
a = number of sections sampled, and
N_i = number of live tagged clams in Section i.

Variance (v) on this estimate can be calculated as

$$v^2 = \frac{A^2 - aA}{a} \left[\frac{a \sum N_i^2 - \left(\sum N_i \right)^2}{a(a-1)} \right]$$ (Bagenal, 1978)

the confidence interval around the population estimate is therefore $N \pm t_{(23,0.05)} \sqrt{V^2/n}$. Survivorship was determined as N/N, where N is the original population.

The second method compares the number of live tagged mussels collected in each section of the transect with the number originally placed in that section of line. The location of quadrats on the original line was mapped as accurately as possible. The number of live clams collected from each section was compared to the number placed in that section to determine survival. If an entire section was not sampled, the estimated percent sampled was compared with that percent of the number originally placed in that section. Survival rate was determined for each section of line. Confidence intervals were calculated based on the mean survival rate of the 24 sections sampled.

The second method would be more accurate than the first if the area in which mussels were originally placed could be determined exactly and the collection quadrat replaced in this exact location. Since the original line was missing at the time of monitoring, the quadrat could not be positioned precisely at each

original line segment. The actual location of collection could only be estimated, based on the tag numbers of mussels collected.

Another source of error in the second method is in assuming random distribution when estimating the number of clams placed in a portion of a section. During the initial relocation, mollusks were placed as randomly as possible within a section. In some cases, animals were clumped due to bedrock or large boulders occupying part of the section. In these cases, basing survival on a percent of animals available for recollection resulted in a high or low survival estimate. Animals may have been clumped in the area collected (high survival estimate) or clumped in the area not collected (low survival estimate).

2.4.2 Growth

All unionid mollusks were measured, (height and length) to the nearest millimeter and weighed to the nearest gram. Lengths, heights and weights in August 1989 were compared to measurements at the time of relocation (May 1987). The reported number of animals exhibiting growth is a conservative estimate. Only those animals showing increase in length, height and weight or those with growth beyond the tag were counted as exhibiting growth.

Growth was evident in animals with shell material beyond the tag. In most cases, however, tags were attached loosely and growth could occur within the slack portion of the tag.

2.4.3 Movement

Most mussels remained in the section of original placement. The position of the collection quadrat within the original transect could be estimated by comparing tag numbers of collected clams with the list of animals placed in each section. In most cases, a few mussels had moved (or were displaced) from each section. Direction and distance of movement was determined by comparing the position of the clam at the time of recollection to the location of the section in which it was originally placed.

3.0 RESULTS AND DISCUSSION

3.1 WATER QUALITY AND PHYSICAL MEASUREMENTS

The Ohio River Basin experienced high rainfall in 1989, resulting in discharge considerably higher than 1988, which influenced the chemical and physical nature of the river (Table 3-1). During previous monitoring efforts, substrate in the corridor consisted of large boulders with silt between crevices, hard sand, or thin layers of silt and sand over bedrock. High discharge in 1989 changed the character of the substrate. Loose gravel and cobble were more prevalent near Points 8, 18, and 40 in 1989. Loose slate, sometimes several inches deep, covered bedrock or other substrates and mussels near Points 30, 32, and 40 (Table 3-2).

Although discharge and flow varied between years, particularly in early summer, measurements collected during the sampling efforts were similar. Temperature was slightly lower in 1989 than 1988, ranging from 27 to 28.5°C. Little or no variation in temperature was evident between surface and bottom measurements (Table 3-3).

Dissolved oxygen levels ranged from 4.6 to 7.5 ppm (similar to August 1988) with some variation between surface and bottom readings. Current velocity was minimal during the sampling effort (<1 foot per second) also varying slightly from surface to bottom.

Although conditions during the two monitoring efforts were similar, the high discharge and resulting increased turbidity and changing substrate during spring and summer months may have affected the unionid mollusk population in the area.

3.2 INITIAL RECONNAISSANCE AND GENERAL OBSERVATIONS

During initial reconnaissance of the transect area, divers noted presence or absence of tagged clams, substrate types, and general bottom conditions. Observation was difficult due to lack of current velocity and the resulting fine silt layer on the substrate. In addition, *Corbicula fluminea* shells were abundant throughout the area.

Table 3-1. Comparison of Ohio River Stage and Discharge Near Cincinnati, Ohio (Markland Dam), 1989

Month	Historical Mean	1988		1989	
		Discharge (cfs)	Stage (ft.)	Discharge (cfs)	Stage (ft.)
April	193,000	126,664	12.26	213,715	12.1
May	127,000	85,221	12.25	266,538	12.1
June	75,000	20,633	12.39	187,723	12.1
July	63,000	22,858	12.39	95,705	12.2
August	59,000	16,655	12.56	62,850	12.3
September	56,000	25,014	12.50	150,393	12.1

Sources: Hunter/ESE, 1989.
USCOE, 1989.

Table 3-2. Substrate Type Near Collection Points

Point	Transact Area	Substrate Type
8	2-B	Silt/gravel/cobble/rubble
18	3-E	Silt/gravel/cobble/rubble
30	5-D	Broken slate over bedrock
32	6-A	Broken slate over slate/silt
40	7-C	Silt/sand/gravel/cobble/slate
50	9-B	Slate over silt/clay

Source: Hunter/ESE, 1989.

Table 3-3. Temperature, Dissolved Oxygen, and Current Velocity Near Relocation Transect, August 1989

	Date				
	8/01	8/02	8/03	8/04	8/05
Time of Reading	0900	0715	0730	0730	0730
Temperature (°C)					
Surface	28.0	27.2	27.3	28.0	28.5
Bottom	28.0	27.2	27.0	28.0	28.5
Dissolved Oxygen (ppm)					
Surface	5.6	5.3	7.5	5.6	6.1
Bottom	5.6	4.8	7.4	4.6	5.1
Current Velocity (ft/sec)					
Surface	0.8	0.25	0.5	0.1	0.25
Bottom	0.4	0.2	0.4	0.2	0.1

Source: Hunter/ESE, 1989.

Very few tagged clams were noticed upon first observation . Although some animals were on the substrate surface, most animals were burrowed below the level of the tag or completely buried below slate. Mussels were oriented with siphons directed upstream, downstream, riverward, and shoreward. Untagged clams were found in similar orientations.

While searching for the tagged clam corridor, divers swam a search pattern around anchors dropped according to theotolite readings. A few tagged shells were found up to 50 feet away from the original transect. Species, tag number and nearest transect point were recorded during reconnaissance (Table 3-4).

In general, tags were in good condition after 2 years. Periphyton and/or bacteria had colonized tags on animals not burrowed into the substrate. Numbers were readable after minimal scrubbing. In most cases, tags on animals burrowed in the substrate were in good condition. Most tags were still securely attached, however, 16 mussels were missing tags and a few tags came off during handling. Apparently some of the animals were sloughing off the tag. In these individuals nacre covered the interior portion of the tag. The exterior periostriacum and nacre were brittle, allowing the shell beneath the tag to break away during handling.

Severe shell erosion was noted on many tagged and untagged mussels (Table 3-5). In a few cases, beaks were completely worn away, leaving holes in the beak area. Some were nearly worn through with only thin shell material remaining. Erosion may have contributed or caused mortality in several cases. Perhaps erosion was due to abrasion; a result of high discharge and tumbling rock on the river bottom.

3.3 SURVIVAL

The major objective of the August 1989 effort was to monitor survival of relocated unionid mollusks. Survival estimates in 1987 and 1988 were similar; near 50 percent. Results in 1989 indicate a lower recovery and survival rate. In August 1989, 24 transect sections were sampled; 425 live tagged mussels and

Table 3-4. Tagged Shells Collected During Reconnaissance

Species	Tag #	Nearest Point	Section of Origin
Fusconaia ebena	299	0	0-C-R
Megalonaias nervosa	4533	44	9-C-L
Quadrula metanevra	2389	34	5-E-L
Quadrula metanevra	3879	40	7-C-L
Truncilla truncata	2738 (tag only)	34	3-E-R

Source: Hunter/ESE, 1989.

Table 3-5. Number of Severely Eroded Unionid Mollusks, August 1989

Species		8		18		30		40		47	
		#	%	#	%	#	%	#	%	#	%
Megalonaias nervosa	Tagged	1	25	1	100	--	--	10	59	4	36
	Untagged	3	33	--	--	--	--	--	--	--	--
Tritogonia verrucosa	Tagged	--	--	--	--	--	--	--	--	--	--
	Untagged	--	--	--	--	--	--	--	--	1	50
Quadrula quadrula	Tagged	1	33	--	--	4	50	--	--	4	27
	Untagged	1	3	1	3	7	12	4	8	2	4
Quadrula metanevra	Tagged	2	20	--	--	--	--	2	13	--	--
	Untagged	--	--	--	--	--	--	--	--	--	--
Quadrula pustulosa	Tagged	3	33	1	9	--	--	--	--	--	--
	Untagged	--	--	--	--	2	20	--	--	--	--
Amblema plicata	Tagged	1	11	--	--	--	--	--	--	--	--
	Untagged	--	--	--	--	4	4	--	--	1	1
Fusconaia ebena	Tagged	1	14	--	--	--	--	--	--	1	10
	Untagged	--	--	--	--	--	--	--	--	--	--
Fusconaia flava	Tagged	--	--	--	--	--	--	--	--	--	--
	Untagged	1	33	--	--	--	--	--	--	--	--
Cyclonaias tuberculata	Tagged	--	--	1	100	--	--	--	--	--	--
	Untagged	--	--	--	--	--	--	--	--	--	--
Pleurobema cordatum complex	Tagged	--	--	1	5	1	17	--	--	--	--
	Untagged	1	25	--	--	--	--	--	--	--	--
Elliptio c. crassidens	Tagged	3	30	--	--	3	75	4	27	--	--
	Untagged	--	--	--	--	1	12	--	--	--	--
Elliptio dilatata	Tagged	--	--	--	--	--	--	1	100	--	--
	Untagged	1	100	--	--	--	--	--	--	--	--
Obliquaria reflexa	Tagged	1	25	1	50	1	25	--	--	1	25
	Untagged	--	--	1	33	--	--	--	--	--	--
Elipsaria lineolata	Tagged	--	--	--	--	1	50	--	--	1	14
	Untagged	--	--	--	--	--	--	--	--	--	--
Total # Eroded	Tagged	13	14*	5	7	10	20	17	12	11	7
	Untagged	7	7	2	2	14	5	4	2	4	2
Total # Collected in Area	Tagged	90		75		51		140		153	
	Untagged	94		125		255		241		200	

* % of eroded shells in sampled area (example 13/90 x 100)

Source: Hunter/ESE, 1989.

84 tagged shells were recovered (Table 3-6). Of the 22 species relocated, 18 species were collected in August 1989. Only *Truncilla truncata*, *Lasmigona costata*, *Ligumia recta*, and *Potamilus alatus* were not represented in the 1989 survey.

3.3.1 Overall Survival

Two methods were used to estimate survival: direct enumeration and direct comparison. Direct enumeration (Bagenal, 1978) estimated average survival of 29.8 to 37.4 percent (Table 3-7). Average survival, based on comparison of animals placed in an area to live animals recovered from the area averaged 32.1 percent with a confidence interval between 21.3 and 42.9 percent (Table 3-8). Results of the two estimates were similar, although direct comparison resulted in a wider confidence interval.

Survival rate in August 1989 was lower than the previous two monitoring efforts. Survival was estimated between 40 and 47 percent in October 1989. August 1988 results estimate survival between 39 and 61 percent. Lower survival in 1989 may be due to displacement of mussels by high spring discharge. Other investigations have experienced similar recovery rates, but have collected relocated clams up to 1 mile from the relocation site (Jenkinson, 1987; Middle Fork Salt River, Hunter/ESE, 1989b). Both cases where mussels have been collected a distance downstream of the relocation site were smaller rivers (i.e., Duck River, Jenkinson; Middle Fork Salt River, Hunter/ESE). Smaller rivers are typically more dynamic than a larger river such as the Ohio and can experience extremely high current velocities capable of dislodging substrate and mussels. Apparently current velocities in the Ohio River in 1989 dislodged pieces of slate and other gravel and rubble material in 1989 since these substrates were present in the area of the transect. If velocities were rapid enough to dislodge large pieces of rock and rubble, one would assume mussels were also dislodged. Undoubtably some of the dislodged mussels survived. Both methods of calculating survival, however, discount survival of unrecovered mussels.

Table 3-6. Number of Tagged Mussels Collected from Each Transect, August 1989

Species	8 Live	8 Dead	18 Live	18 Dead	30 Live	30 Dead	40 Live	40 Dead	47 Live	47 Dead	Total Live	Total Dead	% Live
Megalonaias nervosa	4	0	1	0	1	0	12	5	9	2	27	7	79
Tritogonia verrucosa	1	0	0	0	0	0	1	0	2	0	4	0	100
Quadrula quadrula	1	2	1	0	4		3	1	3	12	12	19	39
Quadrula metanevra	10	0	4	0	8	0	17	2+1 recap	15	1	54	3	95
Quadrula nodulata	3	2	0	0	0	1	2	0	2	0	7	3	70
Quadrula pustulosa	8	1	10	1	4	1	10	4	14	6	46	13	94
Amblema plicata	9	0	11	1	5	2	15	1	5	1	45	5	90
Fusconaia ebena	6	2	4	0	1	1	4	0	10	0	25	2	93
Fusconaia flava	2	0	0	0	0	0	4	1	6	0	12	2	86
Cyclonaias tuberculata	0	0	1	0	1	0	2	0	0	0	4	0	100
Plethobasus cyphyus	2	0	1	0	0	0	1	0	0	0	4	0	100
Pleurobema cordatum complex	19	1	19	1	5	1	30	4	37	3	110	10	92
Elliptio c. crassidens	7	3	5	1	3	1	12	3	11	0	38	8	83
Elliptio dilatata	0	0	0	0	0	0	0	1	0	0	0	1	0
Obliquaria reflexa	3	1	1	1	3	1	1	0	2	2	10	5	67
Actinonaias l. carinata	0	0	5	0	1	1	2	0	2	0	10	1	91
Ellipsaria lineolata	2	1	7	0	1	1	2	0	4	3	16	5	76
Lampsilis ventricosa	0	0	0	0	0	0	0	0	1	0	1	0	100
Total Number	77	13	70	5	37	14	~~118~~ 119	~~22~~ 23	123	30	425	84	83
# Sections Sampled	2		4		6		6		6		24		
Average Number/Section	45		18.7		8.5		~~23.5~~		25.5		21.2		
Total Tagged	90		75		51		~~140~~ 142		153		509		

Source: Hunter/ESE, 1989.

Table 3-7. Number of Live Tagged Unionid Mollusks Collected in Each Sampled Section of the Relocation Transect

	Shoreward	Riverward
Point 8	28	49
Point 18	13	18
Point 19	11	28
Point 30	9	18
Point 31	3	3
Point 32	3	1
Point 40	18	22
Point 41	20	25
Point 42	23	10
Point 47	22	30
Point 48	9	9
Point 49	26	27

$\bar{X}$ = 17.7

$\hat{N}$ = 1,735 ±195.3

S = 33.6 ±3.8

Source: Hunter/ESE, 1989.

Table 3-8. Survival of Relocated Unionid Mollusks by Area, August 1989

Point	Section Number	Percent of Section Overlap	Number Placed in Overlapped Section	Estimated # in Area Collected	Number Collected (Live)	Survival Estimate (%)	Mean	S	n	$t_{(0.05)}$	Survival	95% CI
8	2-A-L	50	74	37	17	45.9	52.3	15.6	4	3.182	52.3	24.9
	2-A-R	50	62	31	12	38.7						
	2-B-L	50	75	37.5	28	74.7						
	2-B-R	50	56	28	14	50						
18	3-D-L	50	50	25	9	36	34.9	26.0	6	2.571	34.9	27.3
	3-D-R	50	50	25	0	0						
	3-E-L	100	43	43	16	37.2						
	3-E-R	100	50	50	16	32.0						
	4-A-L	50	50	25	20	80.0						
	4-A-R	50	50	25	6	24.0						
30	5-D-L	100	45	45	8	17.8	12.3	11.7	6	2.571	12.3	12.3
	5-D-R	100	46	46	2	4.3						
	5-E-L	100	50	50	12	24						
	5-E-R	100	50	50	13	26						
	6-A-L	100	74	74	1	1.4						
	6-A-R	100	50	50	0	0						
40	7-B-L	25	50	12.5	7	56.0	41.0	12.8	8	2.365	41.0	10.7
	7-B-R	25	48	12.0	2	16.7						
	7-C-L	100	40	40.0	19	47.5						
	7-C-R	100	49	49.0	26	53.1						
	7-D-L	100	41	41.0	18	43.9						
	7-D-R	100	49	49.0	16	32.6						
	7-E-L	75	50	37.5	11	34.1						
	7-E-R	75	51	38.25	17	44.4						
47	8-D-L	100	46	46	24	52.2	36.5	9.0	6	2.571	36.5	9.4
	8-D-R	100	50	50	19	38.0						
	8-E-L	100	31	31	11	35.5						
	8-E-R	100	50	50	16	32.0						
	9-A-L	100	69	69	25	36.2						
	9-A-R	100	56	56	14	25.0						

$\bar{X}$ = 32.1 V = 25.6 S = 32.1 ±10.8

Source: Hunter/ESE, 1989.

An alternative to the utilized methods for estimating survival is comparing the number of live to dead tagged mussels collected. A comparison of the number of shells to total number of tagged mussels collected between years yields similar results. In 1987, 31 of the 220 tagged clams (14 percent) were shells. August 1988 results indicated 19 percent of the total collection were shells, while 17 percent of the 1989 collection was shell material.

The estimated survival rate of mussels varies considerably depending upon two assumptions. Assuming that total mortality occurred for non-recovered mussels, survival after 2 years is slightly over 30 percent. If non-recovered mussels are assumed to be living away from the transect, the three monitoring studies indicate a survival rate over 80 percent. A truly accurate estimate of survival is probably between these extremes.

3.3.2 Survival by Area of Transect

Survival rate varied between the areas of transect sampled in 1989. Mean survival was lowest near Point 30 ($\bar{X}$=12.3) and highest near Point 8 ($\bar{X}$=52.3) (see Table 3-8). Similar results were obtained in 1988. Survival near Point 9 was 85 percent and near Point 33 was 27.6 percent.

As in 1988, survival in 1989 appeared to be related to substrate type, even though substrate types varied somewhat between years. The Point 8 collection in 1989 was slightly downstream of the Point 9 collection in 1988. Substrates varied slightly between areas (silt between large rock in 1988; and gravel, rubble, cobble in 1989), but mussels were found burrowed in silt between rocks in both areas. In contract, the area near 5-D and 5-E (Point 33 in 1988 and Point 30 in 1989), was primarily bedrock. In 1988, divers reported clams in the thin layer of silt and sand covering the bedrock. In 1989, divers removed up to 6 inches of broken slate at Point 30 before finding mussels. Mussels and substrate would be less stable in bedrock areas than in protective crevices between larger boulders and rocks.

Substrates near Points 18, 40, and 47 consisted of varying amounts of silt and clay mixed with various sizes of rock. Substrate and clams in this area are

less likely to be dislodged in silt, clay, rock substrate than in the bedrock areas, but more likely to be dislodged than in the more stable substrate near Point 8.

3.3.3 Species-Specific Survival

The majority of individuals of most species survived the relocation (based on the number of live to dead tagged mussels collected). Over 90 percent of the recovered *Tritogonia verrucosa*, *Quadrula metanevra*, *Q. pustulosa*, *Amblema plicata*, *Fusconaia ebena*, *Cyclonaias tuberculata*, *Plethobasus cyphyus*, *Pleurobema cordatum*, *Actinonaias l. carinata*, and *Lampsilis ventricosa* were live. The only species exhibiting high mortality (more shells than live animals recovered) were *Quadrula quadrula* and *Elliptio dilatata* (see Table 3-6). Similar results were obtained in 1988 where *Q. quadrula* was the only species for which more shells were collected than live animals. Although more live animals than shells were collected for most species, percent recovery (number collected in a section compared to the number relocated to the section) was not as high (Tables 3-9 through 3-13).

Many species responded similarly to previous years with respect to survival. *Megalonaias nervosa* and *Tritogonia verrucosa* exhibited high survival in 1988 with over 50 percent recovered in all five areas sampled. A survival rate of over 50 percent in all areas was not observed for any species in 1989. However *M. nervosa* exhibited over 50 percent survival in three of the five areas and *T. verrucosa* in two of the three areas. (No *T. verrucosa* were relocated to two of the areas.) All of the *L. ventricosa* in the sampled areas were recovered in both 1988 and 1989. *Fusconaia ebena*, *Amblema plicata*, and *Elliptio c. crassidens* exhibited high survival in four of the five areas sampled in 1988 and three of the five areas sampled in 1989.

Survival of *Quadrula quadrula*, *O. reflexa*, and *Q. nodulata* was low in both 1988 and 1989. Less than 50 percent of the *Quadrula quadrula* were recovered in any of the areas sampled. Less than 50 percent of the *Q. nodulata* and *O. reflexa* were recovered from four of the five areas sampled in either year. No *Truncilla truncata* were recovered in either 1988 or 1989.

Table 3-9. Mussel Species Collected and Percent Recovered (Estimated) from Transect Point 8, August 1989

Species	Number Collected* Live	Number Collected* Dead	Number Placed in Overlapped Sections†	Estimated # in Area Collected**	Survival Estimate**	Recovery Estimate††
Lasmigona costata	0	0	0	--	--	--
Megalonaias nervosa	4	0	5	4	100	100
Tritogonia verrucosa	1	0	2	1	100	100
Quadrula quadrula	1	1	21	11.5	8.7	17.4
Quadrula metanevra	9	0	36	18	50.0	50.0
Quadrula nodulata	3	1	7	4	75.0	100
Quadrula pustulosa	8	1	37	18.5	43.2	48.6
Amblema plicata	9	0	26	13	69.2	69.2
Fusconaia ebena	6	1	23	11.5	52.2	60.9
Fusconaia flava	1	0	2	1	100	100
Cyclonaias tuberculata	0	0	1	0.5	0	0
Plethobasus cyphyus	2	0	5	2.5	80	80
Pleurobema cordatum complex	18	1	54	27	66.7	70.4
Elliptio c. crassidens	7	3	17	10	70.0	100
Elliptio dilatata	0	0	1	0.5	0	0
Obliquaria reflexa	3	1	11	5.5	54.5	72.7
Actinonaias l. carinata	0	0	1	0.5	0	0
Ellipsaria lineolata	2	1	16	8.0	25.0	37.5
Truncilla truncata	0	0	3	1.5	0	0
Potamilus alatus	0	0	0	--	--	--
Ligumia recta	0	0	0	--	--	--
Lampsilis ventricosa	0	0	0	--	--	--
Total Number	74	10	268	138.5	59.2	69.2
Total Tagged	84					

* Excludes individuals that moved in the area.
† Includes total number in all sections overlapped by sampling quadrat.
** Estimates based on percent of sections sampled.
†† Includes live and dead tagged mussels.

Source: Hunter/ESE, 1989.

Table 3-10. Mussel Species Collected and Percent Recovered (Estimated) from Transect Point 18, August 1989

Species	Number Collected* Live	Number Collected* Dead	Number Placed in Overlapped Sections†	Estimated # in Area Collected**	Survival Estimate**	Recovery Estimate††
Lasmigona costata	0	0	0	--	--	--
Megalonaias nervosa	1	0	3	1.5	66.7	66.7
Tritogonia verrucosa	0	0	0	--	--	--
Quadrula quadrula	1	0	14	9.5	10.5	10.5
Quadrula metanevra	4	0	31	20.5	19.5	19.5
Quadrula nodulata	0	0	5	3	0	0
Quadrula pustulosa	10	1	76	43.5	23.0	25.3
Amblema plicata	11	1	27	15.5	71.0	77.4
Fusconaia ebena	4	0	12	8	50	50
Fusconaia flava	0	0	2	1.5	0	0
Cyclonaias tuberculata	1	0	1	1	100	100
Plethobasus cyphyus	1	0	6	3.5	28.6	28.6
Pleurobema cordatum complex	19	1	58	45.5	41.8	44.0
Elliptio c. crassidens	3	1	24	13.5	22.2	29.6
Elliptio dilatata	0	0	0	--	--	--
Obliquaria reflexa	1	1	8	5	20.0	40.0
Actinonaias l. carinata	5	0	7	5.5	90.1	90.1
Ellipsaria lineolata	7	0	18	15	46.7	46.7
Truncilla truncata	0	0	1	1	0	0
Potamilus alatus	0	0	0	--	--	--
Ligumia recta	0	0	0	--	--	--
Lampsilis ventricosa	0	0	0	--	--	--
Total Number	68	5	293	193	35.2	37.8
Total Tagged	73					

* Excludes individuals that moved in the area.
† Includes total number in all sections overlapped by sampling quadrat.
** Estimates based on percent of sections sampled.
†† Includes live and dead tagged mussels.

Source: Hunter/ESE, 1989.

Table 3-11. Mussel Species Collected and Percent Recovered (Estimated) from Transect Point 30, August 1989

Species	Number Collected* Live	Number Collected* Dead	Number Placed in Overlapped Sections†	Estimated # in Area Collected**	Survival Estimate**	Recovery Estimate††
Lasmigona costata	0	0	--	--	--	--
Megalonaias nervosa	1	0	6	6	16.7	16.7
Tritogonia verrucosa	0	0	--	--	--	--
Quadrula quadrula	4	4	19	19	21.1	42.1
Quadrula metanevra	8	0	30	30	26.7	26.7
Quadrula nodulata	0	1	14	14	0	7.1
Quadrula pustulosa	4	0	96	96	4.2	4.2
Amblema plicata	5	2	18	18	27.8	38.9
Fusconaia ebena	1	1	15	15	6.7	13.3
Fusconaia flava	0	0	3	3	0	0
Cyclonaias tuberculata	1	0	2	2	50	50
Plethobasus cyphyus	0	0	2	2	0	0
Pleurobema cordatum complex	5	1	61	61	8.2	9.8
Elliptio c. crassidens	3	1	10	10	30.0	40.0
Elliptio dilatata	0	0	--	--	--	--
Obliquaria reflexa	3	1	15	15	20	26.7
Actinonaias l. carinata	1	1	6	6	16.7	33.3
Ellipsaria lineolata	1	1	16	16	6.3	12.5
Truncilla truncata	0	0	2	2	0	0
Potamilus alatus	0	0	--	--	--	--
Ligumia recta	0	0	--	--	--	--
Lampsilis ventricosa	0	0	--	--	--	--
Total Number	37	14	315	315	11.7	16.2
Total Tagged	51					

* Excludes individuals that moved in the area.
† Includes total number in all sections overlapped by sampling quadrat.
** Estimates based on percent of sections sampled.
†† Includes live and dead tagged mussels.

Source: Hunter/ESE, 1989.

Table 3-12. Mussel Species Collected and Percent Recovered (Estimated) from Transect Point 40, August 1989

Species	Number Collected* Live	Dead	Number Placed in Overlapped Sections†	Estimated # in Area Collected**	Survival Estimate**	Recovery Estimate††
Lasmigona costata	0	0	--	--	--	--
Megalonaias nervosa	12	5	26	21.5	55.8	79.1
Tritogonia verrucosa	1	0	2	2	50.0	50.0
Quadrula quadrula	3	1	19	14.5	20.7	27.6
Quadrula metanevra	17	2	43	36.75	46.3	51.7
Quadrula nodulata	2	0	9	6	33.3	33.3
Quadrula pustulosa	10	3	67	43.5	23.0	29.9
Amblema plicata	15	1	30	27	55.6	59.3
Fusconaia ebena	4	0	11	7.25	55.2	55.2
Fusconaia flava	4	1	7	5.0	80.0	100
Cyclonaias tuberculata	2	0	2	2.0	100	100
Plethobasus cyphyus	1	0	2	1.75	57.1	57.1
Pleurobema cordatum complex	30	3	105	69.25	43.3	47.7
Elliptio c. crassidens	12	2	26	20.0	60.0	70.0
Elliptio dilatata	0	1	1	1	0	100
Obliquaria reflexa	1	0	11	10.25	9.8	9.8
Actinonaias l. carinata	2	0	2	2	100	100
Ellipsaria lineolata	2	0	17	11.25	17.8	17.8
Truncilla truncata	0	0	--	--	--	--
Potamilus alatus	0	0	--	--	--	--
Ligumia recta	0	0	--	--	--	--
Lampsilis ventricosa	0	0	--	--	--	--
Total Number	118	19	379	281.0	42.0	48.8
Total Tagged	137					

* Excludes individuals that moved in the area.
† Includes total number in all sections overlapped by sampling quadrat.
** Estimates based on percent of sections sampled.
†† Includes live and dead tagged mussels.

Source: Hunter/ESE, 1989.

Table 3-13. Mussel Species Collected and Percent Recovered (Estimated) from Transect Point 47, August 1989

Species	Number Collected* Live	Dead	Number Placed in Overlapped Sections†	Estimated # in Area Collected**	Survival Estimate**	Recovery Estimate††
Lasmigona costata	0	0	--	--	--	--
Megalonaias nervosa	8	2	17	17	47.1	58.8
Tritogonia verrucosa	2	0	5	5	40.0	40.0
Quadrula quadrula	3	8	24	24	12.5	45.8
Quadrula metanevra	14	0	30	30	46.7	46.7
Quadrula nodulata	2	0	7	7	28.6	28.6
Quadrula pustulosa	13	5	59	59	22.0	30.5
Amblema plicata	5	0	14	14	35.7	35.7
Fusconaia ebena	9	0	26	26	34.6	34.6
Fusconaia flava	4	0	5	5	80.0	80.0
Cyclonaias tuberculata	0	0	1	1	0	0
Plethobasus cyphyus	0	0	--	--	--	--
Pleurobema cordatum complex	34	2	72	72	47.2	50.0
Elliptio c. crassidens	11	0	19	19	57.9	57.9
Elliptio dilatata	0	0	--	--	--	--
Obliquaria reflexa	2	2	7	7	28.6	57.1
Actinonaias l. carinata	2	0	2	2	100	100
Ellipsaria lineolata	3	3	12	12	25.0	50.0
Truncilla truncata	0	0	1	1	0	0
Potamilus alatus	0	0	--	--	--	--
Ligumia recta	0	0	--	--	--	--
Lampsilis ventricosa	1	0	1	1	100	100
Total Number	113	22	302	302	37.4	44.7
Total Tagged	135					

* Excludes individuals that moved in the area.
† Includes total number in all sections overlapped by sampling quadrat.
** Estimates based on percent of sections sampled.
†† Includes live and dead tagged mussels.

Source: Hunter/ESE, 1989.

Fusconaia flava, *Cyclonaias tuberculata*, and *Actinonaias l. carinata* all exhibited high survival in three of five sampled areas in 1989. Furthermore, all of the *A. l. carinata* and *C. tuberculata* were recovered in two areas. All *Fusconaia flava* were recovered near Points 8 and 4, and survival was 100 percent at Point 8 and 80 percent at Points 40 and 47. However, no *F. flava* were recovered from either Point 18 or Point 30. *Ellipsaria lineolata* exhibited high survival in three of the five areas sampled in 1988, but survival was low in all areas in 1989.

Overall, *Quadrula quadrula* and *Truncilla truncata* appear to be the least adaptable to relocation. *M. nervosa*, *T. verrucosa*, *L. ventricosa*, *F. ebena*, *A. plicata*, and *E. c. crassidens* were recovered at the highest rates.

3.3.4 Survival Between Monitoring Events

One concern with relocation and monitoring is the continued disturbance of mussels. With random sampling and the absence of permanent bottom markers, overlap between years in the sampling of sections is unavoidable. A portion of three areas sampled in 1989 overlapped or were near areas sampled in 1988. One area overlapped a portion of an area sampled in 1987. The recollection of these areas allows for the evaluation of the condition and survival of those animals continuously disturbed. Of the 509 mussels collected in 1989, one hundred and seven were also collected in 1988 and six were collected in 1987 (Table 3-14). The majority of mussels (89 percent from the 1988 collection and 67 percent from the 1987 collection) were still live in 1989. All species appeared healthy, with only a few shells collected for any one species.

Table 3-14. Survival of Mussels Between the Two Monitoring Events

Species	Number Collected in August 1989 and August 1988		Number Collected in August 1989 and October 1987	
	Live	Dead	Live	Dead
Megalonaias nervosa	9	4	--	--
Tritogonia verrucosa	2	--	--	--
Quadrula quadrula	2	1	--	--
Quadrula metanevra	14	1	--	--
Quadrula nodulata	1	--	--	--
Quadrula pustulosa	9	1	4	--
Amblema plicata	15	1	--	--
Fusconaia ebena	6	1	--	--
Fusconaia flava	--	--	--	1
Plethobasus cyphyus	2	--	--	--
Pleurobema cordatum complex	17	2	--	1
Elliptio c. crassidens	11	--	--	--
Obliquaria reflexa	3	1	--	--
Actinonaias l. carinata	2	--	--	--
Ellipsaria lineolata	1	1	--	--
Totals	94	13	4	2
Percent Live	89		67	

Source: Hunter/ESE, 1989.

3.3.5 Comparison with Native Unionid Mollusk Population

Species and number of untagged mussels collected during the diving effort near the transect are presented in Table 3-15. In general, species composition was similar to the relocated population but relative abundance differed. In the sections sampled, *Quadrula quadrula* and *Amblema plicata* were the dominant species in the native population. The majority of mussels relocated were *Pleurobema cordatum* complex and *Quadrula pustulosa*. Although *Quadrula quadrula* was abundant in the native population, 37 percent were collected as shells, suggesting high mortality as observed in the relocated *Quadrula quadrula*.

The average number of native unionids per 10-foot by 5-foot section was similar in 1988 and 1989 (20.5 total, 16.2 living in 1988 and 19.1 total and 15.7 living in 1989). Density of the tagged mussel population was comparable with 21.2 total per section and 17.7 living per section. Density of tagged clams has declined from 29.1 in 1988 to 21.2 in 1989 while the native population has remained fairly stable.

3.4 GROWTH

Of the eighteen species collected in August 1989, some individuals of 11 species exhibited growth (Table 3-16). The animals reported as exhibiting growth were those whose length, height, and weight were more than May 1987 measurements, or in which shell material was secreted around the tag. The number of individuals reported as exhibiting growth is therefore a conservative estimate. Less than 10 percent of most species had obviously grown since May 1987. However, the only *L. ventricosa* collected had grown as had one of the four *C. tuberculata*.

Primarily young individuals (<10 years of age) exhibited growth. Younger individuals secreted up to 0.25 inch of shell material. Growth was not inhibited by tags, as shell material was produced beyond the tag in most cases.

Growth was less detectable in older individuals since older unionids grow only 1 or 2 mm per year. The only older individuals in which growth was apparent were *Megalonaias nervosa*, *Elliptio c. crassidens*, and *F. ebena*. The tags were apparently tight on these individuals and shell material was produced around the

Table 3-15. Number of Untagged Mussels Collected Near the Relocation Transect, August 1989

Species	8		18		30		40		47		Total	
	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead
Anodonta g. grandis	0	1	1	0	0	0	0	0	1	0	2	1
Megalonaias nervosa	7	2	12	0	35	1	23	1	8	0	85	4
Tritogonia verrucosa	0	1	0	0	0	0	0	0	2	0	2	1
Quadrula quadrula	15	18	20	16	34	22	40	12	32	14	141	82
Quadrula nodulata	0	0	6	1	3	0	3	0	7	1	19	2
Quadrula pustulosa	7	0	7	0	10	0	9	0	15	1	48	1
Amblema plicata	16	10	46	3	91	19	115	16	83	11	351	59
Fusconaia ebena	2	0	0	0	0	0	0	0	0	0	2	0
Fusconaia flava	1	2	5	0	3	0	1	0	1	1	11	3
Pleurobema cordatum complex	3	1	0	0	8	0	4	0	1	0	16	1
Elliptio c. crassidens	2	0	2	0	8	0	1	0	4	0	17	0
Elliptio dilatata	1	0	0	0	1	0	5	1	0	0	7	1
Obliquaria reflexa	1	0	2	1	8	0	2	0	7	0	20	1
Actinonaias l. carinata	0	0	0	0	1	0	0	0	0	0	1	0
Ellipsaria lineolata	1	0	1	0	4	0	1	0	0	0	7	0
Leptodea fragilis	1	0	0	0	1	0	0	0	0	1	2	1
Potamilus alatus	2	0	2	0	4	2	5	2	8	0	21	4
Truncilla truncata	0	0	0	0	0	0	0	0	1	1	1	1
Total Number	59	35	104	21	211	44	209	32	170	30	753	162
# Sections (10x5')	5		8		12.5		11		11.5		48	
Average #/Section	18.8		15.6		20.4		21.9		17.4		19.1	
Total Untagged	94		125		255		241		200		915	

Source: Hunter/ESE, 1989.

Table 3-16. Species Exhibiting Growth Between May 1987 and August 1989

Species	8		18		30		40		47		# Exhibiting No Growth	Total *	
	#	%	#	%	#	%	#	%	#	%		#	%
Megalonaias nervosa	--	--	--	--	--	--	3	18	--	--	31	3	9
Quadrula quadrula	1	33	--	--	--	--	--	--	--	--	30	1	3
Quadrula metanevra	2	20	--	--	--	--	--	--	--	--	55	2	4
Quadrula pustulosa	--	--	1	9	--	--	2	14	1	5	54	4	7
Amblema plicata	--	--	--	--	--	--	--	--	1	20	49	1	2
Fusconaia ebena	1	14	--	--	--	--	1	25	--	--	25	2	7
Cyclonaias tuberculata	--	--	--	--	1	100	--	--	--	--	3	1	25
Pleurobema cordatum complex	3	15	2	10	--	--	2	6	--	--	113	7	6
Elliptio c. crassidens	2	20	--	--	--	--	--	--	--	--	44	2	4
Ellipsaria lineolata	--	--	--	--	--	--	1	50	--	--	20	1	5
Lampsilis ventricosa	--	--	--	--	--	--	--	--	1	100	0	1	100
# Exhibiting No Growth	81		72		50		131		150		484		--
Total	9	10	3	4	1	2	9	6	3	2	--	25	5

* Percent based on total number collected (see Table 3-6).

Source: Hunter/ESE, 1989.

tag. Length, height and weight measurements, however, varied little from original measurements.

Overall, 5 percent of the tagged unionids collected had grown since relocated. The highest percentage of growth was near Point 8 (also the area of highest survival). Lowest percentage of animals exhibiting growth was near Point 30 (area of lowest survival) and Point 47.

3.5 REPRODUCTION

Most of the species relocated are summer breeders (tachytictic) with females being gravid between May and August. A few species (*Potamilus alatus*, *Megalonaias nervosa*, *Lampsilis ventricosa*, *Actinonaias l. carinata*, and *Ellipsaria lineolata*) are bradytictic, carrying glochidia over the winter. In October 1987, only one *P. alatus* and two *Ellipsaria lineolata* were gravid. It was expected that more individuals would be gravid in August since many tachytictic species carry glochidia through August and bradytictic species begin developing glochidia in August (Oesch, 1984).

Only three tagged mussels and one untagged mussel were gravid during the August 1988 survey. Six mussels (five tagged and one untagged) were gravid in August 1989 (Table 3-17). Although few tagged mussels were gravid in August, even fewer untagged animals were in a gravid condition. This suggests reproduction may be low in the native unionid mollusk population (as well as the tagged population) or that reproductive activity for most species was completed (tachytictic) or not yet begun (bradytictic) by the August survey.

3.6 BRAIL SURVEY

If mussels were dislodged by high discharge, tagged individuals should be scattered downstream of the transect and perhaps shoreward and riverward. The area around the transect was intensively sampled by mussel brail in an effort to locate potentially dislodged tagged clams (Table 3-18). No tagged unionid mussels were recovered in the survey. Native clams were collected in all areas sampled. Brailing is a relatively inefficient sampling device. If tagged mussels were burrowed into the substrate or under rock they would not be picked

Table 3-17. Unionid Mollusks in Gravid Condition During August 1989 Monitoring

Species	Tag #	Length (mm)
Ellipsaria lineolata	4438	66
	4299	56
	Missing	56
Actinonaias l. carinata	2631	108
Pleurobema cordatum complex	Missing	64
Potamilus alatus	No tag	147

Source: Hunter/ESE, 1989.

Table 3-18. Unionid Mollusks Collected by Brail Near the Transect

Species	50 to 500 feet Upstream		Transect		50 to 500 feet Downstream		Total
	River	Shore	River	Shore	River	Shore	
# of runs	4	4	8	13	4	8	
Amblema plicata	--	5	4	2	3	2	16
Ellipsaria lineolata	1	--	--	--	--	--	1
Elliptio c. crassidens	6	--	3	1	--	--	10
Elliptio dilatata	2	--	--	--	--	--	2
Fusconaia flava	1	1	--	--	--	--	2
Megalonaias nervosa	2	--	--	--	--	--	2
Obliquaria reflexa	1	2	2	4	--	3	12
Potamilus alatus	--	--	--	2	--	1	3
Quadrula nodulata	--	--	--	--	--	2	2
Quadrula pustulosa	2	--	4	-	--	2	8
Quadrula quadrula	--	2	6	1	1	2	12
Tritogonia verrucosa	--	--	--	1	--	--	1
Total Number	15	10	19	11	4	12	71
Number Species	7	4	5	6	2	6	12

Source: Hunter/ESE, 1989.

up by brail. Although no tagged mussels were collected in brail runs, it is still likely that at least some of the unrecovered tagged mussels are in the vicinity of the transect.

3.7 MOVEMENT

Most relocated mussels were collected from the area of original placement. Of the animals that did move, most moved less than 5 feet. About 75 percent of the shells in each section and 80 to 90 percent of live tagged clams remained in their initial location in most of the areas samples.

With the exception of one live individual (collected 70 feet downstream of original area), shells were displaced further than live animals. Tagged shells were collected up to 45 feet and live tagged clams up to 25 feet away from their original location. The original location of tagged mussels with respect to collected area is illustrated on Figures 3-1 through 3-5. The number of tagged animals moving from each section is shown in Tables 3-19 through 3-23.

Very few mussels had moved into the area near Point 8 (see Table 3-19). Four live mussels and only three shells were from sections other than those sampled. Recovery was higher at this point than in other areas sampled. In addition, substrate was stable but allowed crevices for burrowing. Some dislodgement is occurring in the area as one live animal came from 25 feet upstream and one shell from 45 feet upstream. In addition, over 30 percent of animals relocated to the area were unaccounted for (see Table 3-9). Some individuals appear to have moved into the area from riverward, upstream, downstream, and shoreward. One individual apparently moved upstream 15 feet.

Only two individuals collected near Point 18 were from other locations (see Table 3-20). Individuals were probably dislodged from upstream areas as animals came from 20 and 25 feet upstream.

Eight live animals and three shells collected near Point 30 were from other sections (see Table 3-21). The percentage of individuals moving into the area was highest in this area of the transect. Recovery of mussels was lowest in

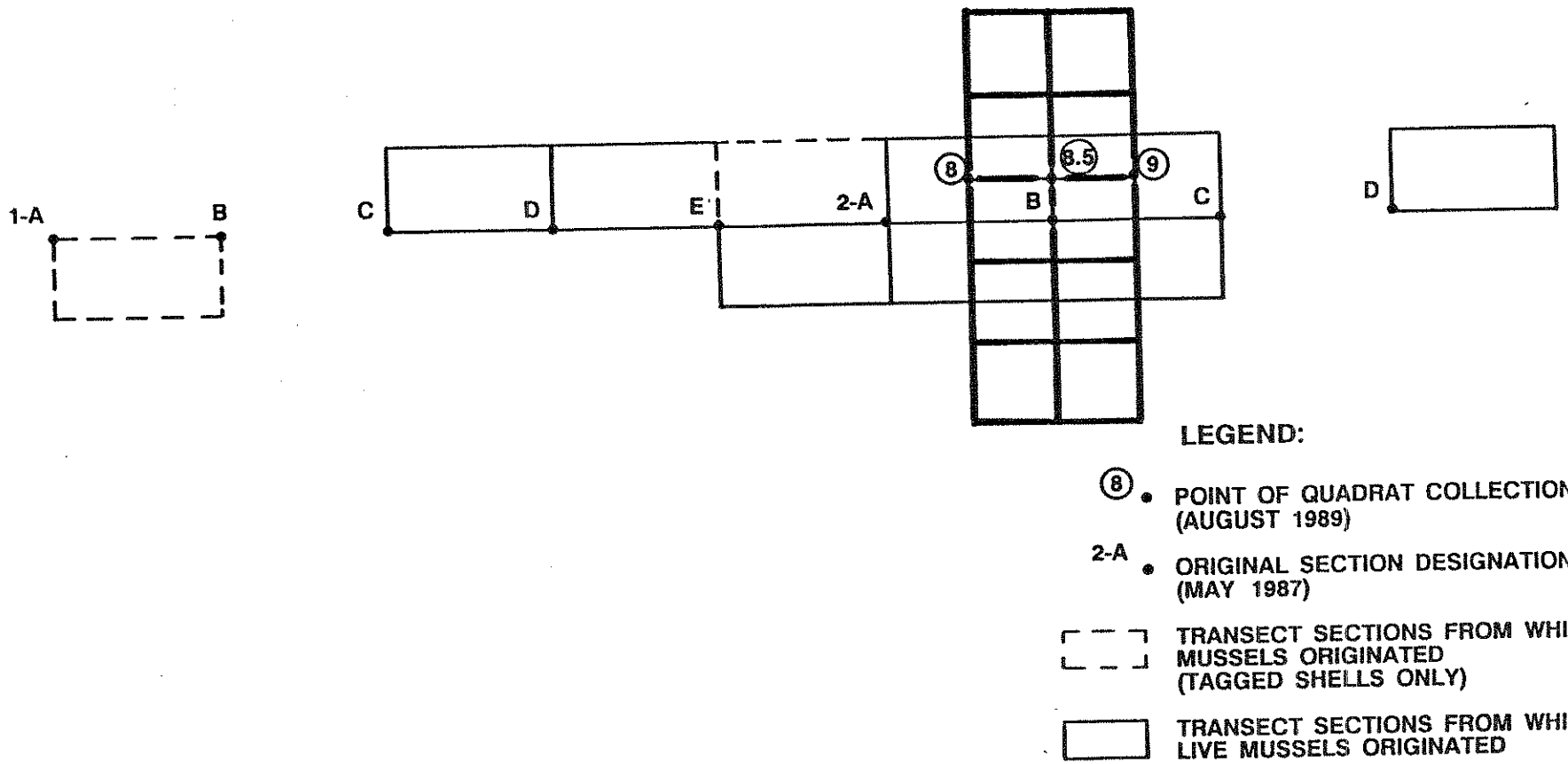
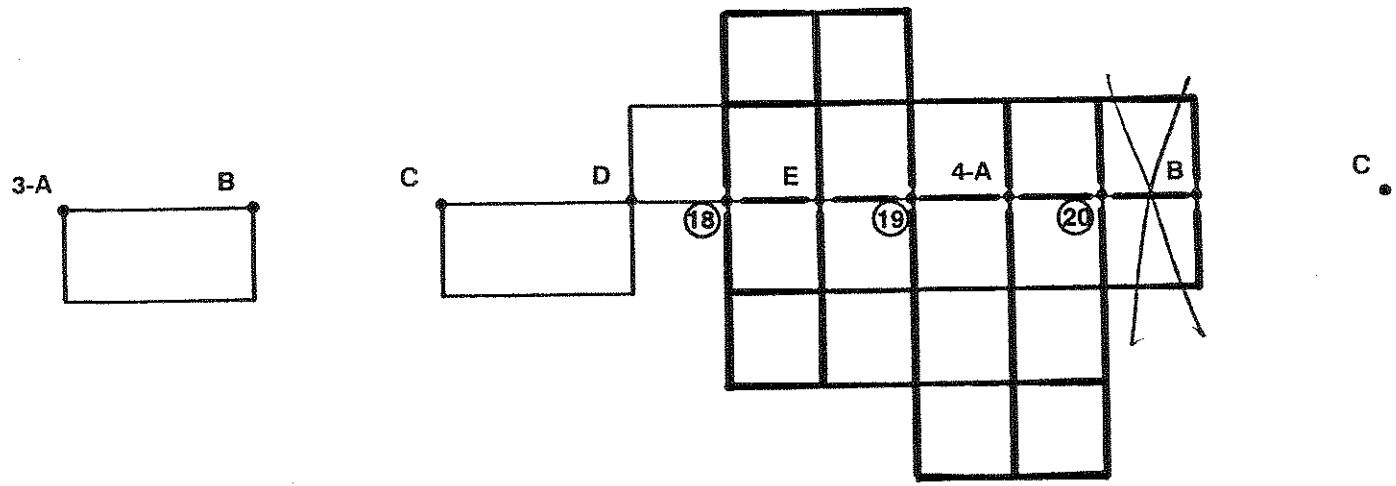


Figure 3-1
LOCATION OF QUADRATS COLLECTED BETWEEN POINTS 8 AND 9 ON RELOCATION TRANSECT, AUGUST 1989

HUNTER/ESE
ENVIRONMENTAL SERVICES, INC.



LEGEND:

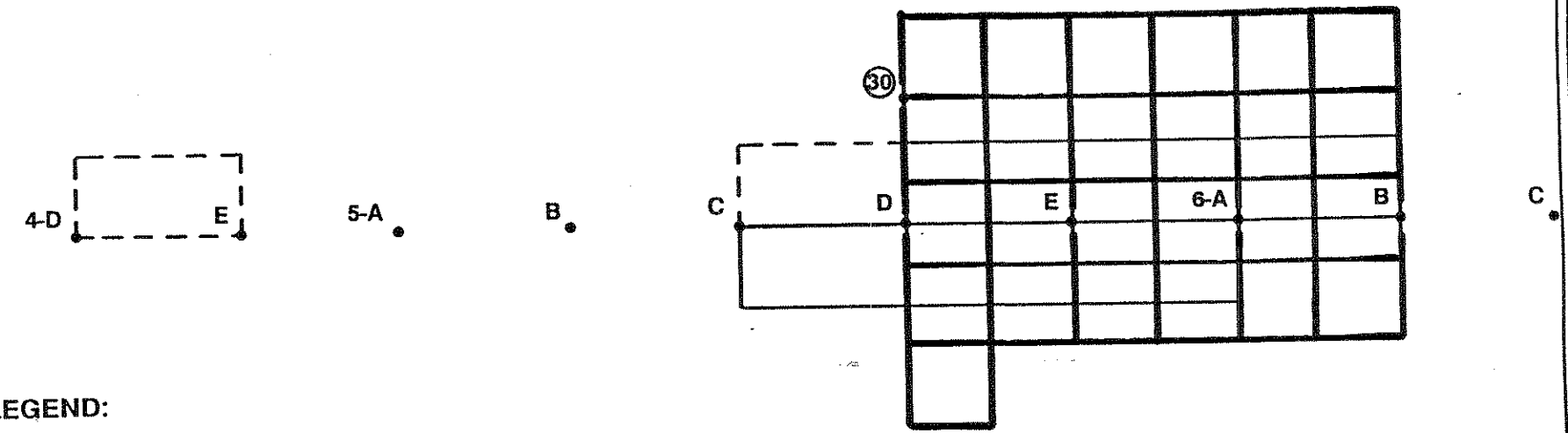
⑱ • POINT OF QUADRAT COLLECTION (AUGUST 1989)

3-A • ORIGINAL SECTION DESIGNATION (MAY 1987)

▭ TRANSECT SECTIONS FROM WHICH LIVE MUSSELS ORIGINATED

Figure 3-2
LOCATION OF QUADRATS COLLECTED BETWEEN POINTS 18 AND 20 ON RELOCATION TRANSECT, AUGUST 1989

HUNTER / ESE
ENVIRONMENTAL SERVICES, INC.

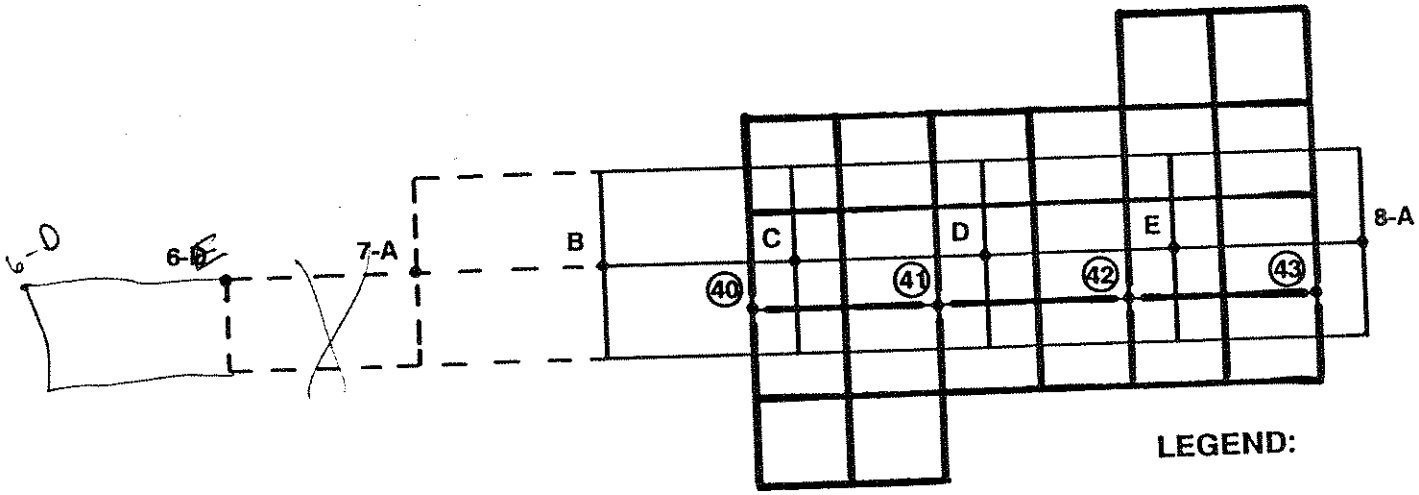


LEGEND:

- (30) • POINT OF QUADRAT COLLECTION (AUGUST 1989)
- 5-A • ORIGINAL SECTION DESIGNATION (MAY 1987)
- TRANSECT SECTIONS FROM WHICH MUSSELS ORIGINATED (TAGGED SHELLS ONLY)
- TRANSECT SECTIONS FROM WHICH LIVE MUSSELS ORIGINATED

Figure 3-3
LOCATION OF QUADRATS COLLECTED BETWEEN POINTS 30 AND 33 ON RELOCATION TRANSECT, AUGUST 1989

HUNTER/ESE
ENVIRONMENTAL SERVICES, INC.



LEGEND:

40 • POINT OF QUADRAT COLLECTION (AUGUST 1989)

7-A • ORIGINAL SECTION DESIGNATION (MAY 1987)

TRANSECT SECTIONS FROM WHICH MUSSELS ORIGINATED (TAGGED SHELLS ONLY)

TRANSECT SECTIONS FROM WHICH LIVE MUSSELS ORIGINATED

Figure 3-4
LOCATION OF QUADRATS COLLECTED BETWEEN POINTS 40 AND 43 ON RELOCATION TRANSECT, AUGUST 1989

HUNTER/ESE
ENVIRONMENTAL SERVICES, INC.

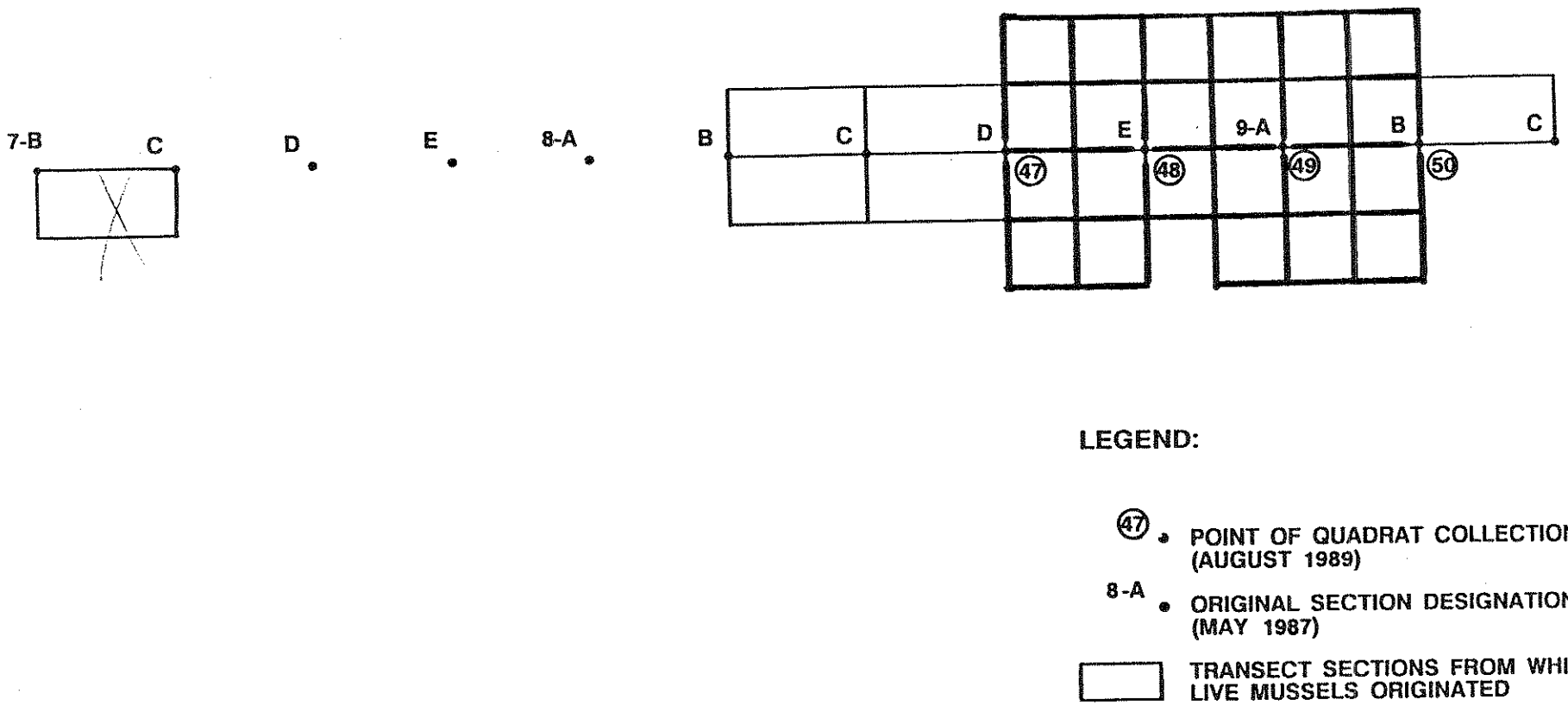


Figure 3-5
LOCATION OF QUADRATS COLLECTED BETWEEN POINTS 47 AND 50 ON RELOCATION TRANSECT, AUGUST 1989

HUNTER/ESE
ENVIRONMENTAL SERVICES, INC.

Table 3-19. Number and Distance of Tagged Unionid Mollusks Moving from the Area of Initial Placement, August 1989, Point 8

	# Live								# Dead								
	5	10	15	20	25	30	35	40	5	10	15	20	25	30	35	40	45
Riverward	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shoreward	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Downstream	1	-	-	1	1	-	-	-	1	1	-	-	-	-	-	-	1
Upstream	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total # Displaced			4*							3							
Total # Collected			77							13							

* Some movement in two directions.

Source: Hunter/ESE, 1989.

Table 3-20. Number and Distance of Tagged Unionid Mollusks Moving from the Area of Initial Placement, August 1989, Point 18

	# Live								# Dead								
	5	10	15	20	25	30	35	40	5	10	15	20	25	30	35	40	45
Riverward	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shoreward	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Downstream	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
Upstream	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Total # Displaced	2	0
Total # Collected	70	5

Source: Hunter/ESE, 1989.

Table 3-21. Number and Distance of Tagged Unionid Mollusks Moving from the Area of Initial Placement, August 1989, Point 30

	# Live								# Dead								
	5	10	15	20	25	30	35	40	5	10	15	20	25	30	35	40	45
Riverward	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shoreward	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Downstream	2	-	1	-	-	-	-	-	-	-	1	-	1	-	-	-	1
Upstream	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total # Displaced			8							3							
Total # Collected			37							14							

Source: Hunter/ESE, 1989.

Table 3-22. Number and Distance of Tagged Unionid Mollusks Moving from the Area of Initial Placement, August 1989, Point 40

	# Live								# Dead								
	5	10	15	20	25	30	35	40	5	10	15	20	25	30	35	40	45
Riverward	6	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-
Shoreward	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Downstream	1	-	-	-	-	-	-	-	-	4	-	2	-	-	-	-	1
Upstream	7	2	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-
Total # Displaced		16								10*							
Total # Collected		118								22							

* Some movement in two directions.

Source: Hunter/ESE, 1989.

Table 3-23. Number and Distance of Tagged Unionid Mollusks Moving from the Area of Initial Placement, August 1989, Point 47

	# Live								# Dead								
	5	10	15	20	25	30	35	<40	5	10	15	20	25	30	35	40	45
Riverward	2	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-
Shoreward	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Downstream	1	5	2	1	-	-	-	1	2	2	1	2	-	-	-	1	-
Upstream	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
Total # Displaced	13*								8*								
Total # Collected	123								30								

* Some movement in two directions.

Source: Hunter/ESE, 1989.

this area in both 1988 and 1989. Substrate was the least attractive to mussels being primarily bedrock overlaid with slate in 1989 and sand and silt in 1988. However, density of native clams in the area was similar to other sections.

Near Point 40, 16 live individuals and 10 dead individuals had moved into the area (see Table 4-22). Most shells came from upstream locations. Live animals came from upstream, downstream and shoreward, but movement was less than 10 feet.

The greatest distance moved was observed near Point 47. One live individual was from 70 feet upstream (see Table 3-23 and Figure 3-5). Shells were from up to 40 feet upstream. Two individuals had moved upstream 30 feet.

In general, the majority of movement over 5 feet was in a downstream direction for both live and dead mussels. Most of the mussels collected from over 5 feet downstream were probably dislodged and transported downstream by high flow, particularly those individuals collected 20 to 70 feet away from their original location. Most downstream movement and the low recovery rate of tagged clams are probably a result of high discharge in 1989 moving mussels and substrate. The similar density of untagged animals in 1988 and 1989 may simply be due to dislodged upstream animals replacing those dislodged near the transect.

Jenkinson (1987 personal communication) reported downstream transport of relocated mussels in North Fork Holston River. Hunter/ESE (1989b) also reported collecting a marked mussel up to 1 mile downstream of the original bed. Both of the above studies, however, were in smaller rivers more subject to periodic high flow. INHS (1989 personal communication) reported loss of marked relocated individuals in relocation areas. In addition, native clams marked and placed in areas with relocated clams were missing and other unmarked individuals were present.

Of the eighteen species collected in August 1989, only nine had moved from their area of original placement (Table 3-24). Highest percentage of movement was observed for *Fusconaia flava* and *Cyclonaias tuberculata* with 42 and 50 percent

of the live individuals having moved from their original location, respectively. These species also exhibited the highest percent movement in 1988. *F. flava* moved primarily downstream (three of five individuals), but one individual moved upstream and one riverward. Similarly, one *C. tuberculata* moved upstream and one riverward.

Only 8 to 15 percent of the live individuals of the remaining species exhibited movement. Movement riverward and shoreward was a minimal distance of 5 or 10 feet. Most upstream movement was only 5 feet, but a few individuals moved upstream a considerable distance. One *Q. pustulosa* and one *P. cordatum* complex were collected 30 feet upstream from their original area. Downstream movement was up to 70 feet. *Q. metanevra* and *F. ebena* moved up to 20 feet downstream. *Elliptio c. crassidens* moved up to 25 feet downstream. *P. cordatum* complex moved up to 70 feet downstream.

Movement short distances (5 to 10 feet) could be due to dislodgement but could also be activity of the individuals, particularly in the upstream direction. A downstream distance of over 10 feet, and particularly as great as 70 feet, is probably the result of high spring discharge moving substrates and individuals not securely anchored in the substrate.

Table 3-24. Distance and Direction of Movement by Live Unionid Mollusks Between May 1987 and August 1989 (Page 1 of 2)

Species	Percent Exhibiting Movement	Number of Unionid Mollusks Exhibiting Movement: Distance Moved (feet) 5	10	15	20	25	30	35	40	70
Quadrula quadrula	8									
Downstream		--	--	--	--	--	--	--	--	--
Upstream		1	--	--	--	--	--	--	--	--
Riverward		--	--	--	--	--	--	--	--	--
Shoreward		--	--	--	--	--	--	--	--	--
Quadrula metanevra	15									
Downstream		1	1	2	1	--	--	--	--	--
Upstream		1	--	--	--	--	--	--	--	--
Riverward		2	--	--	--	--	--	--	--	--
Shoreward		--	--	--	--	--	--	--	--	--
Quadrula nodulata	14									
Downstream		--	--	--	--	--	--	--	--	--
Upstream		--	--	--	--	--	--	--	--	--
Riverward		1	--	--	--	--	--	--	--	--
Shoreward		--	--	--	--	--	--	--	--	--
Quadrula pustulosa	13									
Downstream		2	1	--	--	--	--	--	--	--
Upstream		1	1	--	--	--	1	--	--	--
Riverward		3	--	--	--	--	--	--	--	--
Shoreward		--	--	--	--	--	--	--	--	--
Fusconaia ebena	12									
Downstream		--	--	--	1	--	--	--	--	--
Upstream		--	1	--	--	--	--	--	--	--
Riverward		--	--	--	--	--	--	--	--	--
Shoreward		1	--	--	--	--	--	--	--	--
Fusconaia flava	42									
Downstream		1	1	--	1	--	--	--	--	--
Upstream		1	--	--	--	--	--	--	--	--
Riverward		1	--	--	--	--	--	--	--	--
Shoreward		--	--	--	--	--	--	--	--	--

Table 3-24. Distance and Direction of Movement by Live Unionid Mollusks Between May 1987 and August 1989 (Page 2 of 2)

Species	Percent Exhibiting Movement	Number of Unionid Mollusks Exhibiting Movement: Distance Moved (feet) 5	10	15	20	25	30	35	40	70
Cyclonaias tuberculata	50									
Downstream		--	--	--	--	--	--	--	--	--
Upstream		1	--	--	--	--	--	--	--	--
Riverward		1	--	--	--	--	--	--	--	--
Shoreward		--	--	--	--	--	--	--	--	--
Pleurobema cordatum complex	8									
Downstream		1	1	1	--	--	--	--	--	1
Upstream		1	--	1	--	--	1	--	--	--
Riverward		1	--	--	--	--	--	--	--	--
Shoreward		1	--	--	--	--	--	--	--	--
Elliptio c. crassidens	13									
Downstream		--	1	--	1	1	--	--	--	--
Upstream		1	--	--	--	--	--	--	--	--
Riverward		1	--	--	--	--	--	--	--	--
Shoreward		--	--	--	--	--	--	--	--	--
Total	10									
Downstream		5	5	3	4	1	--	--	--	1
Upstream		7	2	1	--	--	2	--	--	--
Riverward		10	--	--	--	--	--	--	--	--
Shoreward		2	--	--	--	--	--	--	--	--

Source: Hunter/ESE, 1989.

4.0 SUMMARY AND CONCLUSIONS

Results of the 1989 monitoring effort indicate a lower rate of survival than previous efforts. The survival estimates (assuming mortality of all mussels not recovered) for 1988 were 55 percent and 50 percent by direct comparison and direct enumeration, respectively. The 1989 estimates were distinctly lower at 34 and 32 percent, respectively. A decline in recovered mussels with time has been reported in other relocation efforts (Jenkinson personal communication, 1987). Dislodging of mussels and substrate by high discharge in 1989 is the factor most likely responsible for low recovery. Substrates had changed from 1988 with smaller rock, gravel and slate being deposited in sampled areas. If high 1989 discharge could transport substrate, mussels were likely to be transported as well. The collection of live tagged animals up to 70 feet downstream of the initial location implicates transport by currents.

Mussels in areas with thinner substrate should be more susceptible to dislodgement than mussels in areas with more stable substrates. Recovery, survival, movement, and growth data support this conclusion. The most stable substrate (large rock and boulder mixed with gravel, cobble, silt) was found near Point 8. The percent of mussels recovered, percent of live tagged mussels, and percent exhibiting growth was highest in this area (Table 4-1). The area near Point 30 (bedrock covered with slate) had the lowest percent recovered and the lowest number of live tagged mussels in comparison to shells. The percent of individuals exhibiting growth was also lowest in this area. In addition, the area near Point 30 had the highest percentage of movement (see Table 4-1).

Dislodged tagged mussels would presumably tumble along the bottom and come to rest within a relatively short distance of the transect. Attempts to locate mussels near the transect by brail, however, were unsuccessful. Brailing, being an inefficient sampling device, may not have detected the scattered tagged individuals.

Table 4-1. Summary of Survival, Growth, and Movement by Transect Section, August 1989

Transect	Mean Percent Survival of Live Mussels	% Collected Live vs. Shells	Percent of Individuals Exhibiting Growth	Percent of Individuals Exhibiting Movement
8	59	88	10	5
18	35	93	4	3
30	12	73	2	22
40	42	86	6	14
47	37	84	2	11
Total	35	84	5	10

Source: Hunter/ESE, 1989.

Table 4-2. Summary of Survival, Growth, and Movement by Species, August 1989

Species	Percent Survival*	Percent Recovered†	Percent Recovered Live**	Percent of Individuals Exhibiting Growth	Percent of Individuals Exhibiting Movement
Megalonaias nervosa	79	68	54	9	0
Tritogonia verrucosa	100	50	50	0	0
Quadrula quadrula	39	39	16	3	8
Quadrula metanevra	95	42	40	4	15
Quadrula nodulata	70	29	21	0	14
Quadrula pustulosa	78	23	18	7	13
Amblema plicata	90	57	51	2	0
Fusconaia ebena	93	40	37	7	12
Fusconaia flava	86	90	77	0	42
Cyclonaias tuberculata	100	62	62	25	50
Plethobasus cyphyus	100	41	41	0	0
Pleurobema cordatum complex	92	44	40	6	8
Elliptio dilatata	0	67	0	0	0
Elliptio c. crassidens	83	63	52	4	13
Obliquaria reflexa	67	35	23	0	0
Actinonaias l. carinata	91	69	63	0	0
Ellipsaria lineolata	76	34	26	5	0
Truncilla truncata	0	0	0	0	0
Lampsilis ventricosa	100	100	100	100	0
Mean	84	41	35	5	10

* Survival = number collected live/number collected as shells.
† % Recovered = number collected/number relocated.
** Recovered Live = Number collected live/number relocated.

Source: Hunter/ESE, 1989.

The majority of mussels remaining in the transect area appear to be healthy. The majority (84 percent) were live, movement was minimal (10 percent), some growth was observed (5 percent), and a few mussels were gravid (Table 4-2). Highest survival and recovery was observed in *Lampsilis ventricosa*, *Fusconaia flava*, *Actinonaias l. carinata*, *Cyclonaias tuberculata*, and *Megalonaias nervosa*. In addition to high survival, growth was observed in the *L. ventricosa*, 25 percent of the *C. tuberculata*, and 9 percent of the *M. nervosa*. Growth was not evident in *Fusconaia flava* or *A. l. carinata*. *Fusconaia flava* and *C. tuberculata* moved most frequently, while *P. cordatum* complex moved the greatest distance.

Species exhibiting lowest survival and recovery were *Truncilla truncata*, *Elliptio dilatata*, *Q. quadrula*, *Obliquaria reflexa*, and *Quadrula nodulata*. Of these species, only a few *Q. quadrula* exhibited growth.

Although recovery was lower in 1989, observed mortality (number of shells) was low (16 percent). High current velocity in 1989 has apparently affected the population as observed in severe erosion of some shells and transport of mussels away from their initial location. The observation of growth and gravid condition of some individuals suggest that at least some individuals are adapting to their new environment.

5.0 LITERATURE CITED

Bagenal, T (ed.) 1978. Methods for Assessment of Fish Production in Fresh Waters, 3rd Edition. IBP Handbook No. 3. Blackwell Scientific Publications, Oxford.

Environmental Science and Engineering, Inc. (Hunter/ESE). 1988. Report on the Monitoring Study of Relocated Mussels Near Ripley, Ohio. Submitted to the Mussel Mitigation Trust Fund Committee, Columbus, Ohio. March 1988.

Heath, D. 1989. Personal communication.

Hunter/ESE. 1989a. Report for the 1988 Mussel Monitoring Effort (Contract 102). Submitted to the Mussel Mitigation Trust Fund Committee. February 1989.

Hunter/ESE. 1989b. Annual Report 1988 Salt River Basin Biological Studies. U.S. Army Corps of Engineers, St. Louis, Missouri.

Illinois Natural History Survey (INHS). 1989. Personal communication.

Jenkinson, J.J. 1980. The Tennessee Valley Authority Cumberlandian Mollusk Conservation Program. Bull. of AMU 1980: 62-63.

Jenkinson, J.J. 1985. Freshwater Mussel Transplants Evaluated. AMU News 16(1):3.

Jenkinson, J.J. 1987. Personal Communication.

Matteson, Max R. 1955. Studies on the Natural History of the Unionidae. Amer. Midl. Nat. 53:126-145.

Miller, A.C. and D.A. Nelson. 1983. An Instructional Report on Freshwater Mussels. Instructional Report EL-83-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Oblad, B.R. 1979. An experiment in Relocating Endangered and Rare Naiad Mollusks from a Proposed Bridge Construction Site at Sylvan Slough, Mississippi River Near Moline, Illinois. In Rasmussen, J.L., editor 1980. Proceedings of the UMRCC Symposium on Upper Mississippi River Bivalve Mollusks. UMRCC, Rock Island, Illinois.

Oesch, R.D. 1984. Missouri Naiades: A Guide to the Mussels of Missouri. Missouri Department of Conservation. Jefferson City, Missouri.

Stansbery, D.H. and S.D. Cooney. 1985. Survey of the Unionid Mollusks of the Ohio River in the Vicinity of the Wm.H. Zimmer Station (Ohio River Miles 442.6 to 445.6). Report to Cincinnati Gas and Electric Company, Columbus and Southern Ohio Electric Company, and Dayton Power and Light Company.

Williams, J.C. and G.A. Schuster. 1982. Freshwater Mussel Investigations of the Ohio River Mile 317.0 to Mile 981.0. U.S. Army COE, Louisville District, Kentucky Dept. of Fish and Wildlife Resources, and USFWS, Regions III and IV.