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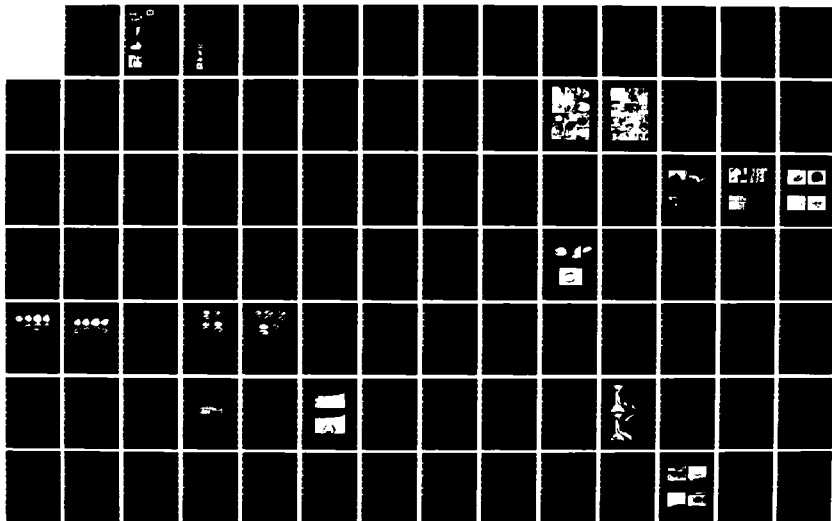
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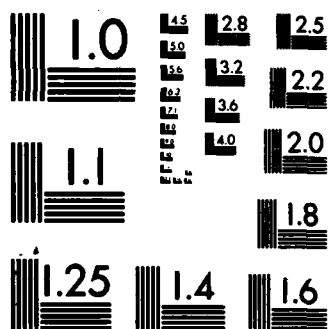
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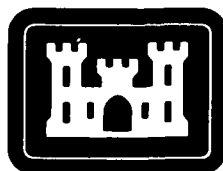
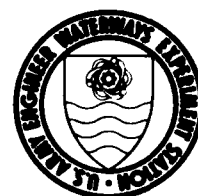
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REPORT OF FRESHWATER MUSSELS WORKSHOP

26-27 October 1982

Andrew C. Miller, Compiler

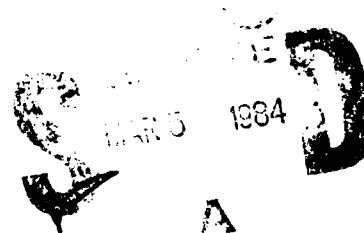
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

October 1983

Final Report

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Field trip on the Meramec River, Missouri, Times Beach Access, on 27
October 1982. Photograph by Andrew Miller, U. S. Army Engineer
Waterways Experiment Station.

Scanning electron photomicrograph of the glochidial shell of *Ligumia
recta*. Photograph by Billy G. Isom, Tennessee Valley Authority.

Conradilla caelata collected from the Duck River, Tenn. Photograph by
John Jenkinson, Tennessee Valley Authority.

Searching for freshwater mussels during stream surveys. Photograph by
Richard Neves, U. S. Fish and Wildlife Service.

COMPONENT PART NOTICE

THIS PAPER IS A COMPONENT PART OF THE FOLLOWING COMPILATION REPORT:

(TITLE): Report of Freshwater Mussels Workshop Held at St. Louis, Missouri on
26-27 October 1982.

(SOURCE): Army Engineer Waterways Experiment Station, Vicksburg, MS.

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THE FOLLOWING COMPONENT PART NUMBERS COMPRISE THE COMPILATION REPORT:

AD#:	P003 058	TITLE:	Biological Aspects of the Freshwater Mussels.
	P003 059		Endangered Species Legislation.
	P003 060		Potential Uses of in Vitro Culture of Freshwater Mussel Glochidia for Conservation.
	P003 061		Some sources of Nomenclatorial and Systematic Problems in Unionid Mollusks.
	P003 062		A Gravel Bar Habitat for Mussels on the Tombigbee River Near Columbus, Mississippi.
	P003 063		Status Report on the Tennessee Valley Authority Cumberlandian Mollusk Conservation Program.
	P003 064		Comments on the Commercial Shell Industry, Past and Present.
	P003 065		Sampling for Freshwater Mussels.
	P003 066		Mollusk Collections at the Ohio State University Museum of Zoology.
	P003 067		Archeological Records of Naiad Mussels Along the Tennessee-Tombigbee Waterway.
	P003 068		A Survey of the Freshwater Mussel fauna of the Little Kanawha River Basin.
	P003 069		Naiad Research in Missouri.
	P003 070		The Status of Freshwater Mussel Research in Virginia.
	P003 071		Unionid Distribution and Abundance Relative to Habitat Characteristics.
	P003 072		Mussel Identification.

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Environmental impact analysis Mussels Mollusks Endangered species		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A workshop on freshwater mussels was held in St. Louis, Mo., on 26- 27 October 1982. This workshop was part of a project on mussels conducted by the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss. as part of the Environmental Impact Research Program (EIRP). The pur- pose of the meeting was to (a) present results of the WES studies on mussels, (b) allow representatives of other Federal, State, and local agencies the (Continued)		

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20. ABSTRACT (Continued).

opportunity to describe results of their studies on mussels, and (c) encourage members of the academic community and commercial shell industry and all other interested individuals to criticize and comment on Government-sponsored research projects dealing with freshwater mussels.

The papers included in this volume, either submitted by the authors or transcribed from tape, deal with studies and projects that were designed to protect or inventory freshwater mussels. Included are descriptions of the Cumberlandian Mollusk Conservation Program of the Tennessee Valley Authority, results of inventories for mussels conducted by the States of Missouri and West Virginia, biological and natural history research carried out by the Virginia cooperative unit in Blacksburg, Va., and information on sampling and identification problems prepared by representatives of the Mississippi Museum of Natural History and the Museum of Zoology at The Ohio State University. In addition, there are (a) information on mollusks identified from archeological sites along the Tennessee-Tombigbee Waterway, (b) observations on appropriate sampling techniques and methods for culturing pearls by representatives from the commercial shell industry, (c) information on an artificial gravel bar for mussels, (d) an update of the Higgins' Eye Recovery Program, (e) studies on Corbicula, and (f) the purposes and goals of members of an amateur shell club.

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PREFACE

The Freshwater Mussels Workshop was held 26-27 October 1982 at Henry VIII Inn and Lodge, St. Louis, Missouri. The workshop was part of the U. S. Army Corps of Engineers Mollusk Study conducted under the Environmental Impact Research Program (EIRP). The EIRP is sponsored by the Office, Chief of Engineers (OCE), and managed by the U. S. Army Engineer Waterways Experiment Station (WES).

Dr. Andrew C. Miller of the Aquatic Habitat Group (AHG), Environmental Laboratory (EL), WES, organized and conducted the workshop. This workshop was carried out under the general supervision of Dr. Thomas D. Wright, Chief, AHG, EL; Dr. Conrad J. Kirby, Chief, Environmental Resources Division, EL; and Dr. John Harrison, Chief, EL. The Technical Monitor for this work unit was Mr. John Bushman, OCE. Program Manager for EIRP was Dr. Roger Saucier, WES. Dr. Miller compiled the papers presented at the workshop into this report.

Commander and Director of WES during the workshop and the preparation and publication of this report was COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

The report should be cited as follows:

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AGENDA

26 OCTOBER 1982

Presented Papers

Day Session

- 0745-0815 Registration
- 0815-0830 Welcome: LTC Paul Chapman, U. S. Army Engineer District,
St. Louis
- 0830-0845 Opening Remarks: Dr. Andrew C. Miller, U. S. Army Engineer
Waterways Experiment Station (WES), Vicksburg, Miss.
- 0845-0900 Purpose of the Mussel Study, Objectives of the Workshop:
Mr. John Bushman, Office, Chief of Engineers (OCE),
Washington, D. C.
- 0900-0945 Biological Aspects of the Freshwater Mussels: Dr. Paul
Yokley, Jr., University of North Alabama, Florence, Ala.
- 0950-1015 Endangered Species Legislation: Mr. John Pulliam, U. S. Fish
and Wildlife Service, Jackson, Miss.
- 1015-1045 Break
- 1100-1115 Use of Museums for Assistance in Identification of Mollusks:
Mr. Paul Hartfield, Mississippi Museum of Natural Sciences,
Jackson, Miss.
- 1120-1150 Potential Uses of In Vitro Culture of Freshwater Mussel Glochidia
for Conservation: Mr. Billy G. Isom, Fisheries and Aquatic
Ecology Branch, Division of Water Resources, Tennessee Valley
Authority (TVA), Muscle Shoals, Ala.
- 1155-1230 Source of Nomenclatorial and Systematic Problems with North
American Freshwater Unionids: Dr. David Stansbery, The Ohio
State University, Columbus, Ohio
- 1230-1330 Lunch
- 1330-1350 Artificial Gravel Bar Development for Mussels in the Tombigbee
River: Dr. Andrew C. Miller, WES
- 1355-1415 Status Report on the Cumberlandian Mollusk Conservation Program:
Mr. John Jenkinson, Fisheries and Aquatic Ecology Branch,
Division of Water Resources, Office of Natural Resources, TVA,
Knoxville, Tenn.
- 1420-1500 Freshwater Mussels, the Commercial Viewpoint: Mr. James L.
Peach, American Shell Co., Knoxville, Tenn.
- 1500-1530 Break
- 1530-1600 Sampling for Mussels: Mr. David Nelson, WES

26 OCTOBER 1982

Presented Papers (Continued)

- 1600-1700 Discussion Group Topic: Protecting Mussel Resources
Group A: Academic Community
Group B: Museums and Shell Clubs
Group C: State and Local Agencies
Group D: Federal Agencies
- 1700 Adjourn Day Session

Evening Session

- 2000-2045 Mollusk Collections of the Museum of Zoology at The Ohio State University: Dr. David Stansbery, The Ohio State University
- 2100-2145 The Tennessee-Tombigbee Waterway: Mr. Jack C. Mallory, U. S. Army Engineer District, Mobile
- 2145-2215 Archeological Records of Naiad Mussels Along the Tennessee Tombigbee Waterway: Mr. Neil Robison, U. S. Army Engineer District, Mobile
- 2230 Adjourn Evening Session

27 OCTOBER 1982

Presented Papers

- 0800-0815 Opening Remarks/Questions: Dr. Andrew C. Miller, WES
- 0815-0845 Survey of the Mussel Fauna of the Little Kanawha River Basin: Mr. John E. Schmidt, Division of Water Resources, Department of Natural Resources, Charleston, W. Va.
- 0850-0920 Mussel Research in Missouri: Mr. Alan Buchanan, Missouri Department of Conservation, Columbia, Mo.
- 0925-0955 Freshwater Mussel Research in Virginia: Dr. Richard J. Neves, Virginia Cooperative Fisheries Unit, Blacksburg, Va.
- 1000-1030 Examining Impacts of Dredging Operations on Mussels of the Meramec River: Mr. Patrick S. McGinnis, Regulatory Functions Branch, U. S. Army Engineer District, St. Louis
- 1030-1100 Break
- 1100-1200 Summary of the Workshop and Recommendations for Protecting Mussel Resources: Mr. John Bushman, OCE
- 1200-1330 Lunch

Field Trip

Background Information: Mr. Norm Stucky and Mr. Al Buchannan, Missouri Dept. of Conservation

Use of the Brail: Mr. Arnold Fritz, Illinois Dept. of Conservation

DISPLAYS

Sampling Gear for Freshwater Mussels: WES

Live Mussel Display: WES

Pearls from Mussels: Mr. James L. Peach, American Shell Co.

The Internal Anatomy of Mussels: Dr. Paul Yokley, University of North Alabama, Florence, Ala.

Mussel Identification: Mr. Tom Freitag, U. S. Army Engineer District, Detroit, Mich.

A Description of the In Vitro Process for Culturing Mussels: Mr. Billy G. Isom, TVA, Muscle Shoals, Ala.

Setting Up a Reference Shell Collection: Mr. Paul Hartfield, Jackson, Miss.

Techniques for Preserving Shells: WES

Unionid Species Distribution and Abundance as Related to Habitat Characteristics: Dr. James Sickie and Carol C. Chandler, Murray State Univ., Murray, Ky.

Identification of Endangered Mussels: WES

Trading Shells: Interested parties

Mollusks from the Mid-Atlantic Slope: Mr. Andrew G. Gerberich, National Museum of Natural History and Man, Washington, D. C.

CONVERSION FACTORS, INCH-POUND TO METRIC (SI)
UNITS OF MEASUREMENT

The inch-pound units of measurement used in this report can be converted to metric (SI) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
acres	2.471044	hectares
cubic feet per second	0.028317	cubic metres per second
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
feet	0.3048	metres
feet per second	0.3048	metres per second
gallons	3.785412	litres
inches	2.54	centimetres
miles (U. S. statute)	1.609347	kilometres
ounces	0.02834952	kilograms
pounds (mass)	0.4535924	kilograms
pounds per acre	0.1835631	kilograms per hectare
square miles (U. S. statute)	2.589998	square kilometres
tons (2000 lb, mass)	907.1847	kilograms
yards	0.9144	metres

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

INTRODUCTION TO THIS REPORT

by

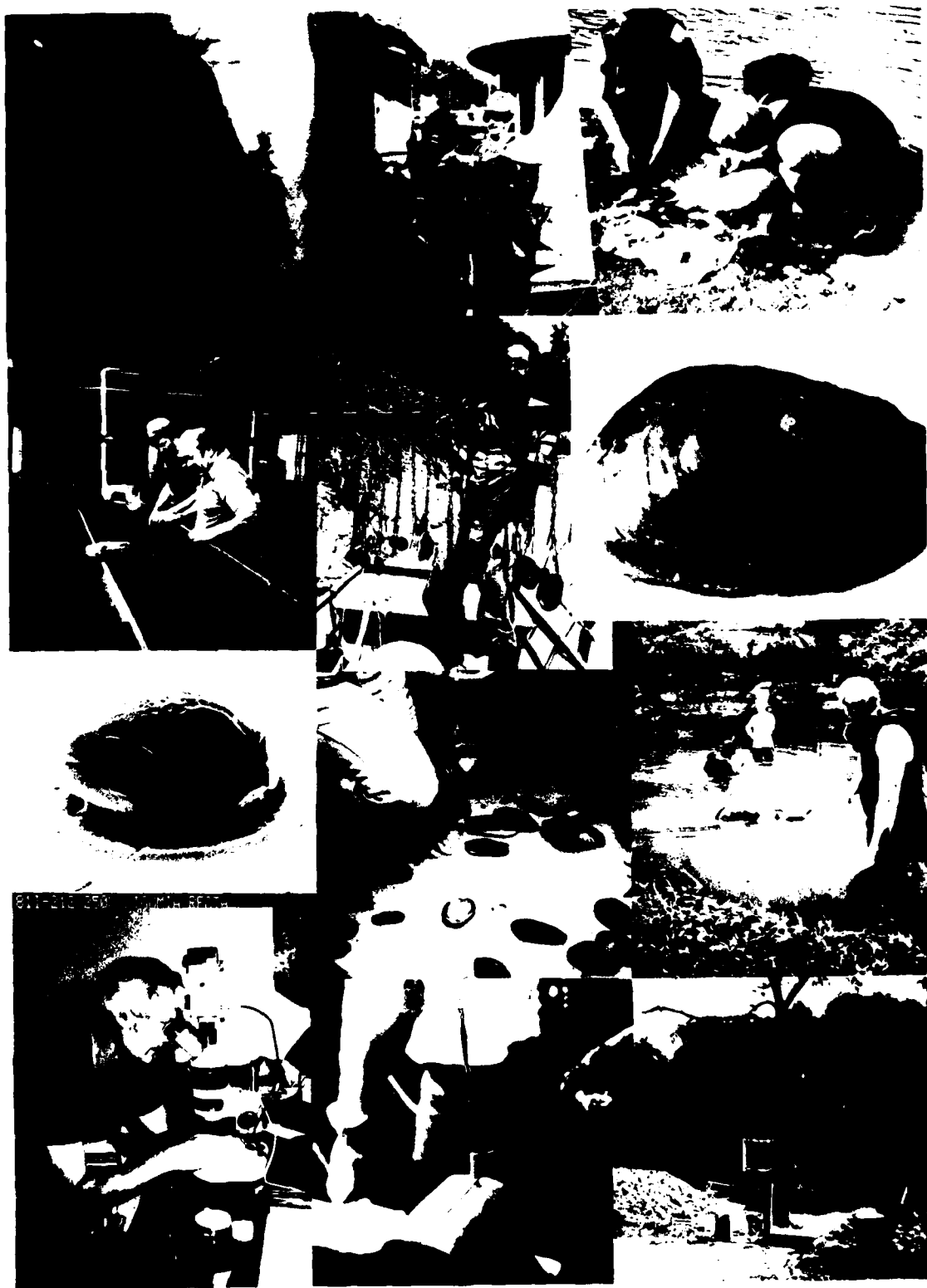
Andrew C. Miller*

The purpose of these proceedings is to present the papers, questions, comments, and responses which were part of this workshop on freshwater mussels. This meeting, part of a 2-year project on mussels at the Waterways Experiment Station (WES), Vicksburg, Mississippi, brought together members of the academic community, museums of natural history, and biologists and planners from State, Federal, and private agencies. The major objective was to describe and discuss recent and ongoing studies on protecting mussels and their habitat and understanding their biology, taxonomic, and reproductive problems. It was the intent of this meeting to provide information that would help Government and other biologists involved with Environmental Impact Statements and Environmental Assessments dealing with freshwater mussels.

Most of the papers in this report were written and submitted for publication by the various authors. These papers underwent revision at WES, then were reviewed by the authors. Some papers (where noted) were transcribed from tapes made at the meeting, edited by Dr. Miller at WES, and returned for review and revision by the authors. All comments and questions made after oral presentations at the workshop were transcribed, edited, and reviewed by the authors and then included in these proceedings.

WES has developed other sources of information on mussels which are available upon request. These include: (1) an annotated bibliography on mollusks prepared by Dr. A. C. Clarke, ECOSEARCH, (2) proceedings of the first workshop on mollusks, held in Vicksburg, (3) an Instruction Report on freshwater mussels, and (4) a field guide on the 25 federally listed mussels prepared by Mr. S. L. H. Fuller, Philadelphia Academy of Sciences, and Dr. A. C. Clark.

* Research Limnologist, Waterways Experiment Station, Vicksburg, MS



Freshwater mussel studies, 1980-1982.



WELCOME

by

LTC Paul Chapman*

It is my pleasure to be here today to welcome you to this workshop on freshwater mussels. I am equally pleased with the number attending. This workshop is being sponsored by WES, and it is an honor to have the workshop located in the St. Louis District. However, from the agenda it is obvious that this is more than a Corps of Engineers Conference. There are presentations scheduled by representatives of the U. S. Fish and Wildlife Service, the Tennessee Valley Authority, State agencies, and the commercial mussel industry, as well as the Corps of Engineers. Also, I understand that early registrants included about one-third from Federal agencies, one-third from State agencies, and one-third from the academic community, with a smaller fraction from the mussel industry, shell clubs, and the general public. Certainly, the subject of this workshop deserves this level of interest and diversity of participation.

The St. Louis District has an active interest in mussels preservation. This has included the study of mussels at various project and permit sites in the District. We have located the Federally endangered pink mucket pearly mussel in the Meramec River and funded the Missouri Department of Conservation to study its distribution. This study concluded that the range of the pink mucket is within the lower 55 miles of the Meramec River, but the study certainly did not answer all the questions we have regarding this species. Pat McGinnis of our Regulatory Functions Branch will be addressing you tomorrow regarding a study that we are currently trying to get underway at dredging sites on the Meramec River. A great deal is known regarding the pink mucket and other freshwater mussels, but a great deal more needs to be learned.

I am pleased that St. Louis has been chosen as the site of the workshop. I think the St. Louis District has something to offer in advancing the state of knowledge on mussels, and this certainly affords an opportunity for more of our personnel to attend the workshop and benefit from your collective knowledge.

I suspect that the midwestern location of St. Louis has also helped many participate in this workshop who might not be here because of budgetary and travel restrictions. St. Louis offers additional advantages since it is an area of high mussel species diversity, which I expect you will find out as you go on the field trip tomorrow, weather permitting.

* Deputy District Commander, U. S. Army Engineer District, St. Louis.

PURPOSE OF THE MUSSEL STUDY AND OBJECTIVES OF THE WORKSHOP^{*}

by

John Bushman^{**}

I appreciate the opportunity to be here today and am encouraged to see the large number of people attending this workshop. We have over 100 people in the audience: representatives from the FWS, the U. S. Environmental Protection Agency (EPA), at least three State agencies, the U. S. Army Corps of Engineers (CE), museums, and nearly a dozen colleges or universities. Although we are anxious to begin the presentations, let me take just a few minutes to make some introductory comments concerning this workshop and the studies on mussels at WES.

The CE has a mission not only to plan and develop water resource projects but to regulate various activities, such as dredging, which take place in navigable waterways. This involvement with natural resources as they may be affected by operation and development activities was brought about mainly by passage of the National Environmental Policy Act in the early 1970's. However, of all the Federal statutes this agency must respond to, one of the most significant, from the standpoint of freshwater mussels, is the Endangered Species Act of 1973, as amended. It was because of that legislation that Federal biologists, regardless of their background or interests, were called upon to collect information on mussels inhabiting areas that could be affected by CE construction or maintenance activities. This meant that the biologists had to provide an assessment on virtually every action their agency undertook or even contemplated on a waterway. A survey could be no more than 100 ft in length, or perhaps up to several hundred miles on a large river such as the Ohio or Mississippi.

In the spring of 1980 the Office, Chief of Engineers (OCE), censused CE Districts to determine the depth of their involvement with mussels. We found that at least a dozen District offices, which ranged from the upper Mississippi River to the Mobile Basin and encompassed the Ohio and middle Mississippi Rivers, either had or were developing a program on mussels. Because of this intense interest expressed by the field, OCE authorized WES to immediately commence a 2-year project on this important group of organisms. The objective of the WES program was to bring together information on methods for sampling, identifying, and protecting these invertebrates. It was planned that the results of the WES project would be of use to all biologists, regardless of their affiliation, who were interested in protecting and understanding the freshwater mussels. The information obtained during this project would be disseminated by way of workshops, an Instruction Manual, and various other publications. This is the second workshop for this project; the first workshop on mussels was held in Vicksburg, Mississippi, in May 1981.

Let me emphasize that there are at least two aspects to this project conducted by WES which are unique. First of all, WES did not develop information on the

^{*} Transcribed from tape and reviewed by the author.

^{**} Technical Monitor, Office Chief of Engineers, Washington, D. C.

mussels by simply reviewing and abstracting past publications on collecting and identifying mussels. This project benefited by the direct participation of experts from other Federal agencies, museums, and universities that are actively working on mussels. Many of those that supplied information for this project are here today to make presentations.

The second point I wish to emphasize concerning this study is its mechanism of funding. Typically, the field offices provide ideas for studies for the research laboratories by way of what we call a "mission problem statement." These statements, which are brief descriptions of research needs, are sent to OCE where they are ranked and consolidated. They then become the basis for some of the direction of the large research programs managed by WES and other CE research facilities. However, as I said before, this project on mussels was funded as a result of interest expressed directly by the field biologists. OCE responded to District needs without the mission problem statements because we recognized that studies on freshwater mussels were a high-priority item not only in the Federal Government but in other organizations as well.

Recently, OCE again censused District offices to assess their involvement with the mussels. We identified at least 14 Districts that were either directly or indirectly involved with studies on these invertebrates. During the last few years there has been a great deal of CE cooperative work with State, Federal, and local agencies. Mussel studies have been conducted by universities and colleges, WES, and museums. To date, about 100 permit actions have involved the freshwater mussels. At least two CE biologists are members of Fish and Wildlife recovery teams. We feel that information provided and professional contacts made at meetings such as this have had their part in encouraging and implementing high-quality work on the freshwater mussels.

Let me conclude by again thanking all who have been involved with this study. This includes not only those who participated in this and the past workshop, but also those who assisted WES in the conduct of this project. Thank you.

SUMMARY OF THE WORKSHOP

by

John Bushman

and

Andrew C. Miller

The purpose of this workshop was to highlight recent studies on freshwater mussels which pertained specifically to their protection. To achieve this goal, members of the academic community and workers from museums of natural history made presentations and joined the discussions. There have been papers prepared by biologists employed with both State and Federal agencies. In addition, the commercial shell industry has been represented at this meeting, both in formal and informal sessions. While this meeting was funded by the U. S. Army Corps of Engineers, we are fortunate to have had the support of all who gave of their time and resources to attend. Without exception, every State and Federal agency represented provided travel funds to enable their people to attend; everyone involved, attendees, discussion group leaders, and those with papers to present, all made their time available to help with this meeting.

The research conducted by Mr. Billy Isom, TVA, under the Cumberlandian Mollusk Recovery Program, is particularly impressive and suggests many avenues for future studies, all with extremely high potential. For example, his techniques could be used to produce large numbers of very rare mussels that might be in danger of becoming extinct. The commercial shell industry could use his methods to culture organisms that exhibit specific features necessary for jewelry or pearl production. For those that conceive the freshwater mussels as a viable source of protein, an artificial culturing process could produce large numbers of desirable individuals. However, the avenues of pure research that lead from these studies may well be as exciting as the practical benefits. One has only to scan the discussions following presentations by Mr. Isom and Dr. Neves to realize that there are many unanswered questions concerning host specificity among the bivalve mollusks. Studies done by Mr. Isom could provide a vehicle for research with both theoretical and applied benefits. We are concerned that the techniques for artificial culture not be lost or put aside because of budgetary restrictions or lack of interest. We need to have other workers in Government-sponsored as well as university laboratories continue this important work.

Mr. John Jenkinson, also from TVA, described the efforts of his agency to bring about the large-scale relocation of great numbers of the mussel Conradilla caelata in the impact area of the Columbia Dam project in Tennessee. Dr. Miller from WES described a design for an artificial mussel habitat for placement in the Tombigbee River adjacent to the Tombigbee Waterway. Some critics feel that benefits of these Government-sponsored projects to protect mussels are small when compared with the tremendous overall impacts of these large-scale water resource projects. This may be true; however, a biologist working for the Federal government is propelled by the wishes of higher authority: legislative mandates, the Congress, and vocal participants

and critics of water resource development. The Federal biologist is attempting to protect the resource.

The endangered species legislation provided much impetus for the workshop and the studies undertaken by TVA, The U. S. Fish and Wildlife Service (FWS), and other agencies. Mr. John Pulliam, FWS, in Jackson, Mississippi, discussed this legislation. The questions and comments following his talk reveal the frustration of many who work with the application of these laws. One point of interest concerning the Endangered Species Act is that it must be renewed periodically. In fact, it has been recently extended with certain changes.

We are fortunate to have had participation from the commercial shell industry at this workshop. These people present a viewpoint much different from those involved with theoretical and legislatively directed studies; for the commercial shell buyers the mussel resource is the mainstay of their livelihood. Mr. James Peach, American Shell Company, described how shells are harvested and processed to form the nuclei of cultured pearls. It is our opinion that biologists studying mussels have little utilized the resource of knowledge in the commercial shell fisherman who can often provide data on location of mussel beds and the types of shells in various areas, as well as advice on sampling techniques. Representatives from two other commercial shell companies, The Tennessee Shell Company and M. D. Cohen Co., also participated in this meeting and provided comments.

Mr. David Nelson, WES, displayed and described sampling devices that are used to collect mussels. Most of this equipment can be built easily with inexpensive materials. His presentation prompted many interesting questions and comments. Mr. Harold Mathiak from Wisconsin elaborated on his use of the modified pitchfork. The president of the Tennessee Shell Company, Mr. John Latundresse, had an observation that probably surprised most of us. The first commercial use of a "so-called brail" was actually a cedar bush that was weighted to sink to the bottom and then towed over mussel beds. Perhaps some enterprising biologist should test and evaluate this technique.

Mr. Paul Hartfield from Jackson, Mississippi, pointed out acceptable protocol when requesting the use of a reference collection or the assistance of a curator at a museum. Dr. David Stansbery, Curator of Bivalve Mollusks at The Ohio State University, provided two presentations. In one presentation he described all phases of the work of curating mollusks at the Museum. The care with which he and his staff treat specimens, their labels, and records should make us all take account of the manner in which we conduct our professional business. Dr. Stansbery's first paper dealt with the problem of nomenclature with freshwater mollusks. Anyone who has alternately marveled at or been frustrated by the subtle variations among shells should find Dr. Stansbery's paper interesting and informative.

While the endangered species legislation has been a point of focus for much mussel research, so has the development of the Tennessee-Tombigbee Waterway. Mr. Jack Mallory of the U. S. Army Engineer District, Mobile, described some features of this project. He also presented an introduction to Dr. Miller's discussion of habitat development in the Tombigbee River. Mr. Neil Robison, also from the Mobile District, discussed an archeological survey recently completed along the Tennessee-Tombigbee Waterway. His presentation encouraged

many questions and comments, notably from Dr. Harold Murray, Trinity University, Texas, who also studied shells in archeological middens.

The State Biologists, Mr. John Schmidt from West Virginia and Mr. Al Buchanan from Missouri, respectively, provided examples of surveys conducted to identify the common and uncommon mussels in a particular area. This emphasis on exploratory work to protect and understand aquatic habitats should serve as a model for State and Federal biologists. The importance of well-executed research, with its potential for improving our understanding of the fauna, is commented upon by Dr. Paul Yokley in a short paper in these proceedings. Mr. Pat McGinnis of the U. S. Army Engineer District, St. Louis, described the other aspect of the work done by Al Buchanan, that of the involvement of the CE with permit requests as they relate to the mussel fauna.

Dr. Jim Sickle and his associates from Murray State University, Kentucky, summarized their work on mussel distribution and substrate characteristics. Among other species, they discussed the habitat of the spiny mussel Canthyrta spinosa which is unusual, restricted in its range, and deserving of protection. Dr. Ed Stern, from the University of Wisconsin, updated his work on the Higgins' eye Recovery Plan which he described in detail at our first workshop. Mr. Tom Freitag, a biologist from the Detroit District, brought an example mussel reference collection to this meeting and summarized salient identifying characteristics of certain species for this report.

Dr. John C. Williams, Eastern Kentucky University, and Dr. Marc Imlay (FWS), a malacologist from Columbia, Missouri, presented brief summaries of their recent work. Dr. Williams has just completed a survey of the Ohio River for the Louisville District, and Dr. Imlay is studying competition between native and exotic mollusks.

We are fortunate to have had many participants from the Greater St. Louis Shell Club at this meeting. Mr. Alan Gettleman, a member of the club, prepared and presented a paper on the purpose and background of their organization. We were impressed with the high degree of professionalism of the members and the manner in which they interact with museums and other professionals in the scientific community.

One of our objectives at this workshop was to solicit comments from attendees on research needs with freshwater mussels and mechanisms or procedures for protecting the organisms and their environment. To meet this need the group was split into four small groups, based upon professional background, to discuss a selected list of topics (Table 1). The workshop attendees were broken into the following groups:

- a. Members of the academic community.
- b. Malacologists and shell collectors from museums and shell clubs.
- c. Workers from State and local agencies, and the commercial shell industry.
- d. Individuals from Federal agencies.

The purpose of segregating attendees was to enable each group to form opinions and recommendations based upon their collective backgrounds. With heterogeneous groups there is a tendency for each discipline within the unit to present their views strongly in attempts to be heard. With members from similar backgrounds a group is more able to provide clear and concise opinions unclouded by internal divergencies of opinion. However, a problem with this arrangement is that the cross-fertilization of ideas within a group is minimal. An individual from a museum or university does not have the opportunity to sit next to a Federal biologist and understand, if not concur with, his problems and points of view.

We have summarized the points brought forth at each group session as recorded by two discussion leaders (Tables 2-5). As one would anticipate, biologists from universities and colleges (Table 2) stress the importance of carrying on baseline environmental studies, as well as tackling problems on taxonomy, artificial culture, reproduction, genetics, behavior, and water quality as they apply to mussels. They were discouraged with the way in which the Endangered Species Act does not protect habitats unless an endangered species is present. They were in favor of establishing a committee of malacologists to make recommendations concerning research needs on mussels and thought that periodic meetings and workshops were very important.

Representatives of museums and shell clubs also favored workshops and formation of a committee that could discuss research needs on mussels. They favored the "popular education" role of the Federal Government and stressed the importance of such items as the color chart of mussels of the Upper Mississippi River prepared by Mr. S. L. H. Fuller and jointly funded by the FWS and the CE. The nature of the comments (Table 3) of this group reflected their frustration concerning inadequacies of the Endangered Species Act, the effects of sand and gravel dredging, and the loss of free-flowing streams because of development of water resource projects. They suggested that the CE publish construction plans for the next 100 years, which assumes, we suppose, that the U. S. Congress and the American public, who drive this construction program, are gifted with that foresight. This group was concerned with the development of artificial gravel bars for mussels, expressing an opinion that this might then make it permissible to destroy natural habitat which could cause a decline in species diversity. They noticed that this workshop did not deal with all impacts of reservoir construction on mussels; an individual from the commercial shell industry stated that the commercially valuable shells are harvested mainly from the man-made lakes. It was their opinion that the overall loss in diversity should not be underemphasized and was not adequately brought forth at this meeting.

The representatives from States stressed the importance of baseline surveys and pointed out that statistically valid standardized sampling design is difficult since each collecting area is unique (Table 4). The commercial shell fisherman expressed the opinion that baseline surveys should go beyond the question of presence or absence of a particular species and investigate why changes in species composition are taking place. As a group, these people appeared most interested in declining mussel stocks in streams and lakes and felt that future studies should concentrate on this particular problem.

Federal biologists expressed concern over impacts of gravel dredging and pollutants on freshwater mussels (Table 5). They were interested in the possibility of a dredge which would be less damaging to mussel habitat and in studies of relocating mussels to areas not being dredged. They felt that studies were needed on the propagation of endangered species and habitat development, statistics of small samples, systematic inventories of streams, development of good management practices for endangered species, and investigation of limiting factors in critical habitats. Representatives from Federal agencies pointed out that much information resides in internal reports in various offices which could be useful for those involved in mussel studies.

It is evident that all groups were unanimous in their opinion that workshops on mussels as well as a committee to direct studies on these organisms would be valuable. The publication of information, coordination of ideas, and synthesis of study results among a diverse group of those interested in protecting mussels were obviously of paramount importance. Growing out of this was a general feeling of frustration with conservation laws. In some cases this could be the failing of the laws, but as John Pulliam stated, it could also be the result of individuals simply not adequately carrying out legislative mandates.

All attendees, regardless of their affiliation, were quick to cite specific studies that should be initiated. The impacts of dredging, channelization, and pollution and methods for propagating uncommon organisms and protecting habitat were judged important. The ecological requirements of certain species or the best techniques to sample populations and understand host-specificity relationships were also discussed. Attendees identified needs for specific studies to bring forth a general understanding of certain concepts. Indeed, research such as this could provide information that would be of value to Federal and State biologists as well as those in museums and academic institutions.

Table 1

Topics for Group Discussion: Protecting Mussel Resources

Discussion Questions

1. Based on your experiences, provide recommendations on research needs, sampling methods, or techniques for protecting mussels and their habitats.
2. Criticize, comment on, or amplify any of the points made during the presentations at this workshop.

Special Topics For Consideration

1. Concerning the problem of statistically valid sampling design for the sampling of freshwater mussels,
 - a. Has there been enough work?
 - b. Should more work be done?
 - c. Provide additional comments, reactions.
2. To continue the thrust of interest of the CE in freshwater mussels, would it be helpful to Federal and State agencies and academia to plan another workshop or symposium in the future?
 - a. In 18-24 months?
 - b. In 30-36 months?
 - c. Another time period?
 - d. Provide additional comments.
3. Comment on the advisability of establishing an ad hoc committee on freshwater mussels to provide
 - a. Research recommendations.
 - b. Coordination and information exchange among interested groups such as Federal and State agencies, academia, museums, the commercial shell industry, etc.

Table 2
Comments on Research Needs Made by Representatives
from the Academic Community

1. Phylogenetic and genetic problems need to be studied.
2. Ecological studies with emphasis on environmental factors are important areas of research.
3. There is a need for water quality and life cycle requirements for various species of mussels.
4. Baseline studies on streams where water resource projects may be constructed are important.
5. Additional important studies are on taxonomy, spawning, and behavior of freshwater mussels.
6. There is a problem with the Endangered Species Act: if no endangered species are present the habitat may be destroyed, which results in losses of other organisms.
7. A committee of professional malacologists should be established to make recommendations concerning needed work.
8. Periodic meetings on mussels should be held involving Federal, State, and academic organizations.
9. The diversity and format of the present workshop should be maintained in future workshops.
10. Research is needed on the following topics:
 - a. Artificial culture of mussels.
 - b. The effects of pollutants on mussel sperm.
 - c. Studies on breeding requirements for various species of mussels.

Table 3
Comments Made by Representatives of Museums and Members of
Amateur Shell Clubs

1. There is a need for studies of systematics of freshwater mussels and gastropods.
2. It appears that it is illegal to collect a specific mussel, but it may be permissible to destroy its habitat.
3. There has already been quite a bit of statistical work done on small samples. It is important for the investigator to know exactly what he is trying to demonstrate with his data.
4. There needs to be better control of gravel dredging since this operation often destroys mussels.
5. The CE should not manipulate free-flowing rivers and streams. It is not difficult or improbable to resolve conflict among those who want to develop our waterways and those who want to protect our resources.
6. This workshop has not adequately explained the effects of impoundments on mollusks; the impoundments may cause an increase in lbs/acre of certain species, yet the diversity of this new population may be very low.
7. While some valid information can be obtained by creating habitat for mussels, the overall concept is not appealing. Proposing the use of artificial habitat implies that since endangered species can be transported to new areas it is permissible to destroy the natural habitat. Ultimately, man may not be able to maintain the artificial habitat, and the result will be an overall loss in species diversity.
8. Popular education activities funded by the CE are worthwhile; i.e., the charts of freshwater mussels developed by Sam Fuller and jointly funded by the CE and FWS.
9. The attendance at this workshop was impressive; another one should be held within 12 to 24 months. Discussion groups should not be segregated based on interest but should contain a mix of people with different backgrounds.
10. If possible, the CE should publicize construction plans for the next 100 years.
11. An ad hoc advisory committee to discuss mussel studies would be worthwhile. It should contain representatives from the CE, commercial shell industry, museums, academic community, and amateur shell clubs.

Table 4
Research Needs as Proposed by Representatives
from State and Local Agencies

1. Statistically valid standardized sampling design is difficult to obtain because each particular stream or river is often very different.
2. Mussel stocks are declining in many areas. Why? Commercial shellers say that this is caused by contaminants rather than by overharvesting.
3. In most states the most pressing research need is baseline inventory data.
4. A clearinghouse to coordinate information related to mussels is needed. We suggest that WES be involved with this.
5. Future workshops are needed to maintain interest in freshwater mussels. These should be held every 2 to 3 years. An important topic for consideration is the problem of contaminants and freshwater mussels.
6. Commercial shell fishermen are frustrated because most environmental studies start off at the same point: basically documenting what organisms are present at a given location. They feel that it is important to move on to answer the more difficult question of why certain changes take place.
7. The lack of recruitment of freshwater mussels appears to be a significant factor in declining populations. Research should determine what is the cause of this. Contaminants may be the problem.

Table 5
Research Needs as Described by Representatives
from Federal Agencies

1. What are the real impacts of gravel dredging?
2. What are the effects of toxic substances from industrial effluents and the effects of pesticides from runoff on the glochidia, juveniles, and adults of specific species of mussels.
3. An important research area is the propagation of endangered species and habitat development.
4. There is a need for development of good managerial procedures for specific endangered species.
5. There is a need for systematic inventories of streams to determine location, type, and relative abundance of mussels.
6. Relocation of mussel beds following dredging operations is a worthwhile consideration.
7. What are the determining parameters for critical habitat?
8. A dredge should be developed for use in deep water which is not damaging to habitat.
9. What constitutes an appropriate size and number of samples when dealing with freshwater mussels?
10. Additional workshops would be very useful; however, the format should be changed so that more specific areas could be covered. For example, on Day 1 the impacts of dredging should be considered; on Day 2 different topics could be treated.
11. At the next workshop the FWS presentation should include a discussion on case histories of formal consultation processes.
12. The variety of disciplines and interest of those in attendance at this workshop should be maintained.
13. There is much information locked away in various agencies such as the TVA, CE, and FWS. Others are not aware of these studies. It is felt that a workshop consisting of a series of symposia on specific topics could make this information available for all to utilize.

BIOLOGICAL ASPECTS OF THE FRESHWATER MUSSELS
by

Paul Yokley*

Introduction

Dr. Paul Yokley described selected aspects of molluscan biology to provide a general introduction to topics to be presented at this workshop. He discussed history of the commercial shell industry and methods for collecting and identifying these invertebrates and showed slides of glochidia and the internal anatomy of mussels.

The following questions, comments, and responses following Dr. Yokley's presentation were transcribed and edited. In addition, selected pictures from his talk have been reproduced and described.

Discussion

Question: How did you get the pictures of the mussel eggs being fertilized?

Yokley: I took well over 100 slides and sorted through to get the best ones.

Question: About how large are the mussel glochidia when they leave the host fish?

Yokley: No larger than when they attach to the fish, about 150 μ . A human red cell is about 7 or 8 μ , so the glochidium is much larger but barely visible without magnification.

Question: How difficult is it to find glochidia in sand or silt while collecting in the field?

Yokley: It is very unlikely to find glochidia while out in the field. It is possible to find glochidia in an artificial system such as an aquarium after they have dropped off the fish. However, because they are so very small you really need a tank with a round or V-shaped bottom into which the glochidia settle to be able to find them easily.

* Biologist, University of North Alabama, Florence, Ala.



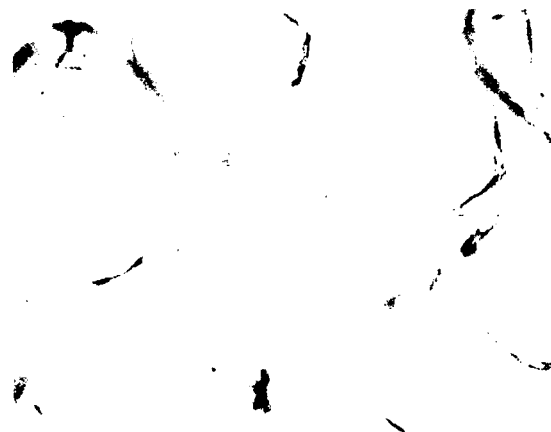
a. Gravid outer gill and transparent inner gill of freshwater mussel



b. Rosefin shiner with glochidia on exposed gill

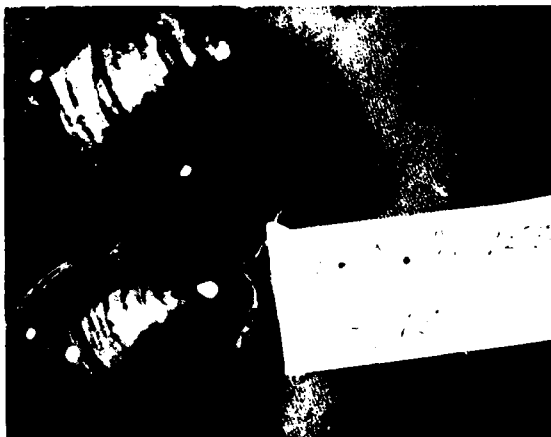


c. Rosefin shiner gills after 12-day infection with glochidia (100 X)



d. Glochidia of Medionidus conradicus

Figure 1. Glochidia from freshwater mussels



a. A method for marking mussels.
Holes are drilled with the aid of
a template



b. Badly eroded and metallic-stained
specimens collected from the
Tennessee River, mile 203.8,
20 Sept 1969



c. Variations in shell quality
(specimens collected at mile 153.4
on the Tennessee River)



d. Pleurobema cordatum, 8 days after
dropping from host gill (200 X).
Picture shows growth of new shell

Figure 2. Freshwater mussel shells



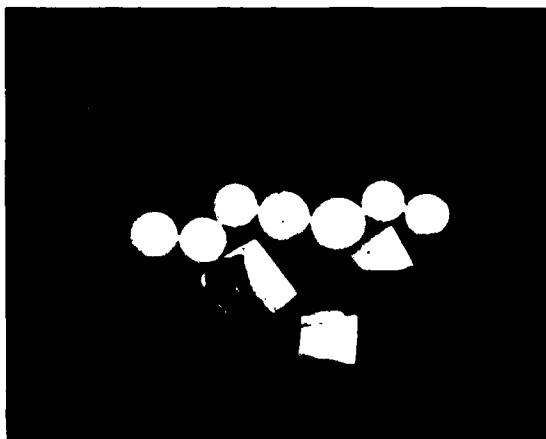
a. Shell used for button industry



b. Pearl button, front side



c. Baroque pearls found in freshwater mussels



d. Nuclei, cut and processed from mussel shells, for making cultured pearls

Figure 3. Commercial uses of freshwater mussels

ENDANGERED SPECIES LEGISLATION

by

John J. Pulliam, III*

Introduction

This presentation is for

I have been asked to talk to you today about endangered species legislation. Because of habitat changes such as dams, agriculture, logging, and pollution in the rivers of the United States, many species of freshwater mussels have become extinct or are threatened with extinction. These factors bring the Endangered Species Act and freshwater mussels together.

Presently there are 25 species of mussels listed as endangered under the Act. There are an additional 48 mussel species in the Southeast alone that are being considered as candidates for listing. Eleven of these are thought to be already extinct.

Purpose of the Endangered Species Act

The FWS, acting for the Secretary of Interior, is charged with the responsibility of determining which species should be listed as endangered or threatened. An endangered species is any species which is in danger of extinction throughout all or a significant portion of its range. This excludes insect pests. A threatened species is any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

The definition of "species" as used in the Act includes any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature. The determination whether or not to list a species is based on any of the five following factors:

- a. The present or threatened destruction, modification, or curtailment of its habitat or range.
- b. Overutilization for commercial, sporting, scientific, or educational purposes.
- c. Disease or predation.
- d. Inadequacy of existing regulatory mechanisms.
- e. Other natural or man-made factors affecting its continued existence.

* Endangered Species Listing Biologist, FWS, Jackson, Miss.

A very long, tedious, and complicated process precedes the listing of any species. All available data must be reviewed and analyzed, including public comment which is solicited normally by letter, newspapers, Federal Register, and public meetings and hearings. Once a species is listed, the FWS is required to develop and implement a recovery plan for the conservation and survival of those species. We have some guidelines on the preparation of these plans which may be developed by FWS personnel, contract, or recovery team.

Specific Provisions of the Act

Section 5 of the Act provides the authority to acquire land use funds from the Land and Water Conservation Fund Act to conserve fish, wildlife, and plants which are listed pursuant to Section 4 of this Act. Section 6 provides for cooperation with the States on endangered species programs. This cooperation includes management agreements and cooperative agreements, with Federal cost-sharing.

Other than listing, the most controversial aspect of the Act is interagency cooperation, more commonly called Section 7 consultation. There is much misunderstanding regarding the Endangered Species Program, and most of that is centered around this section and its impact on private citizens. As you can see from the title (Interagency Cooperation) and the content of Section 7, consultation is required only for Federal projects or actions that are permitted, licensed, or funded by a Federal agency. There is no impact on a private citizen unless it is through one of these actions. The ultimate purpose of the Act is to provide for consideration by Federal agencies of endangered and threatened species, as well as the economic, energy, and social objectives of those agencies. Section 7 is the most significant portion of this legislation from the standpoint of Federal construction agencies such as the CE.

This section is very involved and in addition requires that the FWS publish regulations regarding interagency cooperation. Therefore, we will just briefly cover the steps in the cooperation process for construction projects as follows:

- a. The construction agency shall request from the FWS information on species listed or proposed to be listed that may be present in the project area.
- b. For those species which may be present, the construction agency shall conduct a biological assessment to identify any of those species which are likely to be affected by such action.
- c. When it is determined that a listed species is likely to be affected, the agency initiates consultation with the FWS. Notice that this includes any effect, whether positive or negative. Such a determination precludes the agency from making an irreversible or irretrievable commitment of resources which would foreclose the consideration of modifications or alternatives to the identified activity or program.

- d. After the agency determination, it is up to the FWS to determine whether or not the action will promote the conservation or is likely to jeopardize the continued existence of a listed species or result in the destruction or adverse modification of its critical habitat. Reasonable and prudent alternatives shall also be included.
- e. The agency shall ensure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of its critical habitat. Their other option is to apply to the Endangered Species Committee for an exemption. The Committee may grant an exemption after the applicant meets three requirements if (1) there are no alternatives, (2) other benefits outweigh conserving the species, (3) such action is in the public interest, (4) the action is of regional or national significance, and (5) mitigation and enhancement measures are provided.

Section 8 covers international cooperation, particularly implementation of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (Convention).

Section 9 discusses acts that are prohibited with respect to endangered species. These include taking, delivering, receiving, transporting, and selling of the species and violating the Convention. States with cooperative agreements are excluded from the "taking" restrictions.

Section 10 covers exceptions to Section 9, including permits for the following reasons:

- a. Scientific purposes.
- b. To enhance the propagation or survival of the species.

Section 11 describes the penalties for violating Section 9 of the Act, except for self-defense, including the following:

- a. Fines of up to \$20,000 and imprisonment for one year.
- b. Rewards of up to \$2,500 for information leading to a conviction.
- c. All equipment used in violation of this Act is subject to forfeiture.
- d. Citizen suits are invited.

1982 Amendments to the Act

Unlike most other Acts which Federal agencies are charged to administer, the Endangered Species Act is authorized for a specific time period, normally three years. At the end of that time it is subject to amendments and funding limitation changes. The Act was just reauthorized as the "Endangered Species

Act Amendments of 1982" on 14 October 1982, and there were some amendments to the Act. The following amendments now apply:

- a. The Act has been amended to give priority to the development of recovery plans on those species that are, or may be, in conflict with construction, or other developmental projects or other forms of economic activity.
- b. The Federal share of funding for State cooperative agreement projects was raised from 66-2/3 percent to 75 percent for single-state projects and from 75 percent to 90 percent for multistate projects. However, there is a possibility that cooperative agreement funding may be deleted or severely reduced in the FY 83 budget.
- c. There was an amendment proposed to allow permit or license applicants to consult directly with the FWS. Ultimately, this amendment was contained in the House bill but not the Senate; therefore, the resultant Conference Committee bill requires that consultation take place directly with the Federal agency, but can be initiated prior to the applicant's filing for such permit. The applicant should be involved in every aspect of the consultation process.
- d. Previously when an agency consulted with the FWS according to Section 7 of the Act and received a "no jeopardy" biological opinion on a project, it did not insulate them from being in violation of Section 9 of the Act if an endangered species were taken incidental to, and not for the purpose of, the carrying out of an otherwise lawful activity. Section 10 of the Act has now been amended to allow for this, providing the applicant submits a conservation plan that will minimize and mitigate the impacts of such taking and the taking will not appreciably reduce the likelihood of the survival and recovery of the species in the wild.
- e. Previously, the taking of plants was not prohibited by Section 9 of the Act. This bill amends that section by adding a provision to prohibit the removal and reduction to possession of any endangered plant that is on Federal land.
- f. One of the problems in recovering listed species in the past has been resistance to the introduction of endangered species outside their current range. This problem has been alleviated by an amendment to the Act which provides for the determination of experimental populations. These populations will be treated as threatened rather than endangered; therefore, taking is authorized. In addition, these populations do not receive the full protection of Section 7 of the Act unless it is determined that the population is essential to the continued existence of the species. If it is not essential, then the population is subject only to those protections of Section 7 that apply to species proposed to be listed.

The 1982 bill incorporated other amendments to the Act regarding many procedural changes in listing, consultation, the exemption process, convention implementation, permits, and penalties.

Discussion

Question: What is the point of putting things on the endangered species list if the FWS refuses to name critical habitat for these organisms?

Pulliam: It is my opinion that critical habitat is not required to protect these species. The Act mentions two things of importance: jeopardizing the continued existence of a species and destruction or adverse modification of its critical habitat. The designation of "critical habitat" should be considered as a vehicle for bringing attention to an area. If you feel that the legislation is not protecting certain species, this may not be the fault of the law, but of those who are trying to interpret and enforce the law or perhaps funding limitations.

Question: How consistently does this law apply to various areas of the country? For example, the Indiana bat is listed only for discrete areas in Kentucky although this species is listed as endangered for the entire State of Ohio.

Pulliam: The important thing is not if a species is listed, but how the Act is applied. If an endangered or threatened species is in an area, the legislation must be applied.

Question: Isn't it true that by listing ranges, the FWS may be requiring formal consultation where a species is actually not going to be found?

Pulliam: The range information should be fine-tuned as a result of field studies or other means so that the agency can know for certain if a listed species is actually in an area.

Question: What is the connection between what your agency and the EPA does?

Pulliam: We can get involved with EPA when a permit action could affect a listed species. We must determine if the action will jeopardize the species under the Endangered Species Act. Our agency also provides input under the Fish and Wildlife Coordination Act.

USE OF MUSEUMS FOR ASSISTANCE IN THE IDENTIFICATION OF MOLLUSKS

By

Paul Hartfield*

The best tool for the identification of mollusks is a good systematic collection. There is no photograph, illustration, or wordy description that can begin to compete with a properly identified series of specimens.

Roughly 82 significant collections of molluscan fauna are housed in State and Federal museums, universities and academies, and private collections in North America (Thompson 1982). Many of these institutions provide identification services for a moderate fee, depending upon the bulk of material. Some have facilities for visiting scientists and encourage the use of their collections. Donating your material to a reputable collection ensures the survival of the specimens and the information inherent in them, and contributes to our national collections resource.

Whether you are donating specimens, sending material for identification, or wish to gain access to a collection for the same purpose, there are a few courtesies that should be observed:

- a. Make prior arrangements. If you plan on using a collection, the curator or curatorial assistants may be able to spend more time with you if you're expected.
- b. Negotiate terms in advance. You may find that donating material will reduce any charges that may be made.
- c. Provide complete collecting data. There's nothing worse than trying to break somebody else's code.
- d. Clean your specimens. This usually must be done before a positive identification can be made, and advance cleaning may save time and money.

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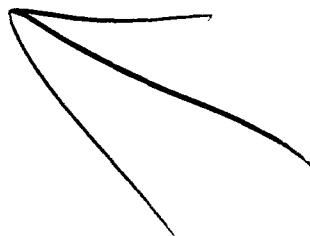
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POTENTIAL USES OF IN VITRO CULTURE OF FRESHWATER MUSSEL
GLOCHIDIA FOR CONSERVATION*

by
Billy G. Isom**

Introduction

LeFevre and Curtis (1912) alluded to advising one of their graduate students to culture glochidia of freshwater mussels. These efforts, which used microscope slides, were not successful. Ellis and Ellis (1926) published a one-page article in Science in which they mentioned having developed an artificial medium for mussel glochidia. In that particular paper they described excising the glochidia from the fish, which undoubtedly contributed to their transformation. Regardless of the success or failure of these early studies, no one has been able to find the chemical formula or procedures of Ellis and Ellis to bring about the artificial culture of freshwater mussels.

When TVA initiated the Cumberlandian Mollusk Conservation Program, a task was submitted on the artificial culture of mussels. The idea behind the work was to develop a process for culturing large numbers of the rare or uncommon species. Since it was assumed that many mussels are host specific for fish, the artificial process could be used if the natural fish host was unavailable or could not be identified. We hoped to develop a universal medium which could work not only on a single species of mussels but would work on all species.

Culturing In an Artificial Medium

We started by studying the biochemistry of the fish and experimented with many techniques commonly used for culturing fish cells in the laboratory. Many of these techniques are fairly well-known and are important in fish genetic studies as well as cancer research. We looked at media developed by Eagle (1959), Earle (1943), Morgan et al. (1950), and Wolf and Quimby (1969). We finally devised a medium which contained all necessary amino acids, vitamins, salts, and antibiotics, and is similar in composition to compounds used in fish cell culture or similar types of studies. The medium also includes fish blood serum which contains a nonspecific component(s) essential for glochidial transformation.

While the medium is complex, the process is relatively simple. The most difficult part is to find a gravid mussel and get it safely back to the laboratory. The female should then be aborted and the glochidia placed in sterile deionized water and rinsed several times. If there is chloride in the water, the glochidia will remain closed and it is impossible to completely remove

* Transcribed from tape; reviewed and revised by author.

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bacteria from them. We do all this work beneath a sterilized Laminar air flow hood, which keeps external contamination out of the medium. Sterile laboratory techniques should be observed at all times. The developing glochidia are kept in a carbon dioxide air incubator, and the pH of the medium is controlled with a carbonate buffer at 7.2-7.3. A refrigerator is used for the medium and other chemical compounds. A refrigerated centrifuge is desirable for this work but not necessary. We also use a tissue culture microscope to observe progress of cultures. It is possible to rear up to a half million glochidia in a two-compartment incubator with no trouble.

The complete paper can be found in Nautilus (Isom and Hudson 1982). See Figure 1 for glochidia photos. If you have any questions or need help in setting up a glochidia culturing process, please do not hesitate to contact us.

Discussion

Question: How do you rear juvenile mussels?

Isom: We take river water and filter it to remove turbellarians and protozoans that are predaceous. For food we use a mixed culture of algae. Our culture system is based on similar systems that are used with marine organisms.

Question: Where do you see the TVA program going from this point?

Isom: Based upon the marine and freshwater literature, we would like to get our juveniles to the 2- to 4-mm stage. At that time they would no longer be preyed upon by protozoans and turbellaria and could be transferred to river water. If we could get transformation of 90 percent of the individuals, and then a third of these to 2- to 4-mm stage, we could be close to getting a population started.

Question: Do you think that rare or endangered species could be used for this project?

Isom: Yes. The medium that is used has been successful on all species that we have tried so far.

Question: Why is there host-specificity for some mussels?

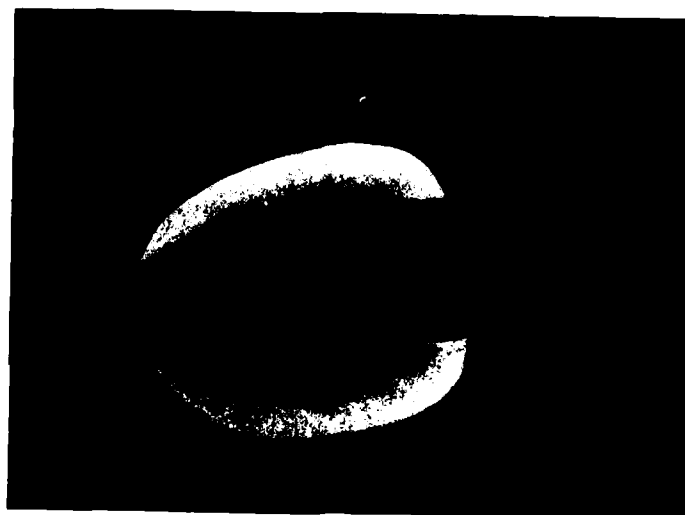
Isom: Based on our laboratory experiments the specific component(s) necessary for transformation is in all fish blood. For example, the pigtoes transformed with the blood serum of the German carp and other fish species. What needs to be done experimentally is to challenge very small fish, of several species that have been raised in a hatchery, with glochidia to see if transformation takes place. I feel that the literature in general indicates that mussels are not host specific. There are simply too many combinations and permutations involved in the host-specificity question to be certain about the implications of many past laboratory host-specificity studies. For example, I know of no one that has ever failed that tried to do a life history study of mussels. That is, everyone finds a fish that will successfully transform glochidia.



a. Ligumia recta (250 ×)



b. Ligumia recta (150 ×)



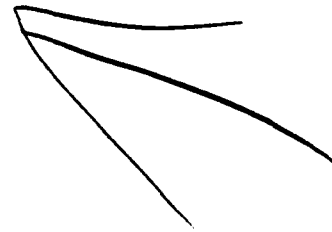
c. Lampsilis ovata (200 ×)

Figure 1. Glochidia of freshwater mussels (pictures taken with scanning electron microscope)

Hart and Fuller summarized glochidia/fish host relationships back in 1974 and they reported multiple hosts, multiple genera, and multiple families. We do know that fish develop immune responses to glochidia and other parasites. For a mollusk conservation program it may be possible to use host fish of any species to get your population started. More work needs to be done to better resolve this important issue.

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SOME SOURCES OF NOMENCLATORIAL AND SYSTEMATIC
PROBLEMS IN UNIONID MOLLUSKS

by

David H. Stansbery*

Introduction

Some time ago I had a layover between flights at the Atlanta airport. I was trying to do some long overdue reading when I was accosted by a toddler armed with a large red apple, a double handful for him. The apple was brought down on my knee with all the force the tyke could muster along with the obvious though garbled demand that I somehow hold forth on the fruit in question. For starters I offered "ap' ple" in my best diction. "Apple!" the youngster cried, "Apple, apple, apple!" banging my knee in perfect time. Then back to his mother down the aisle he proudly proclaimed "apple" in a voice half the waiting room could hear. Mother, obviously pleased with junior's new word, pulled Grandma's attention away from a newspaper and the performance was repeated for all within earshot.

Names are important. Common names are obviously important to all who use them to communicate either orally or through writing. Scientific names are equally important tools of communication--but they are also the symbols we use to express the relationships between the elements and groups of taxa dealt with by biologists and others. Problems arise when one kind of organism is referred to by two or more different names, OR when several different kinds of organisms appear under the same name, OR when an organism dealt with over a span of years under a familiar name suddenly appears under a name which is somewhat or altogether different! How very nice it would be, we muse, if all names were somehow fixed, would never change; if we could get on with biological matters other than systematic problems and their everpresent companion, nomenclatorial changes.

Ignoring these problems will not make them "go away." Wrestling with their symptoms will not solve them and may actually serve as an additional aggravation.

To understand these and related problems it is helpful to review the origin and objectives of our system of zoological classification. Early scholars communicated in Latin, and their descriptions of plants and animals were written in this "universal" language. As the number of recognized organisms grew, the need for a convenient system of reference and classification increased. What was once a descriptive sentence or paragraph in Latin became reduced to a noun, the generic part of the name, followed by a descriptive modifier, the species part of the name. As an aid in finding the original use of this name in the literature, the author of the species and the date of its original

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publication frequently followed. Scientific names were underlined in manuscript so the typesetter would know to set the name in italic type.

Linnaeus may not have invented the binomial system of nomenclature any more than Darwin discovered natural selection, but it was the 10th edition of his Systema Naturae, published in 1758, that was selected as the starting point of our present system of classification. This system has been put to work by successive generations of biologists to accomplish two objectives: (a) to provide a means of storing our growing fund of knowledge about the plants and animals on earth and (b) to provide a means of expressing our best current estimate of the relationships existing between and among these taxa.

The system appears to be capable of achieving both tasks IF species are reproductively discrete (isolated) units, even though morphologically and functionally variable, IF our knowledge of these taxa is complete before classifications are attempted, and IF all human error is avoided. None of these three premises are met, however, and herein lies the origin of nearly all of our systematic and nomenclatorial problems.

It is a curious fact that biologists in general recognize that each of these premises is imperfectly met and yet we demand perfection or near perfection of the classifications that rest upon them. It is not our system of classifying that is faulty. It is rather the extent and complexity of the almost incomprehensible diversity of life on earth that is responsible for most of these problems. Human error can easily account for the rest. I am amazed that our system of classification is as functional as it is considering how little we know about the enormous variability and number of organisms we are attempting to classify.

While the above may explain the problems of systematics in general, what about the unionids in particular? One hears that the so-called "state of the art" in unionid classification is distinctly behind that of zoology in general and that little progress is currently being made in the field. I would disagree on both points. Compared with the vertebrate classes, the classification of unionids is in arrears. This may be due to the relatively few unionid systematists over the years compared to those working on the vertebrates. On the other hand, compared with zoology in general, unionid classification is distinctly above average. Witness such numerous groups as the mites and nematodes, each of which may someday rival the insects in numbers of described species. If progress today seems slow, I would suggest that this slowness is more apparent than real. In moving toward a classification of valid names arranged in a relatively stable system reflecting our current assessment of their relationships, some change is obviously necessary. Progress in systematics means moving through change toward the most stable classification the mechanism of mutation-selection will allow. Accuracy and stability are the goals of systematics.

Any review of current systematic problems in the unionid mollusks would be remiss, however, if it did not admit to difficulties shared with few other animal groups. The morphological variation existing within some of our species is so great as to be unbelievable by researchers in other fields. This polymorphism is frequently correlated with stream size, but a careful comparison of shell form and habitat reveals that this is not always the case.

The morphological clines we observe may be as much, and perhaps as often, due to genetic differences as to environmental influences.

Where the same or different cline occurs from headwaters to mouth in tributary after tributary of the same river system, we treat these forms as a single polymorphic species. Van der Schalie (1941) has proposed that

If for any reason whatsoever one wishes to designate a form [other than taxonomic] it would be more sensible to do so as follows:
Lampsilis siliquoidea form rosacea.

The term ecoform lends itself to those variants that are environmental rather than genetically produced.

In this manner, the described forms Obliquaria flava Rafinesque, 1820; Unio undatus Barnes, 1823; Unio rubiginosus Lea, 1829; Unio trigonus Lea, 1831; and Fusconaia undata wagneri Baker, 1928; are placed in one species, Fusconaia flava (Rafinesque 1820), by many, perhaps most, workers today (Figure 1). This action does not mean that we are certain that all of these forms, presumably ecoforms (Table 1), are in fact one species. It does mean that the evidence to date indicates to most workers that this complex is most probably one species.

New evidence could mean a new inference. The extreme forms undatus and wagneri might, for example, be found to be distinct from Fusconaia flava in certain subtle, yet-to-be-discovered characteristics. In more than one instance we have found that species having distinct, consistently differentiating characteristics in the soft parts actually overlap in shell characters. Putnam (1971) found this to be true of the sibling species Lampsilis ovata (Say 1817) and Lampsilis ventricosa (Barnes 1823). Without soft parts, specimens having shells in the zone of overlap cannot be identified with certainty. All too frequently only the shell is available for determination. This is not necessarily the fault of the collector since an empty shell, carefully considered, is far better than no specimen at all. In any case all of the available evidence is, or should be, taken into careful consideration in arriving at a taxonomic inference.

If all of the several forms of a complex occur together without intergradation, or if they do not occur together at all, we term each form a distinct species. Intergrades are lacking. These very similar "look-alike" species are frequently referred to as sibling species. A good example of this phenomenon is the Pleurobema cordatum complex. It is represented in the Ohio River drainage by four very similar but distinct species (Table 2): Pleurobema sintoxia (Rafinesque 1820), Pleurobema plenum (Lea 1840), Pleurobema cordatum (Rafinesque 1820) and Pleurobema rubrum (Rafinesque 1820) (Figure 2). The recognition of these forms under four different names does not mean that we are certain that they are four distinct species. It does mean that the evidence to date indicates to many, perhaps most, systematists that this complex in the Ohio River system is most probably four distinct species. The same phenotypic results could be theorized as produced by an extreme case of gene linkage as yet unknown in the unionids or elsewhere, sex linkage excepted.

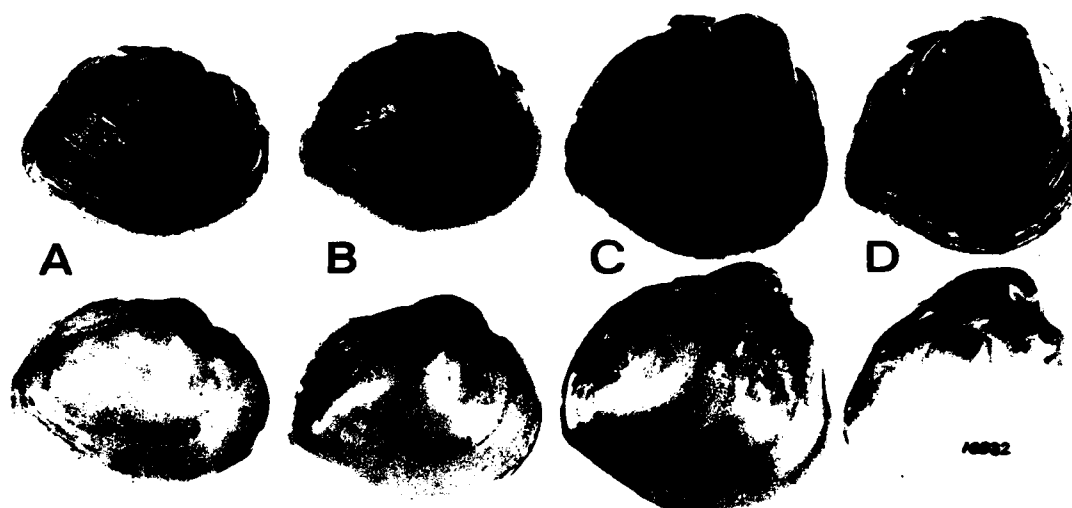


Figure 1. Fusconaia flava (Rafinesque 1820) complex. There are at least six described forms in the F. flava complex. Intermediate intergrading forms are common. The specimens illustrated are from an upstream-downstream cline within the Mississippi River system:

- A. ecoform "flava Rafinesque, 1820," small rivers
 OSUM 15863.8, East Fork Stones River at Brown's Mill, 2.0 mi.
 SSE of Lascassus, Rutherford Co., Tennessee.
 31 August 1965 David H. Stansbery
- B. ecoform "trigona Lea, 1831," medium rivers
 OSUM 15560.11, Stones River above Couchville Pike bridge,
 1.2 mi. W of Couchville, Davidson Co., Tennessee.
 14 October 1965 D. H. Stansbery and J. J. Jenkinson
- C. ecoform "undata Barnes, 1823," large rivers
 OSUM 12076.3, Cumberland River at Dover, Stewart Co., Tennes-
 see.
 summer 1963 Mr. & Mrs. Elbert A. Farless
- D. ecoform "wagneri Baker, 1928," largest rivers
 OSUM 10032, Ohio River at Cincinnati, Hamilton Co., Ohio.
 18 ? collector unknown

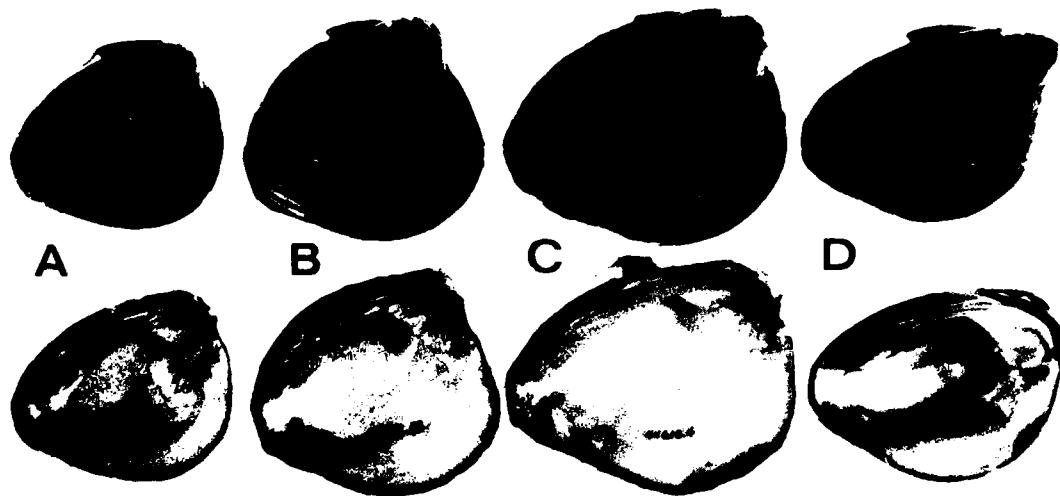


Figure 2. Pleurobema cordatum (Rafinesque 1820) complex. There are at least six sibling species in the cordatum complex. Each species is variable, but intermediate specimens are rare. Four of these sibling species are found in the Green River system of Kentucky.

All specimens illustrated are from a single stream site: Green River at Glenmore, below Lock 5 Dam, 12 mi. N of Bowling Green, Warren Co., Kentucky.

- | | |
|---|--|
| A. <u>Pleurobema sintoxia</u> (Rafinesque 1820).
16 August 1976 | OSUM 39177.3
D. H. Stansbery |
| B. <u>Pleurobema plenum</u> (Lea 1840).
8 October 1969 | OSUM 44402.23
D. H. and H. G. Stansbery |
| C. <u>Pleurobema cordatum</u> (Rafinesque 1820).
21 October 1979 | OSUM 44610.4
D. H. Stansbery, et al. |
| D. <u>Pleurobema rubrum</u> (Rafinesque 1820).
18 August 1971 | OSUM 27166.27
D. H. Stansbery |

Where two or more quite similar yet distinctly different forms are found in different geographic areas with intergrades present only in zones of sympatry, we treat each form as a subspecies. An interesting example is that of the Lampsilis radiata complex which has nearly 40 described names available in the literature. Its range extends from New England west to Lake Superior, south to Texas, and east to Florida. Within this relatively large area are at least nine recognized forms (Figure 3). Although some of these forms are distinct, others of this complex intergrade in zones of sympatry, giving us the following classification (Table 3):

3A Lampsilis radiata hydiana (Lea 1838).

This southwestern subspecies, found in southern Arkansas, Oklahoma, eastern Texas, and Louisiana west of the Mississippi, intergrades with L. r. luteola of the Mississippi midwest.

3B Lampsilis radiata luteola (Lamarck 1819).

This midwestern subspecies is found generally in the Mississippi River drainage, except in southern Arkansas and Louisiana where it intergrades with L. r. hydiana. It is also found in the lower Great Lakes intergrading with L. r. radiata in central Lake Huron to the north and western Lake Ontario to the east. It is absent from the Cumberland and Tennessee River systems of the Appalachian Mountains and Cumberland Plateau.

3C Lampsilis radiata radiata (Gmelin 1791).

This eastern subspecies is found in Atlantic slope streams of the northeast, intergrading with L. r. conspicua to the south in North Carolina and with L. r. luteola to the west in northern New York. Farther north its range extends west to northern Lake Huron and Lake Superior.

3D Lampsilis straminea form claibornensis (Lea 1838).

Long thought to be a distinct species, this form appears to be the upstream ecoform of L. straminea. Its range, limited to gulf coast streams east of the Mississippi River, extends to the Suwannee River system of Florida.

3E Lampsilis straminea form straminea (Conrad 1834).

This form may be the downstream environmental expression of L. straminea. Its range, limited to gulf coast streams east of the Mississippi River, extends through the state of Mississippi into southern Alabama.

3F Lampsilis radiata conspicua (Lea 1872).

This form is tenuously classified as a southern Atlantic slope subspecies of L. radiata. Its known range remains limited to North Carolina, and known examples are few in number.

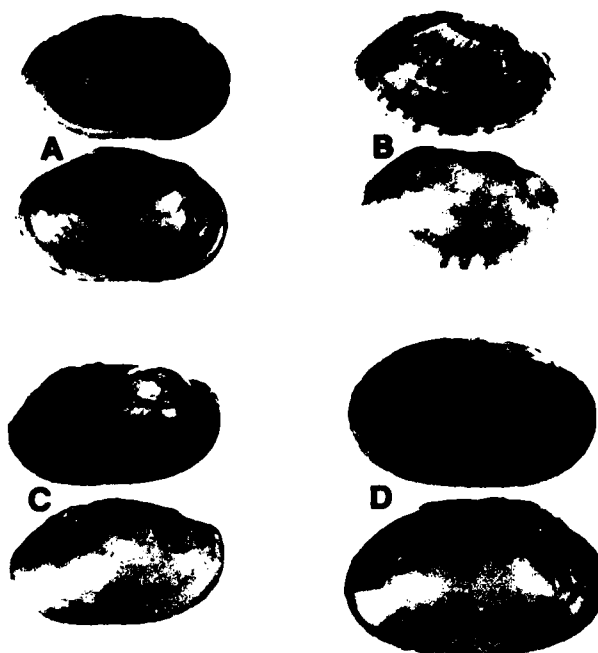


Figure 3. Lampsilis radiata (Gmelin 1791) Complex (continued on p. 53). Nine forms of the Lampsilis radiata complex are recognized here. Those which intergrade in zones of sympatry are classified as subspecies. Those which are distinct and do not intergrade are classified as species. All have a similar shell outline, similar umbonal sculpture, and similar gross morphology of soft parts. They differ primarily in shell color, ray development, texture of periostracum, hinge dentition, and geographical range. All are, however, more similar to each other than to any other such group known.

- A. Lampsilis radiata hydiana (Lea 1838). OSUM 38209, male, "Neches River 14.6 mi. ENE of Lufkin, 2.3 mi. SW of Redtown, Angelina/Houston Co., Texas," 23 September 1972, R. Dale Caldwell collector, length = 73 mm, height = 42 mm, width = 30 mm.
- B. Lampsilis radiata luteola (Lamarck 1819). OSUM 23958.11, male, "Winona Lake, [2.0 mi. SE of Warsaw, Kosciusko Co.], Ind.," 21 July 1933, David T. Jones collector, length = 72 mm, height = 40 mm, width = 28 mm.
- C. Lampsilis radiata radiata (Gmelin 1791). OSUM 10296.1, male (?), "Little Lake, Herkimer Co., N.Y.," 18??, James Lewis collector, length = 74 mm, height = 41 mm, width = 22 mm.
- D. Lampsilis straminea form claibornensis (Lea 1838). OSUM 10591, male, "Pearl River at Sandy Hook, [3±mi. N of Louisiana line, Marion Co.], Mississippi," prior to 1964, Richard Stone collector, length = 86 mm, height = 50 mm, width = 44 mm.

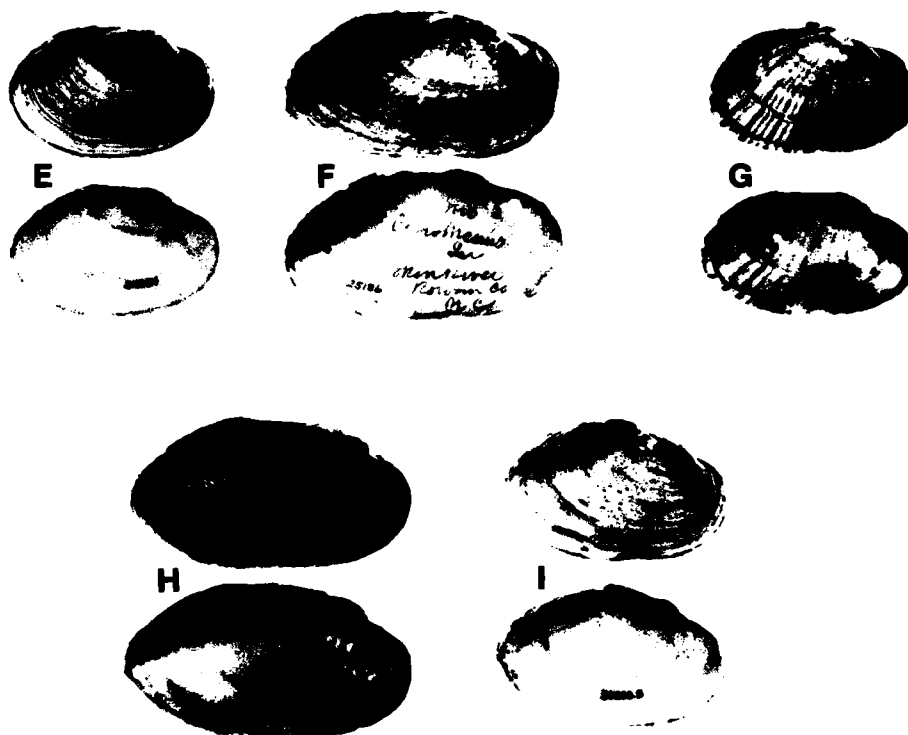


Figure 3. (concluded)

- E. Lampsilis straminea form straminea (Conrad 1834). OSUM 34854, male, "Trib[utary] to Catalpa Cr[ee]k, [1.3 mi. SE of Sessums, 7.7 mi. SE of Starkville], Sec. 23/26, T 18 N, R 15 E, [Oktibbeha Co.], Mississippi," 25 March 1972, via James Williams, length = 73 mm, height = 44 mm, width = 29 mm.
- F. Lampsilis radiata conspicua (Lea 1872). OSUM 25186, male, "Yadkin River, [near Salisbury], Rowan Co., N.C.," 18??, collector unknown, length = 96 mm, height = 50 mm, width = 31 mm.
- G. Lampsilis bracteata (Gould 1855). OSUM 18025, male, Guadalupe River at Kerrville, [Kerr Co.], Texas, 9 June 1967, Chad Murvosh collector, length = 60 mm, height = 35 mm, width = 23 mm.
- H. Lampsilis powelli (Lea 1852). OSUM 21496.4, male, Saline River 3.2 mi. SE of Traskwood, 11 mi. SSE of Benton, Grant/Saline Co., Arkansas, 24 October 1964, Carol B. Stein collector, length = 81 mm, height = 41 mm, width = 30 mm.
- I. Lampsilis virescens (Lea 1858). OSUM 39208.5, male, Estill Fork Paint Rock River at ford 2.9 mi. NNE of Estill Fork, 5.7 mi. SE of Francisco, Jackson Co., Alabama, 1 October 1976, D. H. Stansbery and K. G. Borrer collectors, length = 65 mm, height = 38 mm, width = 24 mm.

3G Lampsilis bracteata (Gould 1855).

This species is apparently restricted to the Brazos and Guadalupe River systems of Texas.

3H Lampsilis powelli (Lea 1852).

This Arkansas species is apparently distinct since intergrades are lacking in collections.

3I Lampsilis virescens (Lea 1858).

This species is known only from the Tennessee River system in eastern Tennessee and northern Alabama.

It should be noted that there are more than a few differences of opinion among unionid systematists. Each systematist brings to his studies his own background of information, experience, and standards. Few unionid systematists working today, or in times past, have had any formal training in systematics, much less unionid systematics. Most became systematists out of a matter of interest and/or necessity and learned both their systematics and a classification of unionids either from the literature or by the apprenticeship method at the elbow of a practicing professional. No one enjoys relearning a procedural system or a classification once it has been mastered. All of us would prefer to retain the information we "grew up with" IF it would allow us to incorporate that which our generation learns along the way. Systematists are in the unhappy position of having the fruits of their labors occasionally disrupt the very system their colleagues use to index and organize our knowledge of life on earth.

The solution to this frustration is neither simple nor perfect, but it is available and should be used. One of the basic rules, perhaps the basic rule, of the International Code of Zoological Nomenclature is known as the "law of priority." The reasons for this "law" are several.

Early on it was found necessary to have some means of deciding which of several available names should be used for a taxon. By selecting the earliest available name and listing all later names for the same taxon as synonyms, it is possible to include in one place all the indices ever used to store information on this taxon. So far this has been the most efficient means yet devised to accomplish this task. It lends itself beautifully to electronic information storage and retrieval. One of the greatest difficulties in the use of this technique is that up-to-date unionid synonymies are generally not available. They are generally not available because of the difficulty of assembling them. One must have a complete or nearly complete library of unionid literature at his or her fingertips. There are probably fewer than a dozen such libraries in the United States. In the absence of an up-to-date index to this literature one must be familiar with who did systematic work on what taxa and when and where it was published. One also needs an intimate familiarity with and understanding of the various morphological forms and their distribution patterns across the range of each complex. Even when the above conditions are met, this is time-consuming, frustrating work and few systematists care to spend their precious research hours in such a pursuit.

But it must be done, and, ideally, it should be done with annotations to aid the user.

It is not necessary, or even desirable, for every researcher to include a synonymy of his experimental animal in nonsystematic publications. This would clutter the literature. Each researcher should, however, use a name currently recognized by a systematist working in his academic area and, if at all possible, he should have this specialist either identify or confirm the identification of the material used.

A further step in adding value to the research paper is to deposit voucher specimens in a permanent museum collection so that the identification can be checked at any time in the future. Scientific names, photographs, written descriptions and collection information all aid in fixing the identity of experimental animals, but the court of last resort should always be the thing itself. Museum collection numbers should be published along with the verified identification and the name of the specialist who verified the identification. These actions will go a long way toward solving our current problems.

We live in the alchemy days of systematics. We have only just begun to understand and organize the diversity of several million species of plants and animals that have taken over a billion years to develop here in the biosphere of the earth. We have no way of knowing when we will reach that degree of systematic and nomenclatorial stability that is our objective. We do, however, have the means of dealing realistically with these problems as they arise. If unionid systematists continue and, we hope, even improve upon their current efforts, our classification will improve gradually over the years ahead. I do not see a royal road to perfection. I do not see any short cuts.

Most of the obvious well-defined species of unionids appear to have been discovered and described. Perhaps the greatest challenge of unionid systematics lies in the future. It may lie in our efforts to identify and differentiate between look-alike sibling species that today pass for one species. It may lie in our finding ways to more easily discern just which phenotypic characteristics of both shell and soft parts are fundamentally due to different genetic composition and which are essentially due to the actions of different environmental factors upon developing organisms having essentially the same genotype. It may lie in our discerning just which phenotypic characteristics are associated with unique genetic materials as opposed to those that are shared among related but different taxa.

Some recent innovations yielding data in these areas include Jenkinson's (1976) work on unionid chromosomes, Calloway and Turner's (1978) studies of glochidial anatomy using electron-scan techniques, and Kokai's investigations (1974, 1976) into interspecific and intraspecific variation of unionid apertural characteristics. Davis and Fuller's (1981) work on the genetic similarity of unionid taxa, including the use of serum-antibody data, holds promise where some classical techniques have fallen short. Ecological studies illustrated by Sickel's (1980) correlation of unionid distribution with substrate composition and the contribution of Horn and Porter (1981) in relating unionid shell shape to environmental factors furnish needed material for systematic studies. Add to the above studies the badly needed records as to just which species or forms are found in which parts of which drainage systems. These

data are made available through the labors and publications of unionid students such as Ahlstedt (1980, 1981), Buchanan (1980), Gordon, Kraemer and Brown (1979), Havlik (1980), Jenkinson and Kokai (1977), Keferl (1981), Murray (1978), Taylor (1980), and others.

These kinds of studies provide the museum collections necessary to serve as foundations for monographic systematic studies such as those by Johnson (1978) and Clarke (1981).

It seems likely that few of the major problems of unionid classification will be solved in the near future. Increased stability will be achieved, however, each time the valid name of a taxon is worked out and put into use; each time a synonymy for a taxon is constructed with care and concern; each time well-documented, carefully preserved material is added to our research collections; each time a paper having new information is published; and each time those interested in the unionid mollusks gather together in the spirit of true cooperation to share what they have learned, and discuss what they would like to learn, about these very interesting though at times frustrating unionid mollusks.

Acknowledgements

I wish to acknowledge the assistance of Kathy G. Borrer and Carol B. Stein in reading the first draft of this paper and in offering a number of helpful suggestions, of A. E. Spreitzer in preparing the illustrations, and of Kathy E. Newman in proofreading and typing the manuscript.

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Table 1
Shell Characteristics of Forms of *Fusconaia flava*
(Rafinesque 1820)

	<u>flava</u> (1A)	<u>trigona</u> (1B)	<u>undata</u> (1C)	<u>wagneri</u> (1D)
Relative height	Very low	Moderately low	Moderately high	Very high
Relative width	Very compressed	Moderately compressed	Moderately wide	Very wide
Umbonal height	Low	Moderately low	Moderately high	High
Posterior ridge	Rounded	Moderately rounded	Moderately sharp	Sharp
Sulcus	Absent	Absent	Scarcely present	Distinct
Outline	Roundly quadrate	Quadrate	Quadrate triangulate	Triangulate

Table 2
Shell Characteristics of Taxa of the *Pleurobena cordatum*
(Rafinesque 1820) Complex

	<u>sintoxia</u> (2A)	<u>plenum</u> (2B)	<u>cordatum</u> (2C)	<u>rubrum</u> (2D)
Outline	Subtriangulate to subrotund	Subtriangulate (isosceles)	Subtriangulate (equilateral)	Subtriangulate (obtuse)
Sulcus	Absent except in old, large-river specimens	Absent except in old, large-river specimens	Prominent	Prominent
Umbonal beaks	Apposed	Apposed	Directed anteriorly	Directed anteriorly
Escutcheon	Moderate	Wide	Narrow	Narrow
Periostracum	Smooth	Cloth-like	Smooth	Smooth
Nacre color	White, pink, orange	White, pink, orange	White, rarely pink	Pink, rarely white

Table 3
Shell Characteristics of Taxa of the Lampsilis radiata (Gmelin 1791) Complex

	<u>hydiana</u> (3A)	<u>luteola</u> (3B)	<u>radiata</u> (3C)	<u>claibornensis</u> (3D)	<u>straminea</u> (3E)	<u>conspicua</u> (3F)	<u>bracteata</u> (3G)	<u>powelli</u> (3H)	<u>virescens</u> (3I)
Periostracum texture	Smooth	Smooth	Cloth-like	Smooth	Corrugate	Cloth-like	Smooth	Smooth	Smooth
Cardinal teeth	Triangulate-heavy	Lamellate, thin	Triangulate-heavy	Triangulate-heavy	Lamellate, thin	Lamellate, thin	Lamellate, thin	Triangulate-heavy	Lamellate, thin
Shell thickness	Thick	Moderate	Moderate	Thick	Moderate	Moderate	Moderate	Moderate	Moderate
Rays	Few, wide-spaced	Numerous	Numerous	Absent	Absent	Numerous	Numerous	Absent	Posterior slope only

RATIONALE FOR AN ARTIFICIALLY PLACED GRAVEL BAR HABITAT
ON THE TOMBIGBEE RIVER*

by

Jack C. Mallory**

Development of the Tennessee-Tombigbee Waterway (TTW) has required a certain amount of stream widening and straightening as well as placing locks and dams at various locations. As most of you know, the Mobile District has received many criticisms and comments concerning the effects of the TTW on mussels as well as other species of aquatic organisms. In fact, Dr. David Stansbery, among others, testified in a court trial some years ago as to the potential harm this project would have on the naiad mussel population. As a result of these comments, the Mobile District became very concerned about aquatic impacts caused by the project. At that time we had a Board of Environmental Consultants working with us. Dean Gerald McLindon from Louisiana State University and a member of the board felt strongly that the District should create some artificial habitat for mussels. He was particularly concerned about mussels which lived in shallow riffle areas, since the project would flood much of that type of habitat. Dean McLindon's concept was pursued by myself and Dr. Dan Nelson who was at the National Laboratory at Oak Ridge and also a member of the Board of Environmental Consultants. We felt that the idea was a good one, but we were concerned that not enough information about the requirements of rare mussels was available to attempt to develop a habitat for them.

A major problem with developing a habitat for mussels in a river such as the Tombigbee is that water velocities must be high enough to keep silt from settling on the substrate, and yet not wash gravel away. Conditions like this occur in most natural rivers, but they could be hard to find in a developed waterway. However, in the fall of 1980 Dr. Jim Williams and Mr. Tom Strekal, then of the FWS in Washington, D. C., and Mr. John Pullium (FWS, Jackson, Mississippi), and I visited some areas along the upper Tombigbee River that we felt could be developed for mussels. We were particularly interested in a minimum-flow release structure that removes water from Columbus Lake at Columbus Lock and Dam. Water from the lake is carried beneath the dam and emptied into the old river channel which rejoins the navigation channel downstream. It occurred to us that here we have the conditions that mussels require. The old river channel below the dam is protected from flood velocities, since the dam will not be overtopped and the emergency spillway is on the other side of the lock. In addition, this channel receives a constant flow of high-quality lake water from the surface of Columbus Lake through the minimum-flow release structure. We believed that gravel could be placed in the area below the out-fall pipe. We could place mussels on the artificial gravel bar if they did not come there naturally.

Since WES is the CE research facility, we approached them for a design plan. A plan for a gravel bar habitat was developed by Dr. Andrew Miller, WES; Dr. Robert King, Central Michigan University; and Mr. Ed Glover, a hydrologist

* Transcribed from tape, reviewed by the author.

** Ecologist, U. S. Army Engineer District, Mobile.

at WES. In all honesty, WES has prepared a plan for bars quite a bit larger than I had originally imagined; however, I believe the plan is workable and impressive.

The Mobile District has to determine construction costs and whether or not funds are available for placement of this habitat. If sufficient funds are available, and I think they will be, then the bars have to be placed in the river channel during a low-flow period. Following this, the bars will either be allowed to seed with mussels naturally, or else common and uncommon mussels can be brought to the habitat from other areas. In addition, we are interested in monitoring the gravel bar and checking on colonization by fishes, aquatic insects, and other invertebrates, as well as the mussels. We feel that this area has tremendous potential as an outdoor laboratory.

If the bars are successful at Columbus, then other bars could be developed at the Aberdeen Lock and Dam which also has a minimum-flow release structure. On a smaller scale, the Canal Section of the TTW has at least half a dozen areas where gravel bar habitats could be placed.

A GRAVEL BAR HABITAT FOR MUSSELS ON THE TOMBIGBEE RIVER
NEAR COLUMBUS, MISSISSIPPI

by

Andrew C. Miller*

Introduction

At the request of the Mobile District, a meeting was held on 13 November 1980 at the WES to discuss the feasibility of scientists at WES developing a plan for an artificially placed gravel bar habitat. The gravel bar habitat would be established in a bendway of the Tombigbee River (river mile 232.9) directly below the minimum-flow release structure in Columbus Dam near Columbus, Mississippi. The site was chosen because it was outside the navigation route for the TTW and it would receive a constant year-round flow of water (200 cfs) from the minimum-flow release structure. In addition, the bendway will be protected from high-water velocities which accompany high discharge in the Tombigbee River. The primary objective of creating the gravel bar habitat was to provide a source of food and cover for riffle-inhabiting species of fish, aquatic insects, and other benthic invertebrates. It was also concluded that this area could be used by many species of naturally occurring mussels.

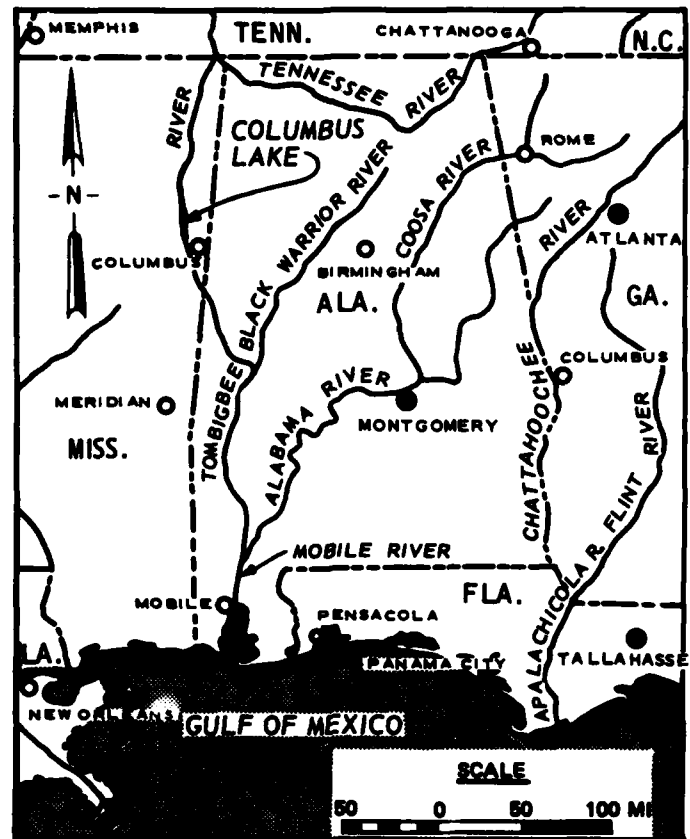
This report presents a proposed design for a gravel habitat consisting of a series of bars and pools to be developed below Columbus Lake at Columbus, Mississippi. The plan includes information on location, recommended substrate types, areal extent, water depths, and velocities for the gravel bar habitat, as well as the types of organisms likely to colonize the habitat.

The Study Area

The Tombigbee River originates in northeastern Mississippi, flows along the eastern portion of the state, then moves into Alabama south of Columbus (Figure 1). It is joined by the Black Warrior River at Demopolis, Alabama, and then by the Alabama River further south. The confluence of the Alabama and Tombigbee Rivers forms the Mobile River, which enters Mobile Bay, an inlet of the Gulf of Mexico.

This is a medium-sized river that experiences frequent and dramatic fluctuations in discharge. For the periods of record (October 1899 to December 1912, August 1928 to current year), discharge at Columbus ranged from 138 cfs to 194,000 cfs; the average for this time period was 6,458 cfs. These changes in water levels were brought about by precipitation which consisted almost entirely of rainfall. In the Columbus area the wettest months are usually December through April; average rainfall for the year is about 54 in.

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VICINITY MAP

Figure 1. Course of the Tombigbee River

On the west side of Columbus Lake is a minimum-flow release structure that directs water from the lake into an isolated bendway that terminates at Columbus Dam (Figures 2 and 3). The structure passes 200 cfs of surface water from the lake and carries it under the dam where it enters a riprapped flume. The lake water then flows down the flume and into the uppermost portion of the bendway. The bendway, which is less than a mile long, was isolated by the placement of the Columbus Dam. The lower end of the bendway connects with the navigation channel about half a mile downriver of the lock structure. When the TTW is complete, navigation traffic will bypass this bendway and move directly to and from the lock. However, fishing and pleasure boats can and probably will move up and down the bendway to the point where flow from the riprapped flume enters.

The only significant source of flowing water in the bendway below Columbus Lake is the minimum-flow release structure located in Columbus Dam. Since the lower end of the bendway connects with the Tombigbee River, water levels in the bendway respond to changes in the river stage. However, because the upper end of the bendway terminates at the lower face of Columbus Dam, there is no continuous flow of Tombigbee River water through the bendway.

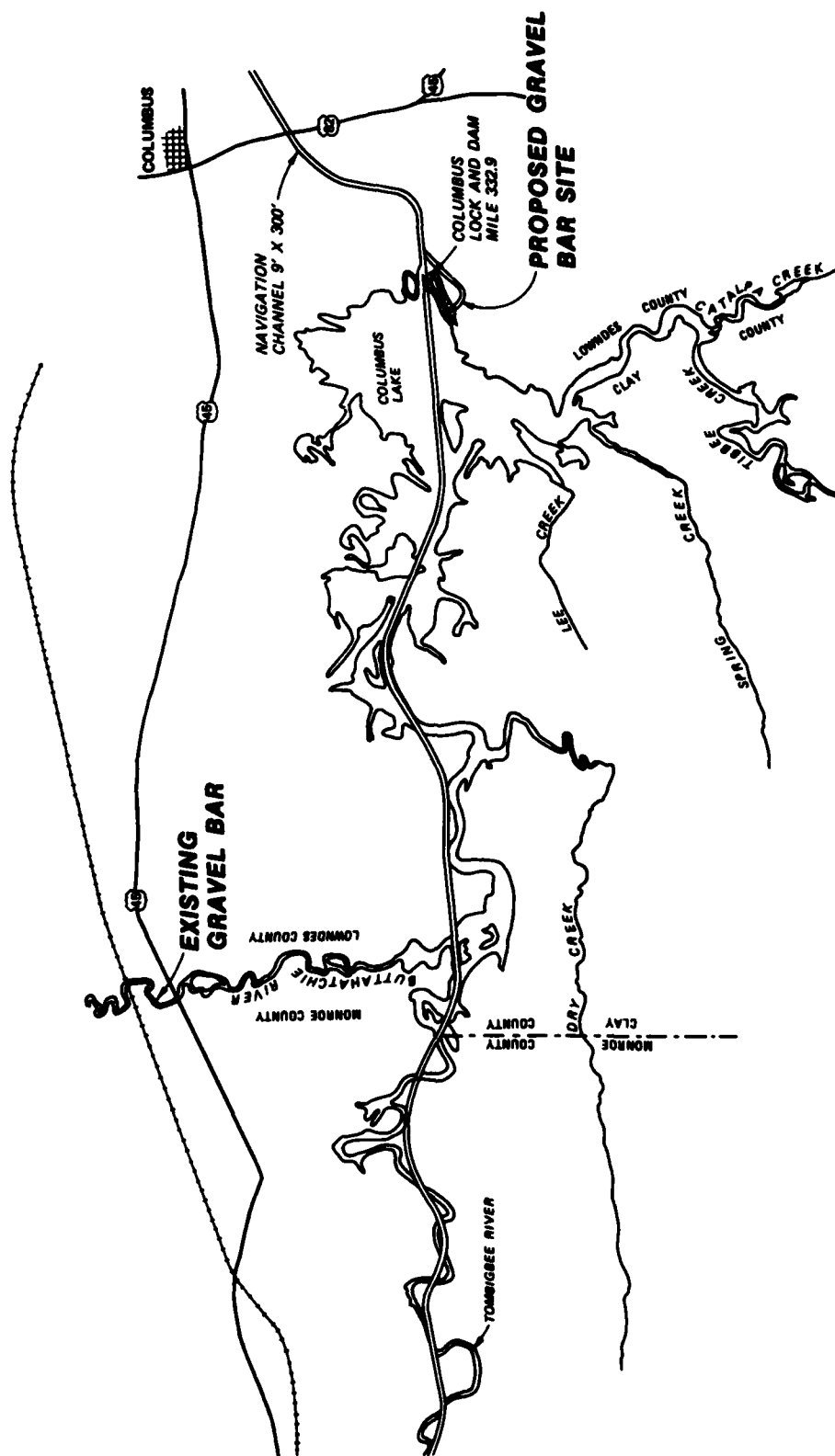


Figure 2. Locations of existing and proposed gravel bars on the TTT



a. Release structure



b. Discharge flowing through riprapped flume into
isolated bendway of the Tombigbee River

Figure 3. Minimum-flow release structure in Columbus Dam
and outfall area below the dam

Design Plans

The first step in construction of the gravel bar complex will be to fill the upper 900 ft of the old bendway (Figure 3b) to an elevation of 130 ft (Figure 4). The required fill material could be any stable mixture of sand or gravel that could be easily obtained and transported to the area. Four distinct gravel bars will then be created by capping the fill material with specific sizes and mixtures of gravel or sand (see Table 1 for specific information on each gravel bar). Each cap of gravel (gravel bar) will be approximately 150 ft long and 170 ft wide (the width of the channel).

The uppermost elevation of each bar will be at 137 ft msl, 1 ft above minimum water levels for this pool. However, a channel will be cut directly through the top of each gravel bar to allow for passage of water. Elevations in each channel will vary among the bars (see Figures 4, 5, and 6) and from side to side within each channel so that at minimum pool water will vary from 1 to 4 ft deep. The constriction of the bendway caused by placement of fill material and the gravel caps will increase the water current across the top of each gravel bar. In bars I, II, and III, the flow will be maintained at 1.5 fps; over the last bar it will be 1.0 fps. These flows will occur in the channels across each gravel bar when the Tombigbee River stage is at or below 136.5 ft.

Between each gravel bar will be a single pool measuring approximately 100 ft in length and 100 ft in width. The bottom elevation in each pool will be at 130 ft msl, which will be the top of the 900-ft length of fill material. It is anticipated that sedimentation will occur in these pools during all conditions of flow in the Tombigbee River. In the unlikely event that these pools fill completely with sediment during high Tombigbee River stages, a channel will always be reestablished by flowing water as stages fall and water is confined. When the river stage exceeds 137 msl, which will occur 60 percent of the time, the entire surface of each gravel bar will be covered with water (Figure 6); the flowing water will no longer be restricted to the narrow channels on the top of each bar. When water flows out of the channels and over the gravel bar surface, the water velocities will decrease in the channels from either 1.5 or 1.0 fps to essentially zero. When this happens, sedimentation will take place; silt and clay particles will settle on the sides of bars and in the channels cut through the top of each bar.

In a natural river, which consists of a series of pools and riffles, gravel bars are usually located in the center of the channel. At low or normal flow, the center of the bar is exposed and water flows along one or both sides of the exposed gravel. During periods of high water, fish and other motile organisms can swim over the entire area; however, at low flow, mussels and other organisms live in the shallow, flowing water to the side of the bars. In the habitat complex designed for the Tombigbee River, the area receiving continuous flow is at the center of the bar, in the channels. These channels will always contain water; they will provide habitat for mussels and other

* The channel across each bar will provide habitat for mussels and other aquatic organisms.

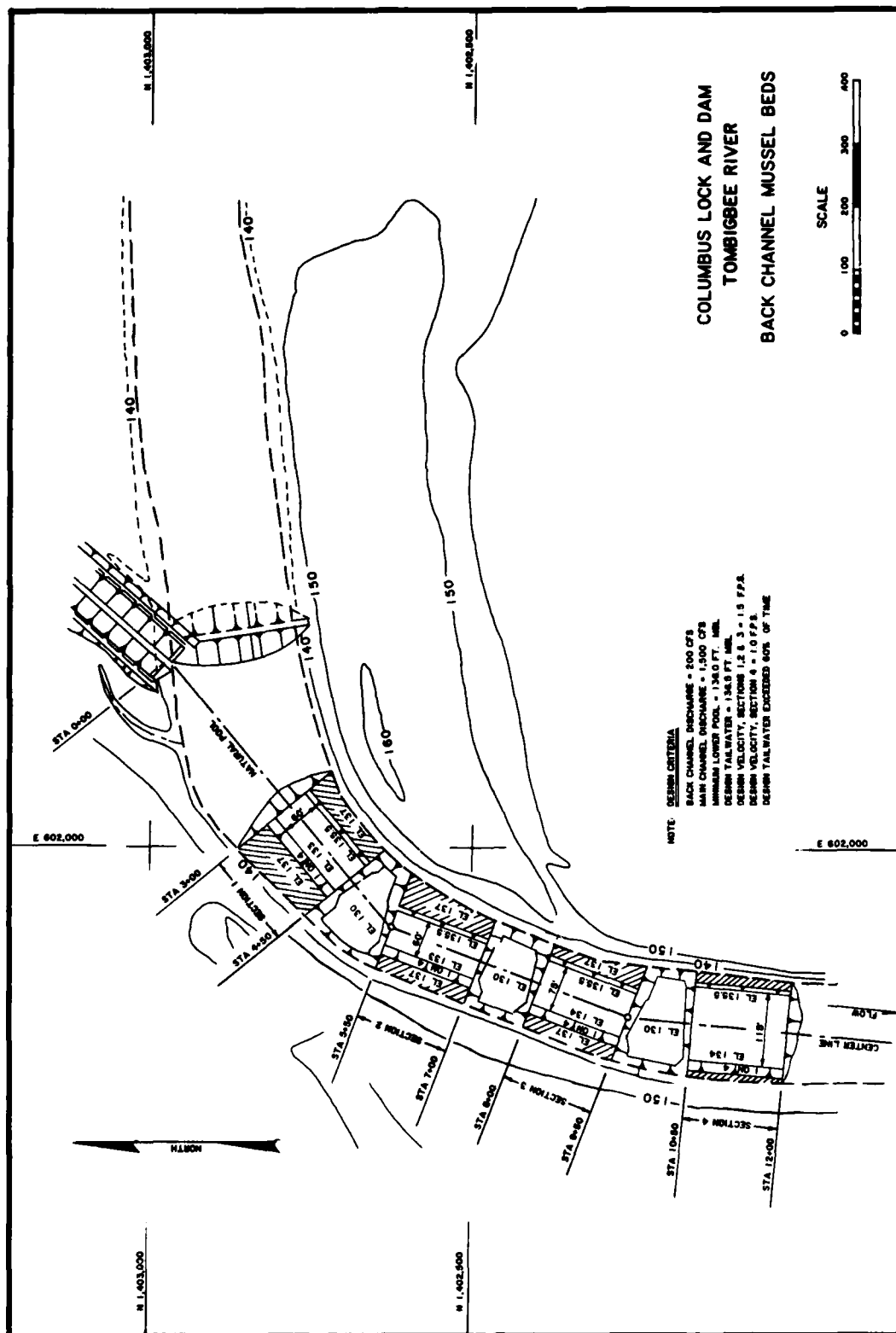


Figure 4. Design plans for proposed gravel bars, to be located at sections 1 through 4 of the bendway on the Tombigbee River

Table 1
Physical Characteristics of Proposed Gravel Bar Habitat

Parameter	Description			
	Bar I	Bar II	Bar III	Bar IV
Bar length, ft	150	150	150	150
Bar width, ft	175	175	175	175
Channel width, ft	60	60	75	115
Channel depth, ft	1.5-3.9	1.5-3.9	1.5-2.9	1.5-2.9
Gravel depth, in. (% composition)	1-5 (80)	1-3 (60)	1-3 (40)	1-3 (20)
Sand, % composition	20	40	60	80
Water velocity, fps	1.5	1.5	1.5	1.0

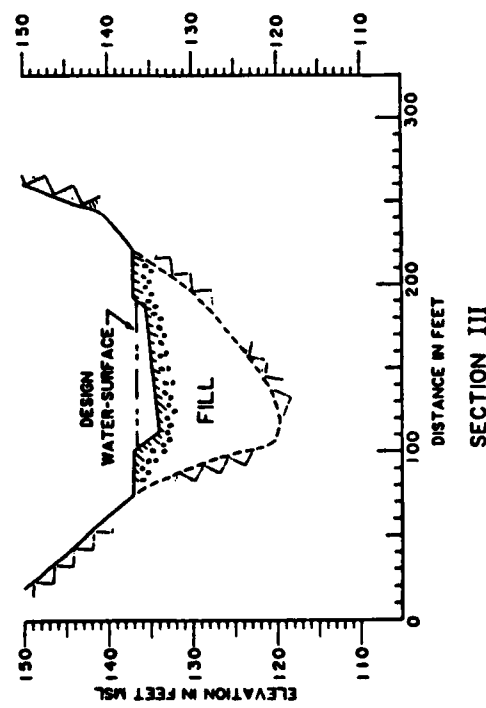
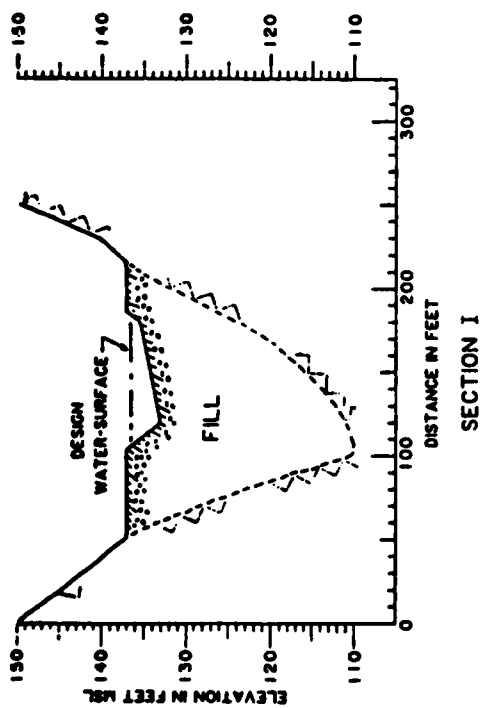
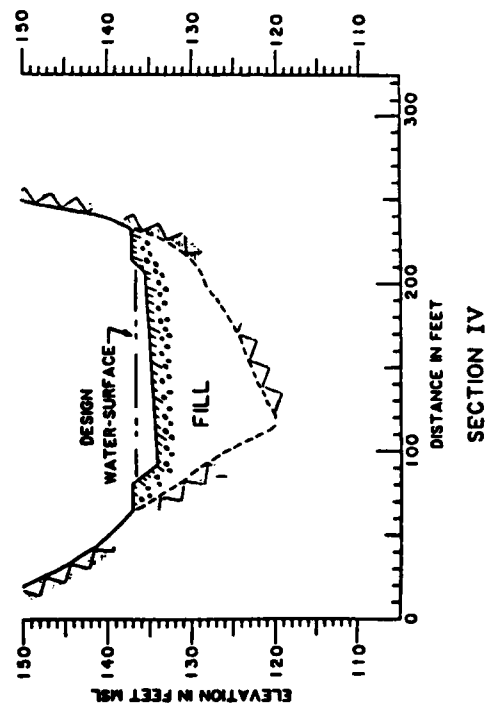
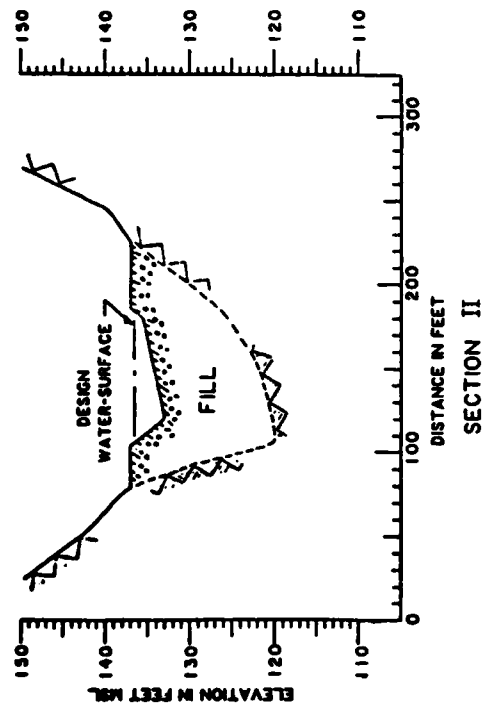


Figure 5. Transverse sections of proposed gravel bars



High Water

Low Water

Figure 6. Artist's conception of the response of bars I and II to conditions of high water (little or no flow) and normal-to-low water (water restricted to the channel across the bar). Mussels and other nonmotile organisms will inhabit the channels (visible at low water) across the gravel bar

aquatic species, regardless of river stage. However, if mussels and other nonmotile species migrate out of the channels and onto the surface of the bars during periods of high water, they very likely will perish when the water recedes. Therefore, it is recommended that large boulders be placed along on the surface of the bars outside of the channels. Large-diameter rock will provide sites of cover for small fish and will discourage lateral movement of unionid mollusks.

When the river stage drops to 136.5 ft msl or lower, the flow over bars I-III will increase to 1.5 fps and to 1.0 fps over bar IV. Based upon a discussion in Vanoni (1975), a flow of 1.5 fps will erode previously settled clay particles. This flow will be sufficient to remove silt or clay from the substrate but will not disturb the gravel or sand/gravel mixtures in each channel across the bar. At bar IV the flow will be 1.0 fps, so some previously deposited silt or clay may not be eroded from the channel. However, as material deposits in the channel at bar IV, constriction will take place and current velocities will increase. Ultimately, an equilibrium between deposition and erosion will exist in the channel at gravel bar IV; water velocities will probably range between 1.0 and 1.5 fps.

It is anticipated that the minimum-flow release structure will always be in operation; if it should be shut down for maintenance or other purposes, flow will cease across the tops of the bars. Sediments will settle that will have to be eroded away when the minimum-flow release structure is again in operation.

Water Temperature

Upper lethal limits of water temperature for certain mussels have been reported to vary with species (Salbenblatt and Edgar 1964); based on data by Matteson (1955), it would appear that water temperatures in the 30's (centigrade) could be harmful to some mussels. Since the minimum-flow release structure removes surface water only from Columbus Lake, there is a chance that water temperatures may be higher than typically riverine levels during July and August. However, mussels successfully inhabit man-made and natural lakes and ponds throughout the South, so there probably will not be a problem caused by water temperatures. Based on previous studies, summer maximum water temperatures in the Buttahatchie were about 30°C and in the Tombigbee River reached no more than 31°C (Howell et al. 1978). In addition, waters below Gainesville Lock and Dam on the Tombigbee River (Ming and Sedberry 1979) did not exceed 29°C.

Colonization

Colonization of any area by mussels requires the presence of host fish or fishes suitably infected with immature forms known as glochidia. It was determined that host fish are present in this section of the river for the majority of the common Tombigbee River mussels (Pennington et al. 1981). In addition, three species of unionids were taken from natural rock substrate

samplers placed in the old bendway in 1981. It is very likely that mussels will be able to naturally colonize artificially placed gravel bars in the area. This does not, however, preclude the possibility of artificially introducing either common or uncommon mussels to this site.

Sedimentation

This pool-gravel bar complex has been designed so that deposited sediments will be swept clean of the substrate when water levels are below 136.5 ft msl. All bottom-dwelling organisms that live on the gravel in the channels of these bars will have to be able to tolerate brief periods of sediment accumulation when slack-water conditions exist. To a certain extent, these conditions normally occur in all natural rivers. The periodic accumulation and removal of suspended material in a river is tolerated by many species. For example, Matteson (1955) pointed out that the lighter thin-shelled species (Anodonta, Leptodea) are more able to burrow out of deposited sediment than the heavier thick-shelled species. Ellis (1936) found that the sand-inhabiting species Lampsilis teres was most readily killed by silt, while the thicker shelled Obliquaria reflexa, Quadrula quadrula, and Q. metanevra were most resistant. It is anticipated that the organisms which colonize the habitat will be able to tolerate frequent periods of sediment accumulations as they do under natural conditions. In general, it is anticipated that the thicker shelled species will be found in the channels where the water velocities are higher and the thinner shelled mussels will be found in the intervening pools.

Corbicula

The Asian clam Corbicula was introduced into this country from the Orient in the 1930's. Since that time this clam has spread throughout much of the United States. Fuller and Imlay (1976) and Vidrine and Bereza (1976) have observed that Corbicula frequently invades disturbed or altered areas. Presumably, newly placed gravel bar habitat could qualify as a disturbed area and could support large numbers of Corbicula. The major concern is that this species could out-compete all other unionid mussels. However, it is hoped that Corbicula will not reach nuisance levels throughout the entire gravel bar habitat since the design plan calls for a diversity of depths, substrate types, and flow.

Relocating Mussels

As described earlier, certain species of mussels will probably naturally colonize the habitat. Relocating certain species from nearby tributary streams should also be considered. This is a fairly easy and inexpensive process. Special attention should be paid to the status review species Dysnomia (= Epioblasma) penita, which exists in fairly high numbers in the Buttahatchie River.

Value of Monitoring the Bars

Because of the experimental nature of this work and its potential for use in other areas of the country, some attention should be given to periodically measuring the success of the gravel bar habitat once it is in place. This would not require a detailed or lengthy study; however, two points are very important: (a) the hydrologic success of the bar and (b) colonization rates by aquatic invertebrates. The first item can be assessed by measuring water depths, velocities, and composition of substrates at various time periods following placement of the habitat system. Colonization rates and community structure in various parts of the bar can be measured by taking a series of quantitative benthic samples at regular time intervals for a year or more after the bars are in place. Long-term monitoring (for a period up to 10 years) would be necessary to judge the success of this habitat for mussels.

Summary

A design for a series of four separate gravel bars with intervening slack water pools was prepared for possible placement in a bendway of the Tombigbee River at river mile 232.9 below Columbus Lake near Columbus, Mississippi. The proposed design for this habitat complex was based upon biological, physical, and chemical studies on the Buttahatchie and Tombigbee rivers. The habitat will provide proper substrate, sources of food and cover for common and uncommon mussels and other aquatic invertebrates and vertebrates. The area for placement is out of the main navigation channel of the Tombigbee River and directly below a minimum-flow release structure located in Columbus Dam. The release structure passes 200 cfs into the upper end of the bendway. Lake water will be able to flow over the habitat complex, then down the bendway to the main navigation route on the Tombigbee River.

The gravel bars will be constructed by partially filling the upper part of the bendway at four sites with various sizes and mixtures of sand and gravel. Across the top of each gravel bar, a small channel will be cut which varies in depth from 1.5 to 4 ft and in width from 60 to 115 ft. By constricting the bendway with gravel, the river velocity will be substantially increased in these areas. The water which moves across the first three bars will be flowing at a rate of about 1.5 fps. At the fourth bar, the channel will be wider than the first three and velocities will be about 1.0 fps. It was determined that velocities of 1.5 fps would be sufficient to clear the substrate of settled sediments. The channel over the fourth bar should experience some buildup of sediments; however, equilibrium conditions should develop quickly and water levels will probably increase and remove excess sediment. Sediment will be deposited on the gravel bars during periods of high water (greater than 136.5 ft msl) when there is backflow from the Tombigbee River. During these periods, the entire surface of each bar will be inundated and flow will be virtually nonexistent. At low-flow conditions, water will be retained in the channels on the bars; velocities will achieve 1.0 or 1.5 fps, and excessive sediments will be eroded away from the sand and gravel substrate.

The gravel bars will be approximately 175 ft wide and 150 ft long. To achieve the maximum habitat diversity, each bar will have a unique composition of substrate material. The pools between the gravel bars will have water depths no greater than 5 ft. The bottom can consist of sand or a mixture of sand and gravel initially, but after sedimentation takes place the bottom of the pools will consist mainly of silt and other settled solids.

Each portion of the habitat has been designed to be suitable for specific species of aquatic organisms. Those intolerant of slack water will be able to exist in the channels on top of the gravel bars; species able to tolerate soft substrate and little or no flow should find suitable areas in the pools between the gravel bars.

Discussion

Comment: Is the Mobile District building the gravel bar to mitigate for lost habitat under the Fish and Wildlife Coordination Act (FWCA)?

Response by Jack Mallory: As a biologist working for the Mobile District, it is my job to help design the waterway to reduce adverse impacts to fish and wildlife. With development of the waterway, the diversity of the original riverine system has been reduced; this gravel bar project will increase the value of the overall habitat for a variety of aquatic species. When Congress authorized this project in 1946, there were no funds for fish and wildlife mitigation. Currently, we are developing a mitigation plan to present to the Congress. This artificial gravel bar project is independent of the plan.

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STATUS REPORT ON THE TENNESSEE VALLEY AUTHORITY
CUMBERLANDIAN MOLLUSK CONSERVATION PROGRAM

by
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Introduction

At the previous CE-sponsored Mussel Workshop, I presented the evolution and description of the Cumberlandian Mollusk Conservation Program (CMCP) being conducted by the TVA (Jenkinson 1982b). This report describes what has been accomplished by the CMCP staff since May 1981 and our plans for future work. No attempt will be made here to cover the details of our various accomplishments because several extensive CMCP research reports are to be published early in 1983.

Early in its development, the CMCP was organized into two broad sequences of activities: (a) a group of nine research phase activities which would be completed first and (b) an undetermined number of conservation phase activities designed to implement the recommendations of the research activities. Both phases of this program have the common goal of contributing to the survival and enhancement of Cumberlandian freshwater mussels (and other aquatic species) which exist in the Tennessee River system. The primary focus (and raison d'etre) of this program has always been the two endangered freshwater mussel species (Conradilla caelata and Quadrula intermedia) that persist in the proposed impoundment pool of Columbia Reservoir on the Duck River in middle Tennessee.

Research Phase Activities

Most of the research phase activities of this program were started in 1980 and were proposed to be completed by October 1982. The field work has met that schedule, but data analysis, and particularly report preparation, are behind schedule by a few months. The current status of each research phase activity is presented in the following paragraphs.

Float surveys of Tennessee Valley streams to examine freshwater mussel populations were discontinued in 1981 after approximately 650 miles of streams had been covered. Two of the individual stream surveys have been reported in the literature (Ahlstedt 1982; Ahlstedt, in press); and the data have been used to update recommendations about proposed endangered or threatened species (Jenkinson 1982a). A composite activity report is in preparation.

Data from fish surveys of selected stream reaches completed in 1980 have been used to compile a list of potential Cumberlandian mussel fish hosts. The

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draft report describing this activity is now being edited and should be published soon.

Actual determination of the fish hosts for Cumberlandian mussel species, using experimental infection of fishes with glochidia, was anticipated to continue for several years. To date, this activity staff has identified hosts for Carunculina moesta (Lea 1841) [= Toxolasma lividus lividus (Rafinesque 1820)], Conradilla caelata (both reported in Jenkinson 1982b) and now for Quadrula cylindrica (the whitetail shiner, Notropis galacturus). This activity will continue, with probable emphasis in 1983 directed to Quadrula intermedia.

Experiments intended to perfect an artificial culture medium have been successful (see Isom report, this volume). This procedure is in the process of being patented and is available for public use.

Field work on the four research phase activities designed to study mussel habitats or apparently suitable transplant sites (Figure 1) has been completed, as has much of the analysis. Draft reports on each of these activities are being edited prior to publication. The monumental data base created during these multidisciplinary studies of fifteen short stream reaches has been computerized and is available for use in many types of ecological analyses.

The final activity in the research phase was to integrate all of the accumulated information in the process of characterizing the habitats of the Cumberlandian species and to select suitable transplant sites for Conradilla caelata, the endangered species abundant in the Duck River. The selection of transplant sites has been completed; however, the habitat characterization analysis is just beginning. The draft report describing the transplant site selection analysis will be augmented with the habitat characterization work before it is published.

Conservation Phase Activities

The conservation activity included in this program from the beginning was the transplantation of Conradilla caelata from the Duck River to suitable sites outside the proposed impoundment area of Columbia Reservoir. Transplant sites were selected as a part of the research phase outputs, the selections were approved by the interagency Coordination Committee and the FWS Permit Office. Actual transplanting of C. caelata specimens began early in October 1982. Up to 1000 are to be placed at each of four transplant sites located on different streams without natural populations of this species (Figure 1). Semiannual subsampling of each uniformly distributed transplant population, with eventual searches for naturally spawned juveniles, will indicate whether these efforts will have succeeded in reestablishing C. caelata in these streams.

A new conservation phase activity, made possible by the successful development of an artificial culture medium, will study the habitat preferences and ecological relationships of newly transformed juvenile mussels. This part of the mussel life cycle has been extremely difficult to observe in nature, but speculation (summarized in Fuller 1974:220-221) and some recent research (Bauer

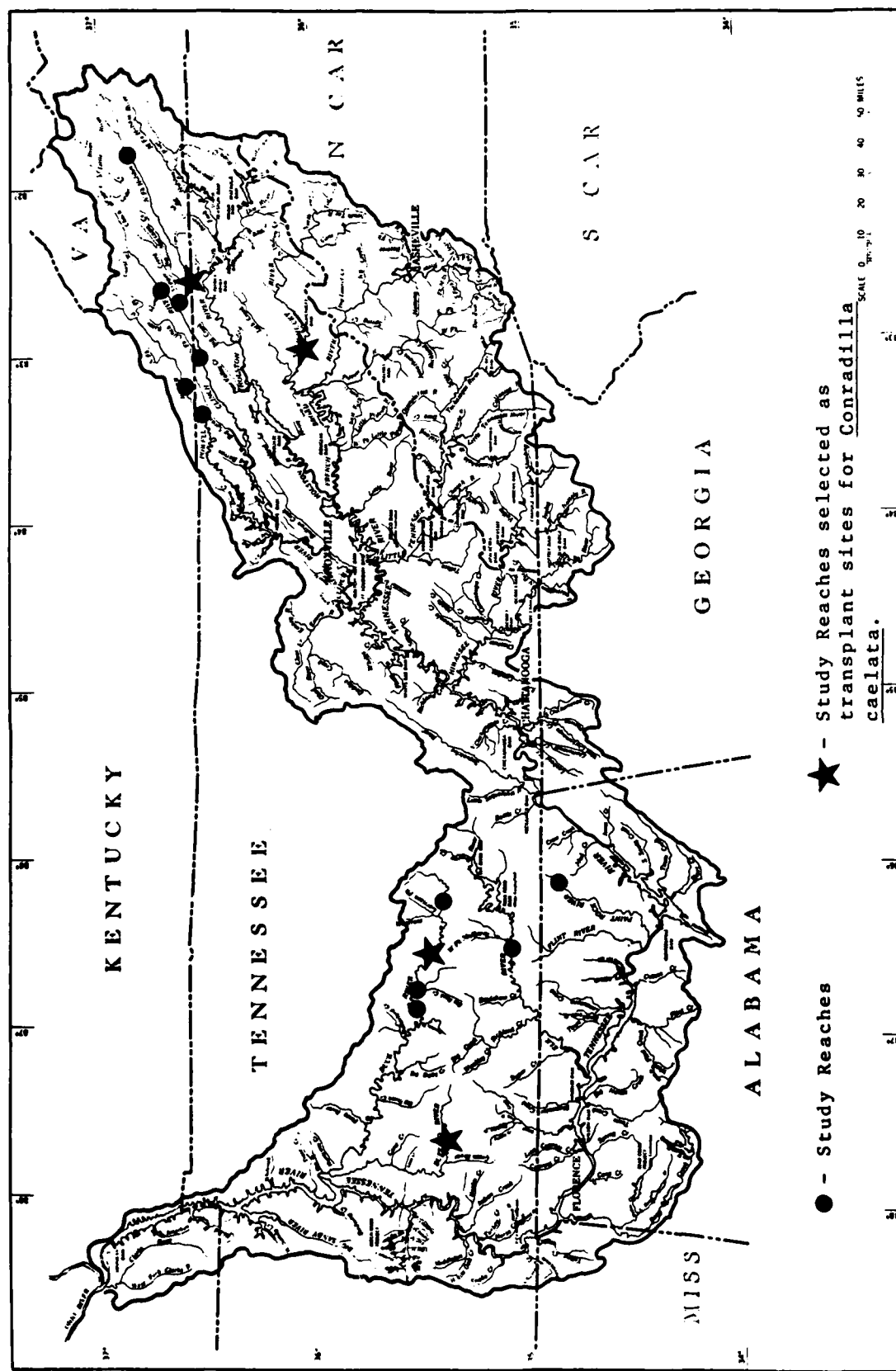


Figure 1. Tennessee River drainage basin showing the locations of the fifteen study reaches examined as part of the CMCP (the four reaches to which *Conradilla caelata* was transplanted during the fall of 1982 are indicated by stars)

et al. 1980) suggest that unique ecological relationships of young mussels may control recruitment.

Other conservation phase activities still have not been planned in detail, largely because the habitat characterization and habitat enhancement analyses are not complete. Two related mussel habitat improvement activities are being organized: one to evaluate and, possibly, to install structural devices; the other to evaluate and implement nonstructural improvements to watersheds. The full range of possibilities from low-dam construction to no-till farming, reforestation, and encouraging present law enforcement is still being considered in our effort to enhance the Cumberlandian fauna.

We are also beginning to plan for the two times when Columbia Dam will impound portions of the Duck River. A salvage operations activity is being formed to explore ways to transplant, or make the best biological use of, the stream-dwelling animals that will be affected when the third-stage diversion pool and, eventually, the full pool of Columbia Reservoir are filled. It would be virtually impossible to transplant all of the stream biota or even all of the mollusks that exist in 54 miles of the Duck River. However, some of these organisms could be salvaged and others could be used to benefit various biological sciences as the subjects of experiments which might not be appropriate for persistent natural communities. We would welcome inquiries and ideas about possible preimpoundment activities.

Cumberlandian Mollusk Conservation Program Summary

The CMCP is still in existence and is beginning to accomplish its purposes. Many of the research phase activities are nearing completion, and the conservation phase activities are taking shape. Current mussel populations have been assessed, some fish hosts have been identified, and an artificial culture medium has been (re)discovered. The large and varied data sets that have been collected have been used to select transplant sites for Conradilla caelata, are in the process of being used to characterize and enhance mussel habitats, and are available for other ecological analyses. Much of this information is being assembled in reports which, in the near future, will be available to interested malacologists and many others. This program has been successful so far because it has been a rare blending of competent people, good ideas, adequate funding, and luck. Let's hope the components stay together until the job is completed.

Discussion

Question: Why was the transplant to the North Fork Holston River made in Tennessee and not in Virginia where the study reach was located?

Jenkinson: In any project there are both biological and political considerations. There was a political consideration that entered into that decision. The transplant site is 1.6 miles downstream from the study reach and, from the biological point of view, is nearly identical to the study reach.

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COMMENTS ON THE COMMERCIAL SHELL INDUSTRY,
PAST AND PRESENT

by

James L. Peach*

Uses of Mussels

This paper discusses the following topics:

→ Mussel for food;

The harvest of freshwater mussel shells in the United States has been very important to its inhabitants for hundreds of years. The American Indians savored the unpolluted mussel for food, and the natural pearls found in the mussels as gems of great value. Natural pearls have been found in burial mounds dating back hundreds of years.

More recently, the University of Tennessee did a study on mussels from the Tennessee and Cumberland Rivers with the Megaloniaias gigantea, to determine if this mussel was indeed suitable for human consumption. The final report concluded that this mussel was edible when properly prepared.

→ Mussel shells for pearl button production;

One of the largest uses for the pearly mussel shell in the 1800's and the mid 1900's was the production of mother-of-pearl buttons for use on all types of garments. During this period, pearl button factories could be found in many areas of the country, with the pearl button capital of the world being Muscatine, Iowa. With the invention of plastics, the demand for pearl buttons from mussels dropped dramatically. Until today, the use of mussel shell for pearl buttons had become almost nonexistent.

→ Mussel shells for pearl culturing;

About the time that the button industry was converting to plastics for buttons, a new market was developing. Mikimoto of Japan had discovered a process for growing fine cultured pearls, and after some years it was determined that some species of pearly mussels from the United States were the most ideal for the culturing process. The process required spherical beads of fine quality mother-of-pearl. The Japanese produced the beads by slicing mussel shells, cubing the slices, then pressure grinding and polishing these cubes into perfectly round mother-of-pearl beads. These beads are surgically implanted into the pearly oyster or other pearly mollusks. The mollusk then coats the beads with layer after layer of nacre and forms cultured pearls. The demand for mussel shell for the cultured pearl industry in Japan peaked in 1966-1967 when approximately 25,000 tons of mussel shell was exported to Japan. The export quantities currently to Japan will fluctuate from 4,000 to 6,000 short tons per year.

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On the horizon is the use of the pearly mussel shell in the culturing of both nucleated and non-nucleated pearls in the United States; the non-nucleated process uses the mussel tissue and the nucleated uses the round mother-of-pearl beads. Pearls of America, Inc. of Ft. Worth, Texas, and Tennessee Shell Company of Camden, Tennessee, have piloted programs which have been successful with plans for expansion in this area of pearl culturing.

Mussel shells for jewelry production

Recently, mussel shells of the pink, purple, and lavender varieties have been used in the manufacture of fine costume jewelry. This requires the cutting of calibrated shapes from the shell itself and polishing to a high lustre, then setting them into various types of jewelry. This is an important commercial activity, but the required quantity of material is less than 25 tons per year.

American Freshwater Mussel Shells for Jewelry and Medicinal Purposes

Freshwater mussel shell pearls for jewelry

Fine quality natural pearls have been found in the pearly mussel for hundreds of years. Even at the present, a small industry exists in this country whereby the irregular shaped natural pearls are made into all types of jewelry using both silver and gold.

Freshwater mussel shell pearls for medicinal purposes

Small-size natural pearls have been used for centuries by the Chinese for medicinal purposes. This requires that the pearl be made into powder form and taken internally. The Chinese contend that this will cure a number of ills, even though the content of the pearl is basically calcium carbonate.

Methods of Shell Harvesting

Diving versus brailing

The primary method of harvesting mussel shells commercially is with divers using surface-supplied air or SCUBA equipment. These divers normally harvest shells in zero-visibility waters by extending their hands in a circular manner to locate the shells and placing the shells into a container which is lifted to the surface.

Brailing

Another method less commonly used today is called brailing. The brail bars normally range from 12 to 20 ft in length, having numerous chains hanging vertically with from 5 to 7 mussel hooks attached. These brails are dropped to the bottom and dragged downstream. When the hooks pass through the opening of the mussel, the mussel closes and hangs on tightly. After the brailer has dragged the brails until he believes that he has some quantity of shell, the

brails are lifted to the surface where the mussels are forcibly removed from the mussel hooks. It should be pointed out that some states only permit the taking of mussels using the brail method; however, the writer believes that diving is more effective and more feasible for the harvest of mussels because it conserves both the natural resource and the production cost. Divers can be very discriminating in harvesting shell, leaving the young shell and shells of no commercial value undisturbed on the bottom; on the other hand, the brail method harvests all types of shell, both big and small. Normally when the mussel is removed from the mussel hook, it is damaged and may die, even though it has no value commercially.

Handpicking

Handpicking is commonly used, especially by youngsters and elderly people. This method normally involves the searching for shell with one's hands or feet and then picking up to retrieve the shell. Of course, this is only effective in shallow water.

Dredging

In past years, dredging was commonly used in many states, although currently this method is not practiced except in a very few states. Dredging can be highly productive in shell beds that have large quantities of mussels, however, statistics have shown that this method is very destructive to the habitat of the mussels and destroys small shell as well as other types of shell that have no commercial value.

The writer has opposed the use of dredging for commercial harvest for many years. However, for experimental sampling done on a small scale, this is perhaps still a viable technique.

Tongs

Tongs similar to the oyster tongs used in the commercial harvest of oysters are still used occasionally in Arkansas. However, this method is not very effective and, because of the great labor involved in harvesting, it is not of much significance. Tongs, like the dredge, can be very damaging to the mussel's habitat because of destruction of young shell and other shells of no commercial value.

→ and Mussel Shell Processing.

Steaming, tumbling, grading, and packaging

After mussel shells are harvested, they are normally brought to a central buying station. At this point, they are placed in large vats and covered with tarpaulin, plastic, etc. Then a burner is placed underneath the vat. This heats the water in the vat and creates steam that causes the mussels to open and the mussels to retract from the shell. After steaming for about 1 to 2 hours, the mussels are thrown onto a rotating tumbler that knocks the meat from the shell. The shell then falls onto a conveyor where the bad-quality

shells are removed. After this, the shells fall into a sacker where they are sacked into 175- to 200-lb bags which are sewn tightly and placed into 40-ft containers for export to Japan. See Figure 1 for photos.

Impact of Impounded Lakes on Commercial Industry

It should be pointed out that most shells that are consumed commercially are found in impounded lakes. The commercial varieties of shell, specifically the washboard (Meglonaias gigantea), mapleleaf (Quadrula quadrula), threeridge (Amblema costata), thrive extremely well in these impounded areas, as well as other shells of less significance commercially such as the pimpleback, three-horn, pigtoe, and ebony shell.

Prospects for future commercial quantities of shell are very bright. In fact, because of the great number of impounded waters in this country, there should never be a shortage of commercially valuable shell. Another point of interest is that the quality of the mussel shells found in impounded waters is generally much higher, so the yield of shell beads is greatly enhanced.

We appreciate the opportunity of cooperating with the CE concerning mussels and pledge to cooperate and support them in the future.

Discussion

Question: What species are used for the pink jewelry?

Response by Dr. Harold Murray: Two species, Proptera purpurata and Cyrtonaias tampecoensis tampecoensis.

Peach: Also the purple pimpleback.

Question: How much per ton do you pay for shells?

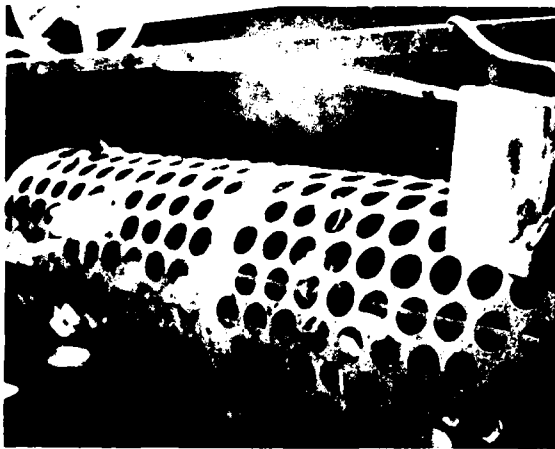
Peach: Anywhere from \$300/ton to \$1200/ton for clean shells.

Question: What is the status of the pollution problem in Japan that was hurting the industry some years ago?

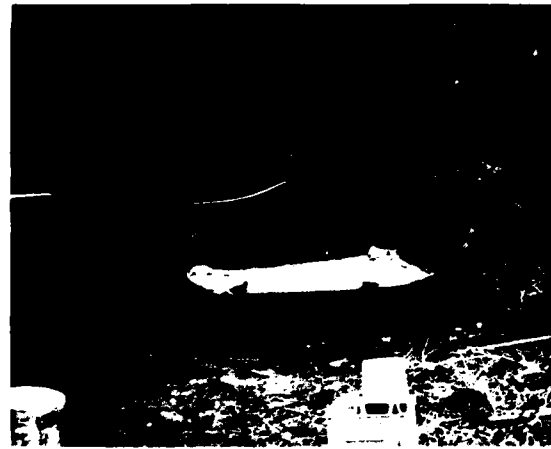
Peach: Those problems are difficult to solve, but they are trying. Eventually it is going to be difficult to raise mussels in that region.

Question: How discriminating are the operators at processing plants in accepting species that are endangered?

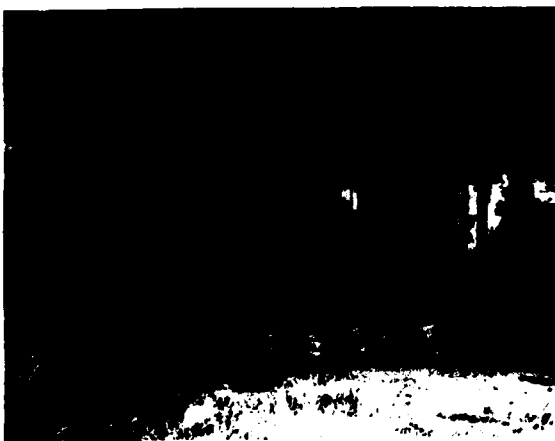
Peach: Generally very few endangered species get to processing plants. The pink mucket is often a problem, since this species is often found in areas where there are commercially valuable shells. Usually in good shell-producing areas, we have not found that many endangered species.



a. A tumbler to separate shells by size



b. Steaming mussels to remove the viscera



c. Sacks of shells ready to be shipped overseas



d. Commercial shell fishermen, Savannah, Tennessee, Sept. 1981

Figure 1. The commercial shell industry

Question: Describe the difference between nucleated and non-nucleated pearls.

Peach: A nucleated pearl has a center core of mother-of-pearl material which is cut from shells of freshwater mussels. In other words, a nucleated pearl consists of from 80 to 90 percent mussel shell with a thin coat of pearly material secreted by the oyster. In the case of the South Sea pearl, a very large nucleus is used and this is left in the oyster for a long time. A non-nucleated pearl is made from mantle tissue which is surgically removed from one mussel and implanted in another mussel. This tissue stimulates production of a pearl.

Question: Why are North American mussels used for pearl culturing?

Peach: The main reason is that we have the best mother-of-pearl material in the world.

Question: So it is the quality not necessarily the thickness of the shell that is important?

Peach: Thickness is a factor. However, we are looking for clean, white, hard mother-of-pearl material. When you contrast that with sea shells, for example, it is very hard to find mother-of-pearl of that purity.

Question: What were the major species of mussels that you were getting from Oklahoma?

Peach: The major species were Quadrula quadrula and Amblema costata and occasionally white pimpleback, although 95 percent were the former two species.

Question: I am fascinated that commercial shells do so well in impoundments. Are you in a position to say that there has been a decline in diversity of species in these impoundments? That is, are there fewer species but more of certain types in these areas?

Response: I would not say that there are as many species as there used to be, but the species that are surviving are doing extremely well. They are healthy, and I think that we would not have many mussels at all if weren't for these impounded areas.

Question: Where do you find mussels in the impoundments? The upper ends or near the dam, for example?

Response: Actually in an impoundment we find them all over, although in some areas they are more concentrated than in others. In the deep water where there is no current, there may be no shells at all. Most are found in water less than 15 ft deep.

Question: On what kind of bottom do you find mussels in impounded areas?

Response: It can vary. We take them from sand, mud, gravel, and hard bottom. The substrate is usually very diverse.

SAMPLING FOR FRESHWATER MUSSELS

by

David Nelson*

On the afternoon of the first day of this workshop Mr. David Nelson discussed methods for construction and use of various types of mussel sampling gear. He described use of the brail, modified rakes and pitchforks, the basket, and dipnet dredge. Detailed drawings and lists of parts for these and other mussel collecting equipment can be found in IR-83- , An Instruction Manual for Freshwater Mussels by Miller and Nelson, available from WES.

Questions, comments, and responses following Mr. Nelson's presentation were transcribed and edited and have been placed in this report. In addition, pictures of selected types of sampling gear have been included. (see Figure 1).

Discussion

Comment: I feel that a gray-sided viewing bucket which reduces glare is preferred over a bucket with white on the inside.

Nelson: I agree.

Comment by Harold Mathiak: I have a few comments about the modified pitch fork. The tines are covered with 1-in. fabric; the first inch is bent down over the tines and secured with wire. I used a pitchfork mainly in murky water where you cannot see the bottom. I find it useful to work upstream and to stay in undisturbed water. I recommend that the pitchfork be used while working alone, so that you do not bother others. It is also handy for keeping your balance and is useful for protecting against dogs.

Comment: I have used rakes with both netting and hardware cloth; however, the hardware cloth destroys the substrate.

Nelson: So you recommend the netting rather than the hardwood cloth?

Answer: Yes.

Comment: I recently tested the crowfoot or bent hooks and the dovetail hooks. There was a great difference between these two hooks: the crowfoot caught a lot more mussels than the straight hook. Also, I used a piece of redwood for a bar and found that it held up very well.

Nelson: We have found that the crowfoot hooks damage the mussel soft parts more than the dovetail. At WES we have made bars of cypress, oak, and ash. The hardwoods are very heavy.

* Biologist, WES, Vicksburg, Miss.

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WATERWAYS EXPERIMENT STATION VICKSBURG MS ENVIR.

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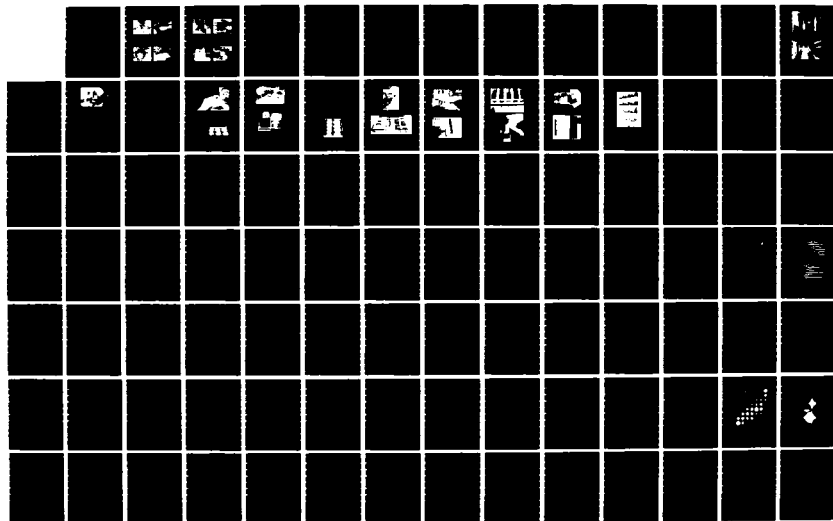
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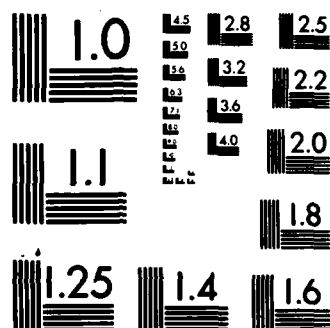
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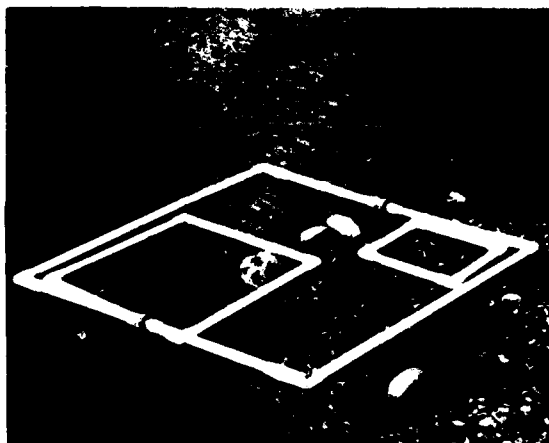
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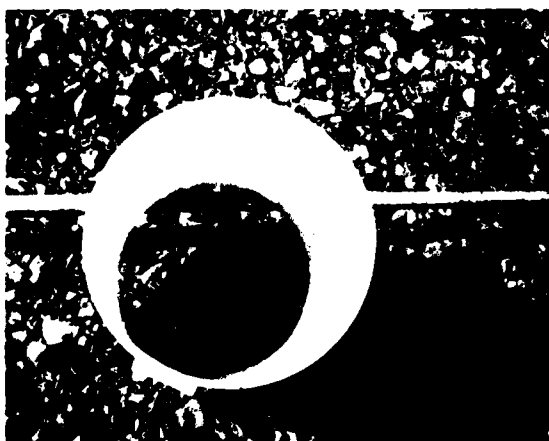
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



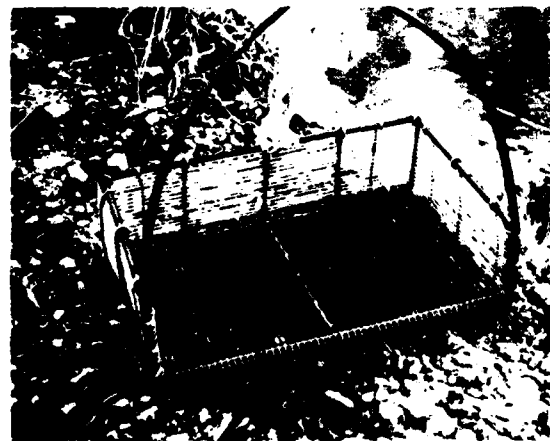
a. Quadrats made from 3/4-in. PVC line (0.0625 m^2 , 0.25 m^2 , and 1.0 m^2)



b. Garden rake with nylon netting



c. See-through bucket with plexiglas base



d. Basket dredge, made and used in Taiwan

Figure 1. Sampling equipment for freshwater mussels



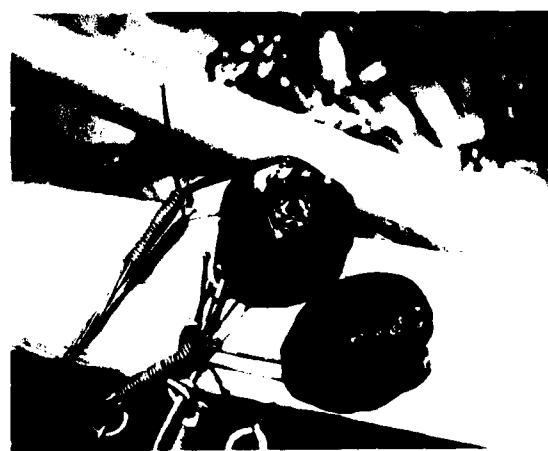
a. Constructing a brail hook



b. Handmade brail hook (top);
commercial hook (bottom)



c. Using a brail on the upper
Mississippi River



d. Mussels caught with a brail

Figure 2. Sampling equipment for freshwater mussels

Comment: We have used a bar made out of white oak and found that it sank right to the bottom. We attached a piece of threaded PVC pipe with caps and let in enough water to adjust the buoyancy of the bar.

Nelson: Yes, and some people have used an iron bar with hooks attached with strings.

Comment by Dr. Richard Sparks: We have finished two summers of work on the commercial harvesting industry and will publish a report next spring. We have found that the dredge definitely breaks up the thin shells. Also the diver can be highly selective. About 99 percent of the mussels our diver brought up were the washboard and threeridge, and these were commercial size.

Question: Where did you get the piano wire to make the brail hooks?

Nelson: It was purchased at a local hardware store in Vicksburg, Mississippi. It is quite stiff and is hard on the hands, so you should wear gloves while working with it.

Question: Have you ever tried attaching monofilament line to brail hooks?

Response by Dr. Richard Sparks: My predecessor tied monofilament lines on crowfoot hooks and was able to pick up very tiny mussels. It seem to be an effective technique. The monofilament line was heated at the end to place a small bubble (or bead) at the tip.

Comment: I put a screen around a quadrat for use in sampling streams. When the current velocity was high, the shells were directed toward the base of the quadrat.

Question: Do you have any idea on the efficiency of the brail?

Response from the audience: 30 percent.

Response from the audience: Wisconsin Department of Natural Resources has used a figure of 1 percent.

Response by Nelson Cohen: It depends a lot on the concentration in the shell bed. Also in the early spring when mussels are open you can pick up from 30 to 50 percent. Of course, each time you go over the bed the number will decline.

Comment by John Latendresse: The first commercial brail, so to speak, was a cedar bush with a weight on it. So if you are in the field and lose your brail, cut down a cedar bush, tie a rock on it, and drag it along on the bottom. You will catch mussels.



AD P003066

MOLLUSK COLLECTIONS AT THE OHIO STATE UNIVERSITY
MUSEUM OF ZOOLOGY

by

David H. Stansbery and Carol B. Stein*

In the early and middle 1800's a gentleman named Henry Moores collected mollusks in central Ohio. He exchanged many of his specimens with Thomas Say and Isaac Lea of the Academy of Natural Sciences of Philadelphia, with John Gould Anthony of the Museum of Comparative Zoology at Harvard University, with an unknown correspondent at the Smithsonian Institution, and with many other early conchologists.

Henry Moores' collection was eventually purchased by The Ohio State University, where it became the nucleus of the University's first Museum of Zoology in the late 1800's. But interest in the museum's shells waned during the mid-1900's, and so far as we can determine, the collection was not used for research for many years. The shells lay unused and all-but-forgotten in open trays in attics and behind exhibits. They became covered with thick layers of soot from the soft coal that heated Columbus buildings before natural gas was used.

In the early 1960's we found both a challenge and an education in cleaning the shells that had been collected a century earlier. In the process, we could not help but observe how different these specimens were from those being currently collected. Growth rates were, for example, frequently much greater in the 1960's than a century earlier. We related this to the increased use of fertilizers, but objective evidence is lacking.

The Henry Moores collections now form a relatively small part of the extensive collections of bivalve and gastropod mollusks at The Ohio State University Museum of Zoology. Over the past two decades these collections have grown at a remarkable rate. Our staff and students have collected hundreds of thousands of freshwater mollusks in many of the streams of North America. Our unionid and pleurocerid collections are among the largest in existence. We have built unusually extensive collections of soft parts of these mollusks. The many large series of specimens have a high degree of statistical significance, making them especially valuable for research involving variation within and between populations. We have over 50,000 lots of unionids alone, which may be larger than any other recent collection of these animals in the United States.

Since such a high percentage of the specimens in the OSUM collections have been collected within the past quarter-century, this is not necessarily the best place to study the early distribution of mollusks. To examine type specimens and other historical material, one should visit the United States Museum of Natural History in Washington, D. C., the Museum of Comparative

* Curators, respectively, of Bivalve Mollusks and Gastropods, Museum of Zoology, The Ohio State University, Columbus, Ohio.

Zoology at Harvard University, the University of Michigan Museum of Zoology, or the Academy of Natural Sciences of Philadelphia.

Some visitors, upon seeing the OSUM collections of freshwater mollusks, remark that now they understand why these animals are endangered! Actually, many of our specimens are shells obtained from midden left by muskrats and other mollusk-eating animals. Sometimes these shell middens are quite extensive. We once filled 18 three-gallon buckets with nested empty fresh unionid shells from a single large midden.

The collections have also grown through the generosity of others. Small but valuable collections are often donated by schools, colleges, and individuals who no longer require research collections. Specimens brought in for identification are frequently added to the collections, supplementing our own collecting and providing samples from sites we have not been able to visit.

Much of our mollusk collecting is done by hand in shallow water in small streams and along the shores and shoals of larger rivers. The museum also owns a large jon boat, which we use for collecting in medium-to-large rivers where SCUBA or crowfoot brailing are more effective collecting methods. The boat and motor are pulled to the field sites on a trailer. Our field laboratory is a modified camping trailer.

The Museum is located on the lower floor of Sullivant Hall at the main entrance to the University campus in Columbus. One of the first things visitors notice when they enter the Museum is our large collection of maps (Fig. 1*). The walls of the main hallway are nearly covered with those maps we most often use for quick reference. We also have an extensive map library (Fig. 2) which contains road maps, books of county maps, state and national drainage maps, and most sizes of U. S. Geological Survey topographic maps, as well as gazetteers. We are especially eager to obtain and preserve old maps and gazetteers, since these include old place names which "live on" in the literature and on old specimen labels, though they have often vanished from modern maps either because the names have changed or the places no longer exist. The maps are kept in a variety of map cabinets which were all obtained from various salvage or secondhand stores. They have been painted to match, and we have repaired many of them and replaced the handles to make them serviceable. Mr. Charles "Hank" Dowdy, a retired science teacher, is curator of our map library. He is one of several volunteers who contribute their time and effort to help with the seemingly endless work that goes into building a research museum.

The map library exists because of our concern that the best possible locale data accompany all specimens in the Museum's collections. The locales given on the labels of all incoming collections are checked out on detailed maps. If we cannot precisely pinpoint the locality, we contact the collector for more information. For this reason the collector's name is one of the most important items on any field label, along with the exact locale and date of collection. Any information added to that on the original label is placed inside brackets [thus].

* Figures 1-23 can be found on pages 102-113 at the end of this paper.

Each collection which comes into the museum is given its own number. This number consists of three parts. First is the Museum's abbreviation, OSUM. Second is the year in which the collection was originally made in the field. The third part is the number assigned to that particular collection in that year's series. The three parts are separated by colons. The first collection received at the Museum which was collected in 1982, for example, would be assigned the collection number OSUM:1982:1. If we receive a 1982 collection ten years from today, it will be assigned the next available number in the 1982 series. A field sheet (Fig. 3) is made out for each of these collections, and the sheets are filed by year of collection and then by number. We also enter the field number on a geographic card, so that we can quickly find out what collections we have in the museum from any one locality, such as the Clinch River at Kyles Ford, for example.

Our field labels (Fig. 4), which we supply to anyone collecting for the museum, contain blanks for all of the detailed locality information which we hope to keep with the specimens. This includes the specific stream or other locality; the drainage, distance and direction from the centers of two towns; section, township and range numbers; and township, county, state, and county names. We now add latitude and longitude, down to the second, to improve our precision and to add a set of permanent, worldwide coordinates. Space is left for remarks so that the collector can note any unusual or significant items which might be of value in future studies.

We acquire collections of specimens faster than they can be processed. A large area in each collection range is devoted to partially processed collections arranged by their collection numbers. These are processed as the time and funds become available. Each is well labeled, and the wet specimens are placed in fresh preservative in rubber-gasketed clamp-top jars. If necessary, the specimens could remain in this stage for a century or more until they can be fully processed into the collection.

Frequently, we receive inquiries as to whether or not endangered mollusk species exist in a particular area. The first thing we do is to check the geographic card file to find out what collections we have from the area. Then we look on the field sheets to find out what has been cataloged from the area, and we check the records for species considered to be endangered. If we do not find records of the species in question, we can go to the uncataloged collections from that locality and examine them for the presence of the endangered species. Even though the uncataloged material is not cleaned, culled, or sorted by species, it is still available for research purposes. It is much easier to unpack a few cartons and jars of uncataloged material than to organize an expedition to go in search of it--especially in midwinter!

The cataloging and processing of a collection of mollusks is very time-consuming. The first thing we do is to rough-sort the material by species. Then we cull the specimens of each species. We try to keep what we believe to be a statistically significant series, generally 30 or more specimens representing both sexes and the entire range of shell sizes present in the sample, as well as a representative sample of specimens preserved in AGW (80% ethanol, 15% water, 5% glycerin). Excess specimens which are in good enough condition for research or study are set aside as duplicate material, and specimens which are of no value are discarded.

Anyone who has a need for examples of a particular species of unionid, or for samples from a specific area, is welcome to write us inquiring about the availability of the desired material. Our duplicate material obviously includes more examples of common species than of rare ones.

After the collection has been culled, the specimens must be cleaned. We attempt to remove all of the environment from the surface of the shell without actually damaging or removing any part of the specimen itself. We have found that it is important to be very particular about cleaning the shells. Sometimes a specimen originally thought to be one species reveals characteristics, when clean, which show it to be a different species. Texture, color, ray pattern, muscle scars, and other important taxonomic characters can be seen completely on a clean shell, but are frequently obscured if the specimen is not properly cleaned.

To clean unionid and gastropod shells we use toothbrushes or handbrushes of varying degrees of hardness, in combination with ordinary household cleansing powder (Fig. 5). Various dental tools have also proven useful for removing foreign materials from shells.

To remove resistant deposits from unionid specimens, we use a Dremel Moto-Flex Tool, Model 232, having a variable-speed control and a flexible shaft with a rotary brush on the end of the shaft. We recommend a brush with stiff non-metallic fibers similar to toothbrush fibers. Our most experienced processors often use a steel brush on shells with an especially tenacious coating. They must be very careful and use a light touch with this tool, however, since the steel has a hardness of five and the shells are much softer, with a hardness of only three. The periostracum is even softer and is very easily scratched with the steel brush.

Small, fragile gastropod and sphaeriid shells are often cleaned with a camel's hair brush, sometimes under a dissecting microscope. A Branson 12 ultrasonic cleaner with a detergent solution is also helpful in cleaning very small shells. Shell cleaning is an exacting task, and it takes a long time to learn to do it well.

After the shells are cleaned, the tentative identifications are verified, and the collection is cataloged. All of the specimens of a given species from a given field collection are considered a "lot," and each lot is assigned its own catalog number. Our catalogs (Fig. 6) are bound "blank books" made especially for OSUM. They have 100% rag paper printed with a line for each lot, and columns for the catalog number, scientific name (which includes the author and date), the initials of the person who identified the specimens, the number of wet and dry specimens in the lot, the field collection number, the name(s) of the collector(s), the specific locality where the collection was made, the township, the county, the state or nation (if not USA), and the date of collection. All entries are made as legibly as possible, and only waterproof, permanent, high-carbon ink is used.

Part of each catalog page is reserved for additional comments and possible changes. For example, as we learn more about the systematics of these animals, our studies sometimes reveal that what was once thought to be a single homogeneous species is actually a composite of two or more taxa. In such a

case, we can go back to the catalog, note the change at the bottom of the page, and remove the specimens of the newly recognized species to a separate lot with a new catalog number.

We catalog all of the lots from a given field collection together, whenever possible, since this saves a lot of writing--we can then use ditto marks for the collections data--and it also lets us see at a glance the faunal composition of the bivalve or the gastropod fauna at that site at that time. The complete list of species and their catalog numbers are then typed on the back of the field sheet (Fig. 7) so we can quickly determine what specimens have been cataloged from that locality.

For each lot, a collection record card (Fig. 8) is typed. These cards are filed in taxonomic order, and within each taxon by drainage order. Simply by looking through the card file for a particular species, a researcher can quickly obtain all of the available recorded data for all the cataloged OSUM specimens of that taxon.

Eventually all of these data will be entered into an electronic data bank so that the information can be retrieved quickly and efficiently by whatever category we wish. Right now we are exploring several alternatives to find the best way to program these data for most efficient use in research.

When catalog numbers have been assigned to the various lots, and the shells have been cleaned, the dry shells are numbered (Fig. 9). In the gastropod collections, some of the shells are so small that it is impossible to write a five digit number on the shell, so specimens less than half an inch long are generally placed in a vial or a gelatin capsule with a slip of paper bearing the catalog number. However, the larger shells are numbered with permanent black or white ink, whichever shows up best on the periostracum.

In the bivalve collection, a more complex system is used. The catalog number, plus a decimal number, is written in permanent black ink on the nacre of each valve of every dry shell in the cataloged collection (Fig. 10). Each specimen in the lot is assigned its own decimal number, beginning with 0.1 for the smallest specimen, 0.2 for the next largest, and so on. This allows one to quickly match up the pairs of valves if they should become jumbled and also allows the researcher to refer to any particular specimen in a lot in a publication if necessary.

The numbered shells of most bivalves are then dipped (Fig. 11) into a solution consisting of 1/4 pound of paraffin dissolved in one gallon of xylene. They are left in a vented hood to dry. As the xylene evaporates, a thin coating of paraffin is left on the entire surface of the shell. This greatly reduces the amount of periostracal flaking and cracking, and yet does not significantly alter the natural color, texture, or appearance of the shell. We do not dip gastropod shells, since very few of them seem to be subject to the flaking of periostracum which is so common in bivalves. Nor do we dip the smaller spheriid species, since under high magnification the paraffin coating is visible.

Each lot of shells is placed in its own tray, lidded box or vial (Fig. 12), together with its label. In the gastropod and sphaeriid collections, small

lots are places in an eight-dram shell vial. A 100% rag content label (Fig. 13) bearing all the data given in the catalog is placed in the vial against the glass, with the left side of the label toward the closed end of the vial. The shells are then placed at the bottom of the shell vial. The vial is filled with a plug of cotton, which holds the shells gently but firmly in place at the bottom and the label firmly against the glass side of the vial. We have found that vials smaller than the eight-dram size do not provide enough space for labels with the amount of data we believe is necessary to keep with the specimens, so the vial is sized to fit the label, not the specimens. Large lots of small snails or sphaeriids which do not fit into the eight-dram vials are kept in boxes with plastic lids. The smallest of these are hinged-lid boxes made completely of plastic. The larger ones are modular pasteboard boxes with lift-off acetate lids, somewhat like Christmas card boxes, which keep the shells from accidentally being jostled from one box to another. Large gastropods are housed like the unionids in open trays in drawers.

Small lots of unionids are stored in open trays (Fig. 14) with special standup labels (Fig. 13) made of durable heavyweight juteboard or 100% rag card stock, as shown in the accompanying illustrations. A piece of thin plastic sponge is placed in the bottom of each tray. This keeps the shells from sliding and bumping into each other when the tray is moved and hence prevents much damage from chipping and cracking of the thin shell margins. The shells gain an extra measure of protection from their positions in the trays. The left valve is first placed nacre-down on the sponge liner, and the right valve is then placed on top of it, also nacre-down. This keeps the shells from rolling about, as they would if the valves were placed together as they are in life. All the valves are placed with the ventral margins toward the front edge of the tray. They are arranged in size sequence in the tray. The standup label is always placed at the left rear corner of the tray and is folded so that all of the collection data can be read without touching either specimens or label. All original labels are kept in the trays with the specimens, along with the OSUM label. The OSUM labels are printed in long strips for ease in typing on our 17-pitch label typewriters (Fig. 15), using carbon ribbon for permanence. They are cut apart after typing, and the standup labels are then folded by hand along a scored line.

Because of the way the specimens and labels are arranged, an investigator can open a drawer (Figs. 16, 17) and scan over the rows of shells and labels, frequently obtaining all the data he needs almost instantly. Geographic arrangement of the lots by drainage system within the species drawers also is an aid to research.

Most lots of shells are kept in drawers which fit interchangeably into strong, relatively inexpensive plywood cabinets (Figs. 18, 19). Labels on the outside of each cabinet identify the taxa kept inside and in many cases also note which drainage systems are represented in that cabinet.

Large series of bivalve shells are kept in labeled boxes on steel shelving (Fig. 20). This material is arranged in the same linear systematic sequence that is used in the cabinets. The catalog number is placed on the end of every box, and each lot also has a locale label on the outside of the first box, as well as a complete typed label inside it. Inside each box (Fig. 21),

the shells are arranged just as they are in the cabinet trays. Two carefully crumpled sheets of newspaper in the top of each box hold the shells firmly in place when the box is closed and tied. A single lot may occupy only one such box, or may be so large that several boxes are required to hold it. We feel that this is a very practical and inexpensive way to store the large lots, and it surely does save on costly cabinet space. Any one specimen of the half-million or so unionids stored here can be located in less than ten minutes.

Nearly all of the mollusks which we collect alive are preserved with their soft parts intact. If time and facilities permit, we relax the aquatic animals in a menthol-water or other solution before fixing them, and the land snails are drowned in air-free jars of water. Unionid shells must be carefully opened a few millimeters and kept apart with a rubber or cork stopper (even a twig or pebble will do in an emergency) before they are carefully placed, aperture ends up, into the AGW preservative. We have found that most sphaeriids and freshwater snails can be preserved adequately, even for micro-anatomical studies, by simply dropping them into AGW. When the field collections are brought back to the Museum, we change them into fresh AGW, removing the stoppers as we go. Inexpensive screw-top, wide-mouth glass jars are used as field containers, but these are not suitable for long-term storage of specimens because most are not tight enough to prevent the alcohol from evaporating. New plastic lid gaskets may solve this problem.

The old-fashioned bail-top glass canning jars with rubber gaskets are excellent containers for alcohol-preserved specimens, but are virtually impossible to obtain now. We currently use two types of jars for most of our wet specimens. For smaller bivalves and for small lots of snails we use glass jars with translucent plastic snap-on lids. These are manufactured by the Wheaton Company and come in 2-, 4-, and 6-ounce sizes. Most bivalves and larger lots of gastropods are kept in rubber-gasketed clamp-top glass jars (Fig. 22) which are made in Europe. Several years ago we joined two other museums in importing a truckload of these jars from France. Since this supply is now running out, we are looking for an economical source within this country. These jars can be quickly opened and closed and are air-tight.

Very large unionid specimens and very large lots of wet specimens will not fit into these jars, since the largest is only a three-liter container. We have used some very large screw-top jars successfully by "buttering" the inside threads of the lids with a melted-together mixture of half beeswax and half petroleum jelly. This compound provides an alcohol-resistant seal, serves as a lid lubricant, and inhibits rusting. This method is time-consuming and messy, however, and the compound must be applied to a dry lid and jar to insure a perfect seal. We are considering using translucent plastic buckets and lids for storage of large series of specimens.

A tape-writer label of stainless steel or plastic bearing the OSUM catalog number is placed into each jar of preserved specimens, in addition to the typed paper label. This is simply insurance against the slight possibility that the label paper may disintegrate or the ink fade.

The specimen jars are stored in a linear systematic sequence on steel shelving. For convenience in organizing and handling the wet collection, we use sturdy, labeled cardboard trays (Fig. 23) with a fire-, alcohol-, and water-resistant coating to hold the jars.

We have found that shells with their soft parts intact kept for many years in AGW do not have the same appearance as shells which are stored dry. In liquid, the periostracum typically becomes darker and pinhead-sized bubbles sometimes form between the underlying prismatic layer and the periostracum. Since the shells store better as dry specimens, we are dissecting out the soft parts of the bivalves, when time permits, and of small lots of snails as they are processed. The soft bodies of the mollusks are placed in individually labeled containers (zipper closure plastic envelopes, vials, or capsules) along with their catalog numbers and stored together in the same jar, while the shells are processed into the dry collection. Since each part of each specimen is marked with that individual's own catalog number, the bodies and shells can be re-associated in the future as they are studied. When operculate snails are dissected and preserved separately, each operculum is placed inside its own shell and held in place by a plug of cotton.

It is impossible to go back in time and take a duplicate sample from a population. Populations are continually changing, in some instances to the point of extirpation or extinction. Environmental conditions, the active agents of selection, are forever changing. Therefore, each museum lot is unique and irreplaceable. Our efforts are directed toward building a collection which will continue to be of genuine research value to scholars long into the indefinite future.

Acknowledgements

We wish to recognize the very real contribution made to this paper by the curatorial assistants of the two mollusk divisions. Both Kathy G. Borrer, Bivalve Mollusk Division, and William N. Kasson, Gastropod Division, are intimately familiar with the collections and activities described here by virtue of some years of daily hands-on experience. Their suggestions for improvements in both factual expression and ease of communication were gratefully received.

All of the photographs were taken, developed, and printed by A. E. Spreitzer with the perfectionism which is becoming his trademark.

Kathy Newman proofread and typed the final manuscript with all of the enthusiasm of a budding malacologist.



(This and all succeeding photographs in this paper taken by A. E. Spreitzer)

Figure 1. Frequently used geologic maps and drainage maps line the main corridor of The Ohio State University Museum of Zoology

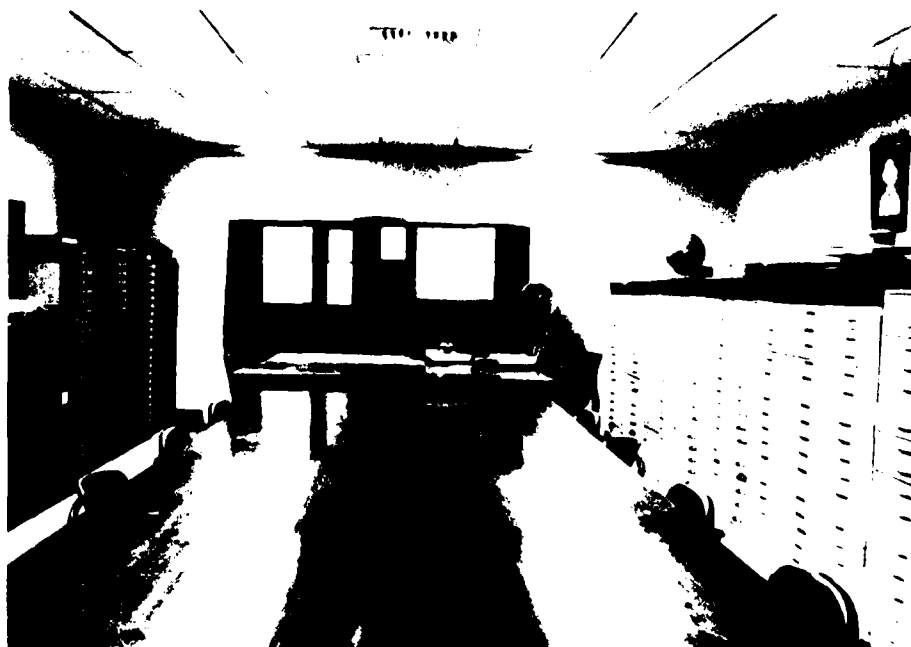


Figure 2. Charles T. "Hank" Dowdy, volunteer map librarian, keeps the OSUM map collection properly organized so researchers can check locales where specimens were collected. The cabinets on the right contain 7-1/2-min topographic maps. Other series of maps and gazetteers are stored along the opposite wall. The large table in the center is used for laying out maps for study

FIELD COLLECTION DATA RECORD (Aquatic)		COLLECTION NUMBER: 00151718	
Collector(s): B.H. Stanbury, James Hagg, Ed Walters		Date: 10 April 1981	
Specific Locality: Ohio River at Rome City, 6.0 mi. N of Cairo			
Sec:	Twp:	Cu:	State: Illinois
Drainage: Ohio River - Mississippi River			
Forms Collected: mussels		Orig. Presv:	
Meth. Capt.: H CS PN DN ED SV RK		Qualitative: Quantitative:	
Coll. Zone: L1 L2 P1 R1 R2 P1 Sh.		Coll. Site: No P1 N1 P1 R1	
Substrate: Cl Sh Gr Co Be BR		Composition: P1 Sh P1 R1	
Flow Stability: 1 C Current: N S F R Depth:		Width: Banks:	
Aquatic Vegetation: N S E Algae Waterwillow			
Temperature: Air:		°C/F. Water: °C/F. Weather:	
Oxygen: PPM.	pH:	Tot. Alk: PPM.	
Oxygen: % Sat.	Turb:	Cor. Dis: PPM.	
Remarks: "This is the second day of field work for the Stanbury and Hagg, Inc. firm in surveying a site for a large-scale facility. Yesterday's work covered the entire 1100' x 500' area of concern along the Illinois bank of the Ohio River. Today the area around the proposed site of the facility was gone over in detail by hydrologist, Mr. Ed Walters. It was found that the substrate was mainly mud and organic debris. Some 6-8" beneath the surface of the silt a layer of fine gravel was found. Living unionids found were 1 <i>Silicula grandis</i> (Am., 1857), 1 <i>Silicula grandis</i> (Stef., 1880), and 6 <i>Potamocorbula aspera</i> (Say, 1827). Some shells of <i>Potamocorbula aspera</i> (Stef., 1880) were common. All other dead shells taken were unionids. It appears that this site is silted in and changing from what once was a more suitable habitat for unionid mollusks." - B.H. Stanbury			
THE OHIO STATE UNIVERSITY MUSEUM OF ZOOLOGY			

Figure 3. Field sheets such as this are filled out for every incoming bivalve collection, even if the collection contains only a single specimen. It provides a useful place to store a variety of data and remarks about the collection which cannot be put on every lot label. A geographic card file provides a quick means of locating all of the field sheets from any locality or drainage system

SPECIMEN COLLECTION DATA FOR THE OHIO STATE UNIVERSITY MUSEUM OF ZOOLOGY			
Original Collection No. _____ Day _____ Month _____ Year _____			
Specific Locality _____			
_____ air miles _____ of the center of _____ (nearest town)			
_____ air miles _____ of the center of _____ (major city)			
Latitude _____	Longitude _____	Section _____	
T _____ N _____	Township _____	County _____	State _____
Drainage _____			
Collector(s) _____			
Name of map used: 7.5' topo. _____ National topo. _____			
Habitat, etc. _____			

Figure 4. Field labels such as this one are given to people who plan to collect mollusk specimens for the OSUM collections. Like all OSUM forms, this is made of durable rag-content paper which has great longevity, even when placed in liquid preservative. When such a label is completely filled out by the collector, processing the collection can proceed smoothly when it arrives at the Museum



Figure 5. Using a toothbrush and cleansing powder, Sam Fitton cleans a unionid shell. The moto-tool hanging at the top of the rack is used on some specimens with especially tenacious coatings

LOT	DESCRIPTION	DATE	LOCATION	COLLECTOR
10000	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10000	10000
10001	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10001	10001
10002	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10002	10002
10003	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10003	10003
10004	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10004	10004
10005	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10005	10005
10006	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10006	10006
10007	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10007	10007
10008	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10008	10008
10009	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10009	10009
10010	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10010	10010
10011	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10011	10011
10012	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10012	10012
10013	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10013	10013
10014	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10014	10014
10015	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10015	10015
10016	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10016	10016
10017	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10017	10017
10018	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10018	10018
10019	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10019	10019
10020	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10020	10020
10021	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10021	10021
10022	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10022	10022
10023	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10023	10023
10024	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10024	10024
10025	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10025	10025
10026	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10026	10026
10027	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10027	10027
10028	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10028	10028
10029	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10029	10029
10030	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10030	10030
10031	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10031	10031
10032	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10032	10032
10033	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10033	10033
10034	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10034	10034
10035	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10035	10035
10036	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10036	10036
10037	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10037	10037
10038	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10038	10038
10039	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10039	10039
10040	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10040	10040
10041	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10041	10041
10042	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10042	10042
10043	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10043	10043
10044	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10044	10044
10045	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10045	10045
10046	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10046	10046
10047	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10047	10047
10048	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10048	10048
10049	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10049	10049
10050	Unionid, variegata (Jan. 1951)	1. 1. 1. 1. 1.	10050	10050

Figure 6. Every lot of mollusks processed into the OSUM collections is assigned its own catalog number and is entered in this permanent bound catalog book. All of the data which will later be typed on the cards and labels are first entered in this book, using permanent waterproof black ink. Each lot has its own line, and notes which pertain to the lots are entered as footnotes at the bottom of the pages as necessary

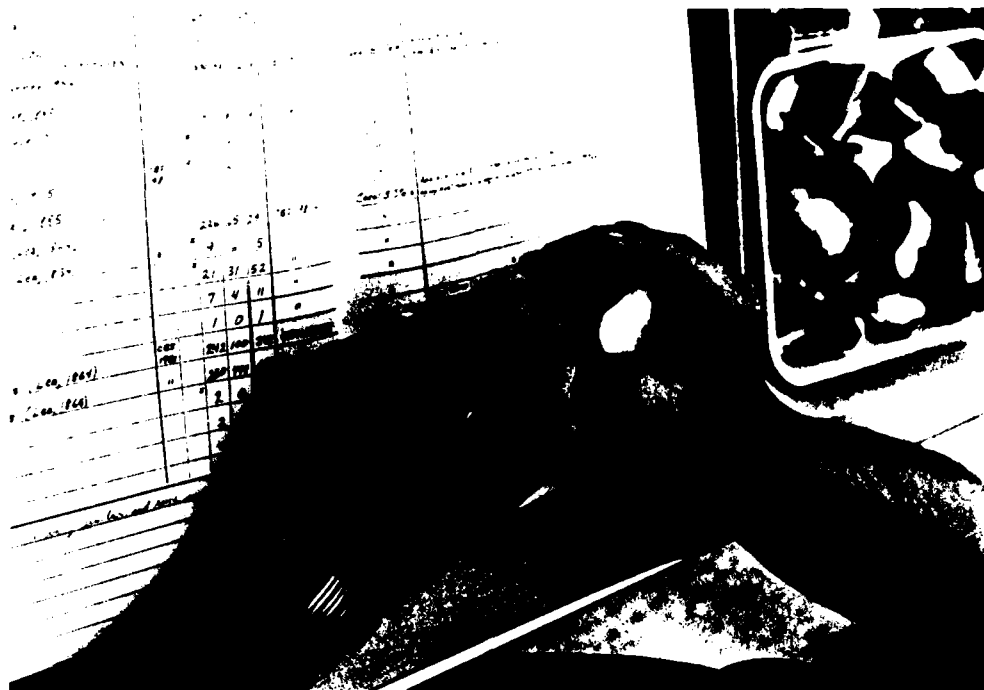


Figure 9. William N. Kasson, curatorial assistant, uses white waterproof ink to number a dark-colored gastropod shell. On light-colored shells, black waterproof ink is used. The soft parts of these specimens have been preserved separately in AGW. The cotton in the aperture of each shell holds the specimen's operculum inside the shell

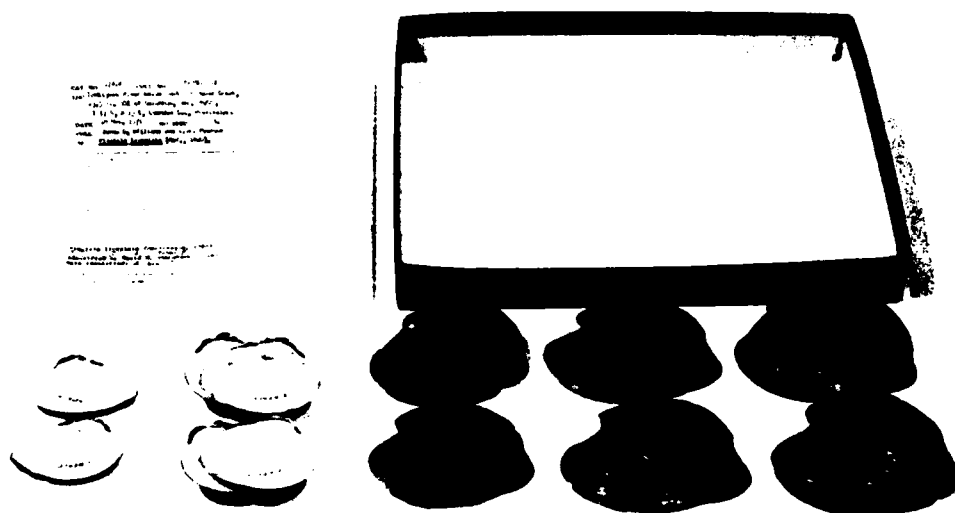


Figure 10. Each valve of every dry bivalve shell is numbered with permanent waterproof ink just inside the pallial line on the nacreous surface. These shells are ready to be placed, together with their original label, OSUM typed standup label, and plastic sponge, in the tray at the upper right

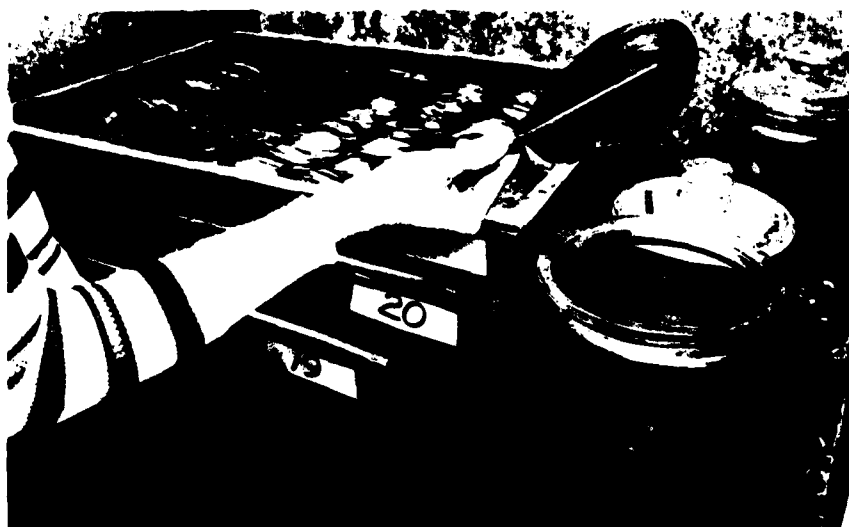


Figure 11. After they are numbered, bivalve shells are dipped in a xylene-paraffin solution and allowed to dry. This leaves a thin film of paraffin on the shell surface, which retards flaking of the periostracum and cracking of the shell

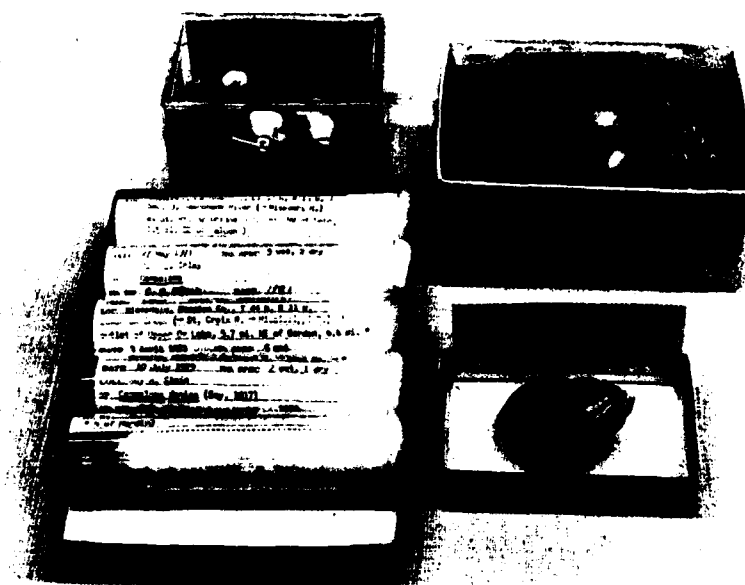


Figure 12. Fully-processed gastropod shells are stored with their labels in four different types of containers. Clockwise, from lower left, these are: 1. glass eight-dram shell vials, six vials per tray (when there are many vials of one taxon, we place stand-up cards at the back of the tray to indicate the river system represented in that tray); 2. hinged-lid plastic box with standup label and plastic sponge cushion; 3. pasteboard box with lift-off acetate lid, standup label, and plastic sponge cushion; 4. open pasteboard tray with standup label and plastic sponge cushion, used for large shells only

ID. BY	DATE
REMARKS	
THE OHIO STATE UNIVERSITY MUSEUM OF ZOOLOGY	
OSUM	COLL. NO.
LOC	
DATE	NO. SPEC.
COLL.	
SP.	
ID. BY	DATE
REMARKS	
THE OHIO STATE UNIVERSITY MUSEUM OF ZOOLOGY	

THE OHIO STATE UNIVERSITY MUSEUM OF ZOOLOGY	
OSUM	COLL. NO.
LOC	
DATE	NO. SPEC.
COLL.	
SP.	
ID. BY	DATE
THE OHIO STATE UNIVERSITY MUSEUM OF ZOOLOGY	
OSUM	COLL. NO.
LOC	
DATE	NO. SPEC.
COLL.	
SP.	
ID. BY	DATE
THE OHIO STATE UNIVERSITY MUSEUM OF ZOOLOGY	
OSUM	COLL. NO.
LOC	

Figure 13. The two types of permanent lot labels used in the Museum's mollusk collections, printed in strip form for ease of typing: at left are standup labels printed on long-lasting card stock; at the right are labels printed on rag-content bond paper used for all wet specimens and all dry gastropod and sphaeriid lots kept in shell vials. After they are typed, the labels are cut apart on the dotted line immediately beneath the Museum's name. The standup labels are folded on the solid line in the middle of each label.

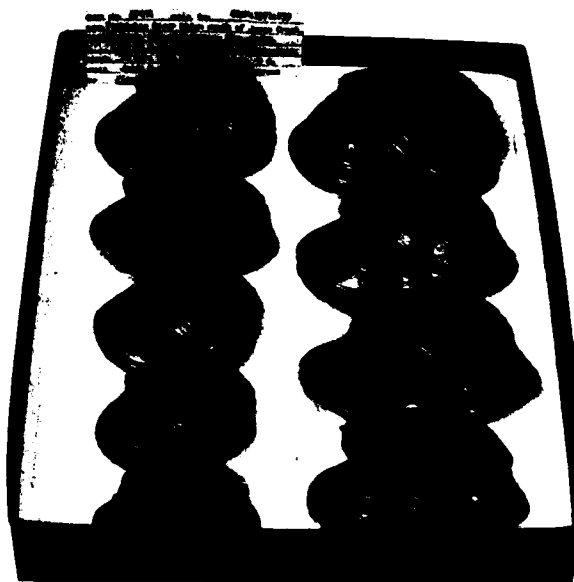


Figure 14. The consistent position and orientation of the shells in this cabinet-ready lot make it very easy to compare most of the features of the specimens without even touching them; also, the shells rarely move from this stable position when the tray is jostled accidentally.



Figure 15. Using a special label micro-typewriter which prints 17 characters/in. and uses a carbon ribbon, Kathy G. Borrer types a strip of specimen lot labels from data entered in the catalog book

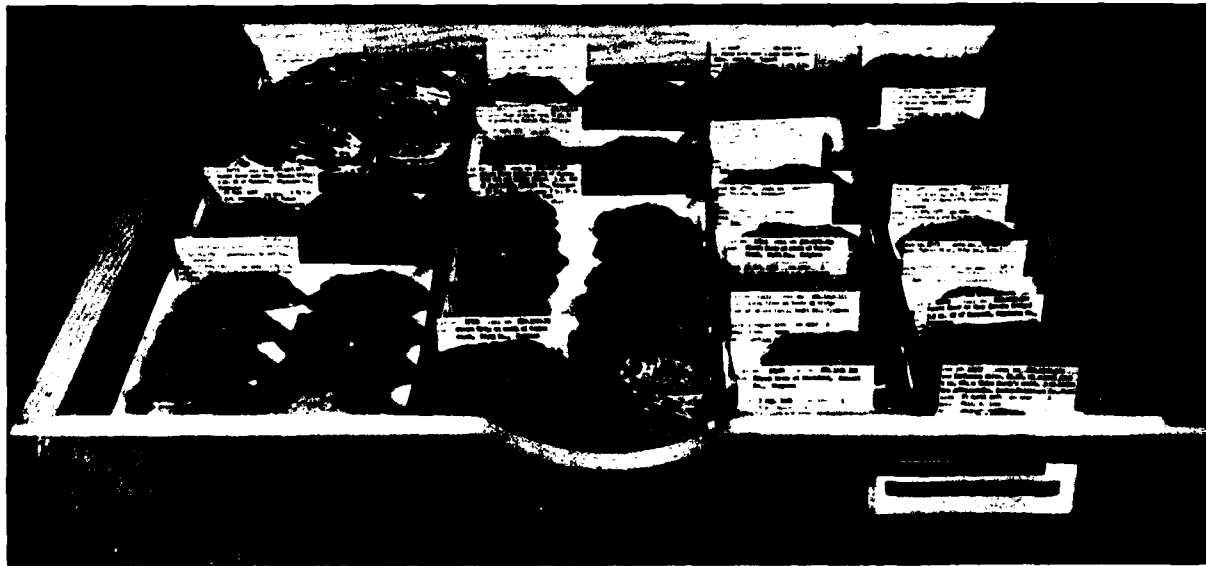


Figure 16. A quick scan of the rows of standup labels in this typical drawer of unionids reveals the shell lots by catalog number, the localities from which the various lots were collected, the dates of collection, names of collectors, and number of wet and dry specimens in each lot. The label on the front of the drawer identifies the species and the drainage system the specimens are from



Figure 17. Modular trays fit neatly into the wooden drawers which are interchangeable throughout the Museum. The channels in the sides of the drawers fit over wooden rails in the cabinets which hold the drawers securely even when they are pulled out more than halfway. The 2-in.-deep drawers are adequate for nearly all bivalves and non-marine gastropods. For very large shells, we simply leave out one or more drawers above the drawer in which they rest



Figure 18. This view down the central corridor of the OSUM Bivalve Research Collection range shows some of the standard wooden cabinets in the left foreground. Behind them are shelves of processed wet material. In the far distance is the entrance to the room of partially processed collections. On the right are the ends of cabinet rows, with part of the processing area in the right foreground



Figure 20. Large lots of unionids are housed in this very efficient and relatively low-cost storage system. The catalog number and species name are printed on the end of each box, and the first box of each lot also shows the locality where the shells were collected



Figure 19. The OSUM Gastropod Research Collection is housed in standard wooden cabinets, with wet specimens in trays on the steel shelving in the background. It is adjacent to, but separate from, the Bivalve Research Collection

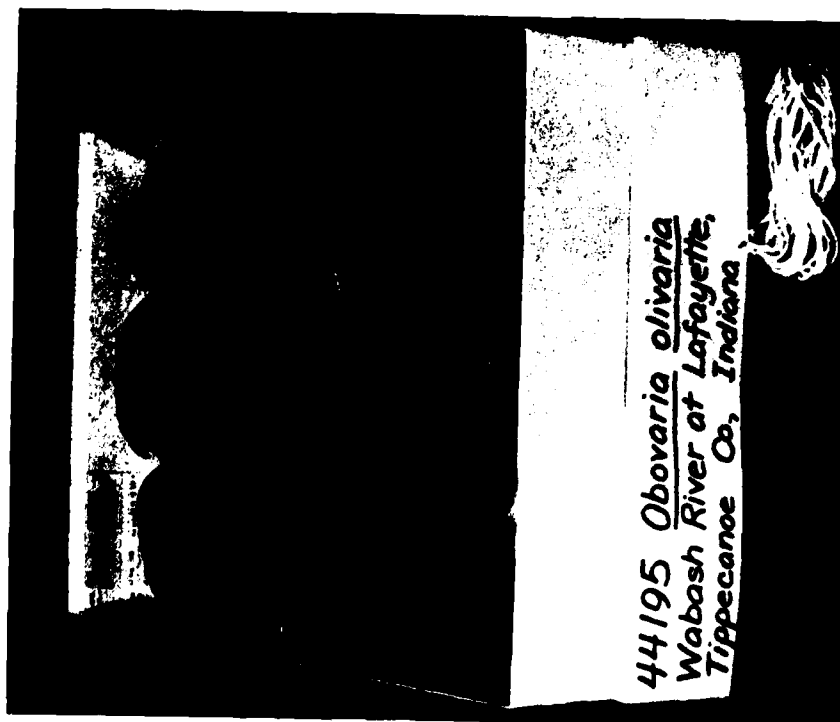


Figure 21. Large lots kept in closed boxes are packed in the same way as the ones in the cabinets, with a plastic sponge sheet on the bottom and a standup label at the back of the box. To keep the shells from shifting, and to cushion them from the weight of other boxes of shells, one or two full sheets of crumpled newspaper are carefully spread in the box lid before it is placed over the shells and tied



Figure 22. This fully processed lot of wet specimens is ready to be put into the collection. Each unionid has been carefully dissected from its shell, which is now in the cabinet or a box. The soft body, together with a label bearing the catalog number of that specimen (which is also written on each valve of the shell), has been placed inside an individual plastic envelope. All of the individually labeled bodies are placed inside the rubber-gasketed clamped top glass jar, together with the typed OSUM label for that lot

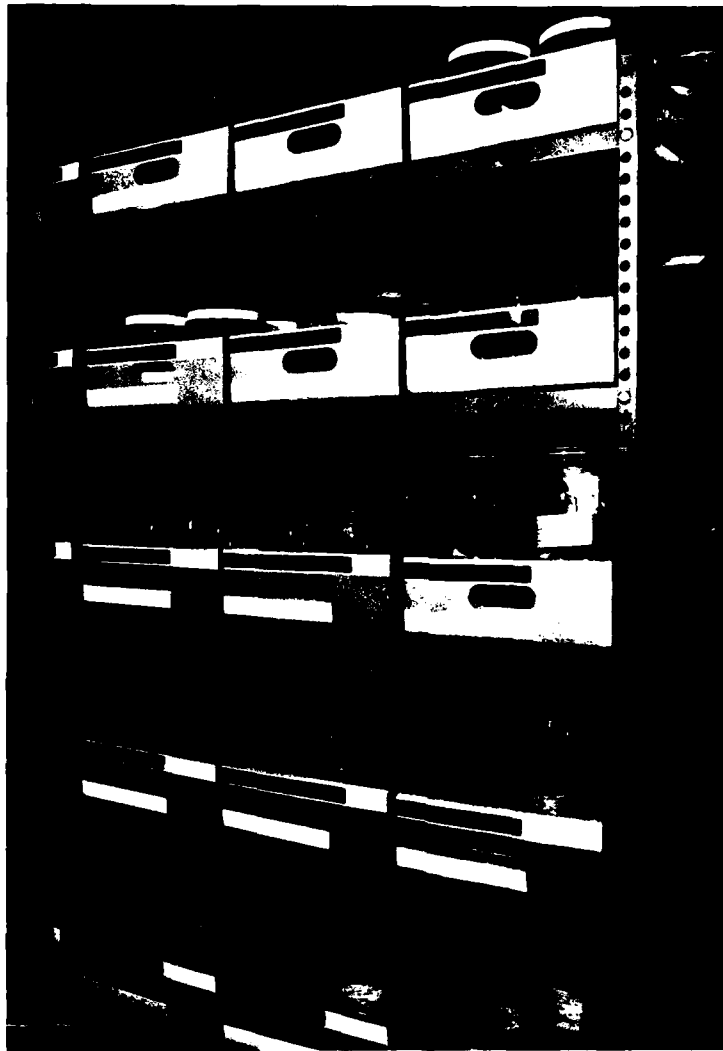


Figure 23. Cataloged wet specimens are kept in labeled trays on steel shelving. Eventually, locale labels will be added to the trays for convenience in locating the specimens

THE NECESSITY FOR PROFESSIONAL MUSSEL STUDIES

by

Paul Yokley

The real key to successful analysis and research requested by the U. S. Army Corps of Engineers and other agencies pertaining to freshwater mussel evaluations is selecting qualified malacologists that have experience in the area to be studied. Contracts are frequently awarded to the lowest bidder and not to the best qualified for the type of work requested.

The results of the work thus do not reveal the very best information being sought, since inexperienced individuals do not find what actually exists in the study area. These false results are reported and become official information.

I can cite more than one example of inexperience or lack of expertise resulting in poor results and inaccurate data. Surveys made by inexperienced individuals without taxonomic training, especially when searching for rare species, produce negative results.

It is strongly recommended that contracts be awarded to the capable, experienced malacologists when freshwater mussel research is involved and not to a consulting group simply with the lowest bid.

ARCHEOLOGICAL RECORDS OF NAIAD MUSSELS ALONG
THE TENNESSEE-TOMBIGBEE WATERWAY

by

Neil D. Robison

Ongoing construction of the Tennessee-Tombigbee Waterway has focused the attention of the malacological community on the potentially threatened mollusk populations that inhabit the upper Tombigbee River. A number of studies document the mussel species which inhabit the Tombigbee River and its tributaries. Important studies include Hinkley (1906), van der Schalie (1939, 1981), Williams and Stansbery (1972), and Yokley (1975, 1980, 1982). These studies describe historical mussel populations but do not speculate upon their prehistoric makeup. In the absence of prehistoric accounts malacologists can speculate on the makeup of past mussel populations by utilizing archeological evidence.

Recent archeological excavation in connection with the Tennessee-Tombigbee Waterway has discovered five sites which contained sufficient mussel valves to make analysis worthwhile. These five sites are: Kellogg (22C1527), Yarborough (22C1814), Lubbub Creek (1P185), 1Gr1x1, and 1Gr2 (Figure 1). The Mobile District contracted for and supervised the excavations of these sites.

The Kellogg Village site (22C1527) is located on the west bank of the Tombigbee River, about 3.3 km north of the Columbus Lock and Dam in Clay County, Mississippi. The Tibbee River enters the Tombigbee River about 2 km downstream from the Kellogg site. Excavations were conducted at the site by Mississippi State University in 1978 (Atkinson et al. 1980).

The Yarborough site (22C1814) is situated in Clay County, Mississippi, on the north bank of the Tibbee River, approximately 4 km upstream from its confluence with the Tombigbee River. This site is on the periphery of Columbus Lake. The University of Alabama excavated at the site in 1980 (Solis and Walling 1982).

Excavations at the Lubbub Creek site (1P185), in Pickens County, Alabama, were conducted by the University of Michigan in 1978 and 1979. Although named for the nearby Lubbub Creek, this site is actually located on the main channel of the Tombigbee River approximately 3.2 km below Alabama Highway 17; Lubbub Creek flows into an adjacent oxbow of the Tombigbee River. This portion of the river has since been impounded to form Gainesville Lake (Peebles 1981).

Sites 1Gr1x1 and 1Gr2, which were excavated by the University of Alabama in 1976, are both within the Gainesville Lake portion of the Waterway in Greene County, Alabama. Site 1Gr1x1 was located near the mouth of Turkey Paw Branch, approximately at navigation mile 268, while site 1Gr2 was situated immediately south of Wilkes Creek at navigation mile 273 (Jenkins and Ensor 1981).

* Archeologist, U. S. Army Engineer District, Mobile, Ala.

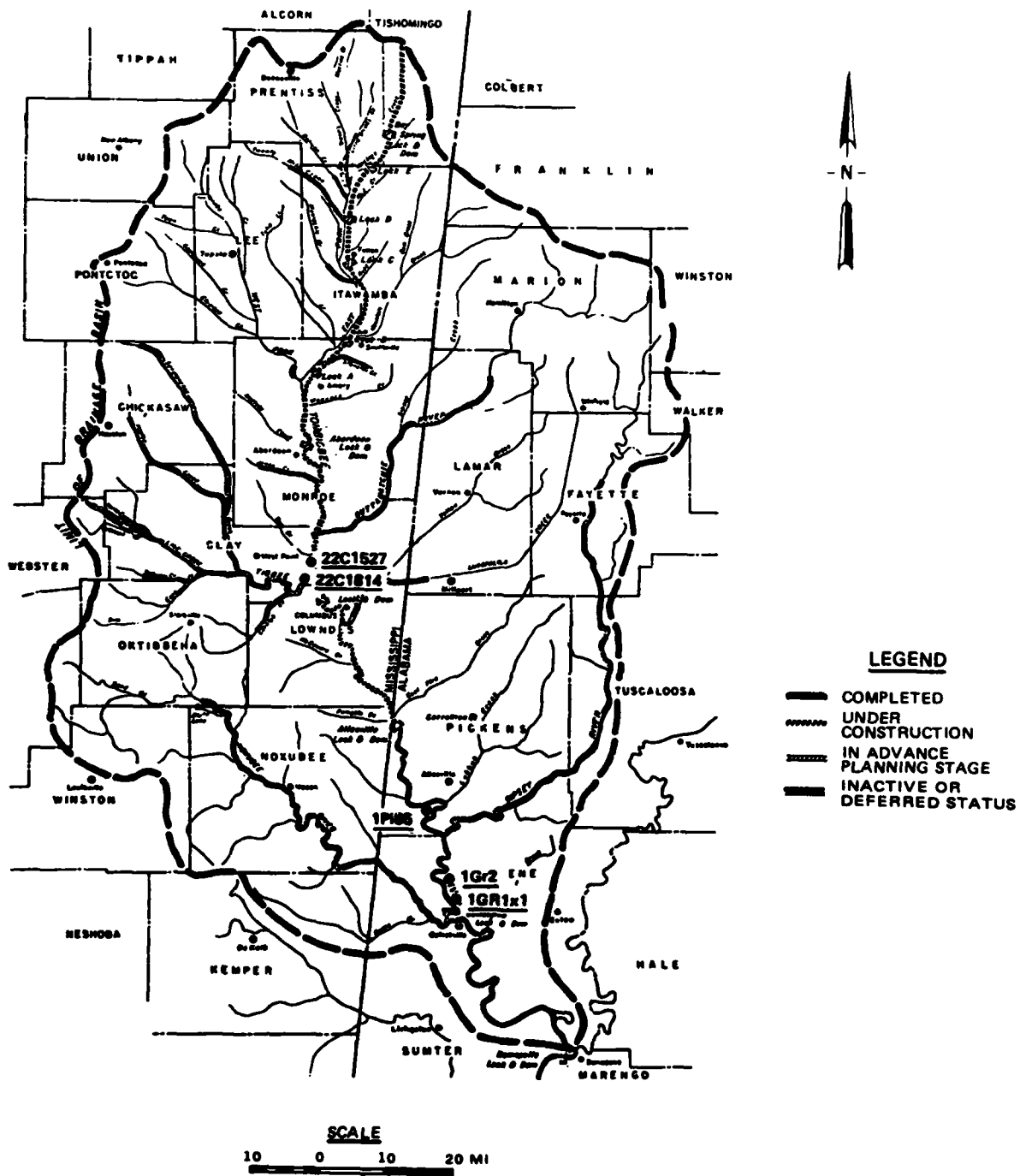


Figure 1. Site locations

Some of these sites contain more than one cultural component and thus display evidence of occupation from two or more periods in time. Often mussel shells were associated with several components. The regional cultural components found at these sites and their approximate dates of existence are displayed in the tabulation below.

<u>Component</u>	<u>Dates of Existence</u>
1. Late Gulf Formational	500-100 B.C.
2. Miller I	300 B.C.-A.D. 100
3. Miller II	A.D. 100-500
4. Miller III	A.D. 500-1000
5. Mississippian	A.D. 1000-1650
a. Summerville I	A.D. 1000-1200
b. Summerville II-III	A.D. 1200-1450 or 1500
c. Summerville IV	A.D. 1500-1650

Tables 1 through 4 display the mussel species found at each archeological site by chronological component. The mollusk identifications for these sites were made by three different researchers who used different sources to designate the taxonomic relationship of the shell specimens. No attempt has been made to standardize the nomenclature used in these reports since these differences often represent major taxonomic disagreements among malacologists which are beyond the scope of this paper to resolve. Examples include the use of Quadrula pustulosa for Quadrula asperata, or Proptera purpurata for Potamilus purpuratus.

Those mussel species found in historic collections from Lubbub Creek and the Tombigbee and Tibbee Rivers are displayed in Tables 5 and 6 (Yokley 1975, 1980, 1982). Table 5 is copied directly from Yokley's 1975 review of Tombigbee naiades.

The archeological specimens used in these studies vary in their degree of preservation. The shell periostracum was absent in all cases, and the nacre color was often faded or obliterated. The identifications were based principally upon valve morphology. Archeological specimens were compared to fresh specimens to verify their identification.

Judging from the size of many shell middens associated with sites, Indian groups often used large numbers of freshwater mussels as part of their diet. Because of their limited mobility, mussels would have been available for Indian exploitation nearly all year round. Only high water or ice in more northerly climes would have made them inaccessible. Based upon ethnological accounts, Indians appear to have gathered mussels solely by hand. Women and children were most likely the principal gatherers of these animals. In all probability, those species utilized were gathered from shallow-water areas near the villages. Species which seem to prefer deeper water or burrow completely into the river substrate would have had limited availability, and very small species might have been completely overlooked. The selection of mussel species may also have been by Indian taste or size preference. Yokley (1975:

70) notes that "as a mussel gets older, the foot enlarges and becomes more fibrous and tougher."

Matteson (1953, 1958, 1960), Parmalee (1956), Stansbery (1965), and others have shown that the identification of archeological mollusk remains can aid in the reconstruction of prehistoric environmental conditions. Since many mussel species require specific habitat conditions, the species composition of the archeological assemblage will reflect the past aquatic environments from which they were gathered. Because of their bulk and the effort required to transport them, the majority of mussel remains at any one archeological site probably came from a single nearby mussel bed.

In examining Tombigbee archeological materials, a number of inferences can be made about prehistoric mussel populations and past riverine environmental conditions. The naiad species found in the archeological samples are the same that have been recovered historically from the Tombigbee River and its tributaries. The Indians were most frequently using those species which historically seem to have preferred to inhabit gravel and sand bars in shallow water with moderate to swift current. Species such as Megaloniaias gigantea, Proptera purpurata, Plectomerus dombeyana, Anodonta imbecillis, etc., which are now generally found in deeper water or quiet pools, are in a minority or absent.

At multicomponent sites not all species occur in the same frequencies for each component. Some of these changes in frequency may represent sample collection errors, but they may also signify changes in the species composition of the mussel beds through time. These sorts of changes happen naturally but could also have been caused by selective human exploitation. The Lubbock Creek site most dramatically displays these changes. During the Miller III occupation of the site (A.D. 500-1000), Fusconaia ebena and Quadrula asperata were the most frequently represented species in the sample, with each respectively making up 27 and 33 percent of the shell sample. This was not the case, however, for the three later Summerville occupations (A.D. 1000-1650) where Pleurobema decisum made up between 33 and 47 percent of the sample and Elliptio crassidens represented from between 16 and 27 percent of the total. For each of the Summerville occupations Q. asperata formed approximately 11 percent of the shell sample and F. ebena made up less than 4 percent of each (Woodrick 1981a). Similar species frequency changes are noted at 1Gr1 and 1Gr2 (Woodrick 1981b). At the Kellogg site though, the species makeup of the Miller II, Miller III, and Mississippian components are much more comparable. Pleurobema decisum makes up an average of 55 percent of the total shell from each occupation (Rummel 1980).

Five species of freshwater mussels endemic to the Mobile River Basin are currently under status review for possible addition to the endangered species list. These five include Quadrula stapes, Pleurobema curtum, P. marshalli, P. taitianum, and Epioblasma (=Dysnomia) penita. Williams (1982), in a report on these five species, stated that all five commonly inhabit gravel and sandbars in shoal areas having moderate to swift current. Similar areas would have been exploited for mussels by the Indians, and several of these species were, in fact, present in the archeological shell samples. Assuming that these shells were not considered undesirable for eating, their numbers in these

samples may reflect in a relative way their former abundance in the Tombigbee and Tibbee Rivers.

Quadrula stapes was found at only two of the sites, Yarborough and Kellogg. The 11 valves of this species found at Yarborough made up only 0.39 percent of the total identified shells. At Kellogg, 11 valves were found with the Miller III component (A.D. 500-1000), and 1 valve with the Mississippian component (A.D. 1000-1650), representing respectively 0.38 and 0.04 percent of each component's total shells. Quadrula stapes was either not very abundant in the past or at least was not a favored food source.

No specimens of Pleurobema curtum or Pleurobema marshalli were recovered from any of the five archeological sites. However, considering the current state of confusion surrounding the genus Pleurobema, archeological specimens of P. curtum or P. marshalli may have been identified as a similar species of Pleurobema, or in the case of P. marshalli as Fusconaia ebena, which it is superficially said to resemble (Williams 1982).

A single valve of Pleurobema taitianum was recovered from the Mississippian component at the Kellogg site. None were noted from the other four sites. Williams (1982) found, however, that specimens of P. cordatum identified by van der Schalie (1938) from the lower Cahaba River are identical to P. taitianum material from the Alabama and Tombigbee Rivers. Perhaps the P. cordatum material from the Lubbub and lGr2 sites could actually be specimens of P. taitianum. At lGr2 P. cordatum represents only a miniscule part of the total shell sample, but at the Lubbub Creek site this species represents between approximately 2 and 11 percent of the total, depending upon the component.

Epioblasma (=Dyanomia) penita was found at three of the five sites: Lubbub Creek, Yarborough, and Kellogg. While this species was not the major type found at any of the three sites, it was well represented in each of the site components. At its maximum it represented nearly 10 percent of the total shell associated with the Mississippian component at the Kellogg site. In the analysis of the Yarborough material it should be noted that Hanley (1982) recognized E. penita and E. compacta as two separate species. However, Johnson (1978) in his recent study of the genus Epioblasma included E. compacta in the synonymy for E. penita. Based upon the recovery frequency in the archeological samples, E. penita was obviously a consistent part of the mussel fauna of the Tombigbee River system.

In summary, of the five species currently under status review, only E. penita was found regularly in the archeological samples. The other four species are either not present or are represented by only a small number of valves. If Williams (1982) is correct in his belief that shoal areas are the preferred habitat for these species, they should have been readily available for Indian exploitation. Their absence from the shell samples strongly suggests (a) that they were never very abundant species in the upper Tombigbee River system, or (b) that they were abundant only in isolated beds. It may also be possible that we are mistaken about their preferred habitats. Some of these species may be found outside shallow shoal areas. Of the other species recovered at the archeological sites, the majority are types that seem to prefer gravel and sandbars in shoal areas and all have been historically documented as being present in the Tombigbee River system.

Discussion

Question: Can you describe the condition of the shells that were found at these sites?

Robison: Most were only fragments, and very few whole shells were encountered. However, this varied from site to site and depended on whether or not the shells were just dumped on the ground or perhaps buried in a feature, a hole excavated in the ground.

Comment by Dr. Harold Murray: I recently came across some information recorded by priests who came into South Texas in 1771. They referred to the Indians "gathering" shell fish with horses. I do not know exactly how this was done. Perhaps the Indians built dredges out of fibers or plants and these were pulled by the horses. On the other hand the old Spanish word for "gather" can also mean "transport" and if that is the translation then we have another concept.

Comment by an unidentified individual, referencing remarks by John Latendresse regarding the early use of cedar bushes to collect mussels: Perhaps they towed cedar bushes behind the horses.

Murray: I did an archaeological study of an old Indian site in South Texas. I examined 18,000 fragments and valves and identified about 12,000 to the genus or species level. One of the things that puzzled me was the total lack of the genus Anodonta in these collections. These samples dated from 3,400 B.C. to 1200 A.D.; we can guess that Anodonta did not come into South Texas until the advent of Euro-Americans into the area.

Question: Did you notice any differences between abundance or scarcity of certain species in the river today as opposed to their abundance or scarcity in some of your archaeological samples?

Robison: The Anodontines are more common today than they were previously. Although other changes have probably taken place through time, I am not sure of them right now.

Question: Is there any evidence that Indians used these shells for purposes other than food?

Robison: Yes, they were used as tools frequently. The smaller shells were frequently used to scrape hides. The larger species, such as Megalonaias, sometimes had holes drilled in them for attachment to sticks for use as hoes. Mississippian groups (from 1000 to about 1650 B.C.) used crushed shells in pottery making. The shell fragments were mixed with pottery clay to act as a bonding agent to help hold the clay together during the drying and firing process. However, freshwater mussels were not as readily used for decorative purposes as were the marine shells.

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Table 1
Kellogg Site (22C1527) Naiades

Species	Late Gulf Formational		Miller II		Miller III		Mississippian	
	#	%	#	%	#	%	#	%
<u>Amblema plicata</u>			2	1.96	61	2.10	31	1.40
<u>Fusconaia ebena</u>					37	1.27	35	1.58
<u>Fusconaia cerina</u>					62	2.14	45	2.04
<u>Quadrula apiculata</u> <u>aspera</u>							1	0.04
<u>Quadrula asperata</u>			10	9.80	369	12.76	169	7.74
<u>Quadrula metanevra</u>							3	0.13
<u>Quadrula rumphiana</u>					4	0.13	1	0.04
<u>Quadrula stapes</u>					11	0.38	1	0.04
<u>Tritogonia verrucosa</u>					13	0.44	11	0.49
<u>Elliptio arctatus</u>					2	0.06	1	0.04
<u>Elliptio crassidens</u>			20	19.60	270	9.33	234	10.62
<u>Elliptio arcus</u>			9	8.82	192	6.64	250	11.35
<u>Pleurobema decium</u>	6	85.71	59	57.84	1571	54.34	1141	51.81
<u>Pleurobema perovatum</u>					32	1.10	4	0.18
<u>Pleurobema taitianum</u>							1	0.04
<u>Lasmigona complanata</u>							1	0.04
<u>Epioblasma penita</u>			2	1.96	179	6.19	208	9.44
<u>Lampsilis straminea</u> <u>claibornensis</u>					11	0.38	10	0.45
<u>Lampsilis ornata</u>					10	0.34	2	0.09
<u>Ligumia recta</u>							1	0.04
<u>Plagiola lineolata</u>					5	0.17	5	0.22
<u>Obovaria jacksoniana</u>					2	0.06	5	0.22
<u>Obovaria unicolor</u>	1	14.28			25	0.86	25	1.13
<u>Truncilla donaciformis</u>					1	0.03	1	0.04
<u>Villosa lienosa</u>					15	0.51	2	0.09
<u>Obliquaria reflexa</u>					19	0.65	14	0.63
Total	7	99.99	102	99.98	2891	99.88	2202	99.93

Table 2
Yarborough Site (22C1814) Naiades

<u>Species</u>	<u>#</u>	<u>%</u>
<u>Amblema costata</u>	562	20.21
<u>Fusconaia ebenus</u>	11	0.39
<u>Fusconaia flava</u>	6	0.21
<u>Fusconaia rubida</u>	52	1.87
<u>Fusconaia undata</u>	80	2.87
<u>Quadrula metanevra</u>	3	0.10
<u>Quadrula pustulosa</u>	65	2.33
<u>Quadrula quadrula</u>	39	1.40
<u>Quadrula stapes</u>	11	0.39
<u>Tritogonia verrucosa</u>	75	2.69
<u>Megalonaias gigantea</u>	7	0.25
<u>Elliptio arcata</u>	11	0.39
<u>Elliptio crassidens</u>	586	21.07
<u>Elliptio dilatata</u>	250	8.99
<u>Pleurobema decium</u>	621	22.33
<u>Pleurobema nux</u>	22	0.79
<u>Strophitus tombigbeensis</u>	1	0.03
<u>Dysnomia compacta</u>	41	1.47
<u>Dysnomia penita</u>	21	0.75
<u>Ellipsaria lineolata</u>	11	0.39
<u>Lampsilis claibornensis</u>	64	2.30
<u>Lampsilis excavata</u>	10	0.35
<u>Lampsilis teres</u>	29	1.04
<u>Leptodea leptodon</u>	1	0.03
<u>Ligumia recta</u>	11	0.39
<u>Obovaria castanea</u>	17	0.61
<u>Obovaria unicolor</u>	121	4.35
<u>Proptera purpurata</u>	9	0.32
<u>Truncilla donaciformis</u>	5	0.17
<u>Obliquaria reflexa</u>	38	1.36
Total	2780	99.84

Table 3
Lubbub Creek Site (1P185) Naiades

Species	Middle Miller III		Summerville I		Summerville II-III		Summerville IV	
<u>Amblema plicata</u> <u>perplicata</u>	40	2.66	5	1.61	34	3.49	45	3.05
<u>Fusconaia ebena</u>	403	26.86	5	1.61	33	3.38	42	2.84
<u>Fusconaia rubida</u>	27	1.80	9	2.91	47	4.82	55	3.72
<u>Fusconaia cerina</u>	1	0.06						
<u>Plectomerus dombeyana</u>	1	0.06						
<u>Quadrula asperata</u>	489	32.60	33	10.67	107	10.98	159	10.77
<u>Quadrula aspera</u>	2	0.13			2	0.20	3	0.20
<u>Quadrula metanevra</u>	27	1.80	5	1.61	47	4.82	30	2.03
<u>Tritogonia verrucosa</u>	12	0.80	1	0.32	1	0.10	8	0.54
<u>Megalonaias gigantea</u>					1	0.10		
<u>Elliptio crassidens</u>	22	1.46	82	26.53	181	18.58	230	15.59
<u>Elliptio dilatatus</u>	5	0.33	7	2.26	11	1.12	57	3.86
<u>Elliptio arctatus</u>							1	0.06
<u>Pleurobema cordatum</u>	89	5.93	5	1.61	110	11.29	54	3.66
<u>Pleurobema decisum</u>	105	7.00	138	44.66	320	32.85	688	46.64
<u>Epioblasma penita</u>	9	0.60	3	0.97	6	0.61	11	0.74
<u>Plagiola lineolata</u>	32	2.13	1	0.32	7	0.71	17	1.15
<u>Lampsilis excavata</u>	40	2.66	5	1.61	3	0.30	4	0.27
<u>Lampsilis straminea</u>	13	0.86	2	0.64	2	0.20	8	0.54
<u>Ligumia recta</u>	3	0.20	1	0.32				
<u>Obovaria unicolor</u>	74	4.93	5	1.61	22	2.25	31	2.10
<u>Obovaria subrotunda</u>	52	3.46	2	0.64	21	2.15	14	0.94
<u>Potamilus purpuratus</u>	6	0.40						
<u>Villosa lienosa</u>	2	0.13						
<u>Obliquaria reflexa</u>	46	3.06			19	1.95	18	1.22
Total	1500	99.92	309	99.90	974	99.90	1475	99.92

Table 4
Naiades From Sites 1Gr1x1 and 1Gr2

Species	1Gr1x1				1Gr2					
	Miller II		Miller III		Miller I		Miller II		Miller III	
<u>Amblema plicata</u>	19	1.72	4	1.03			6	1.01	2	0.47
<u>Fusconaia ebena</u>	508	46.05	132	34.19	7	14.00	378	63.63	174	41.13
<u>Fusconaia flava</u>									3	0.70
<u>Fusconaia undata</u>	4	0.36								
<u>Quadrula asperata</u>	321	29.10	163	42.22	22	44.00	83	13.97	95	22.45
<u>Quadrula aspera</u>	3	0.27	3	0.77			4	0.67		
<u>Quadrula metanevra</u>	42	3.80	8	2.07			5	0.84	13	3.07
<u>Tritogonia verrucosa</u>	1	0.09							1	0.23
<u>Elliptio crassidens</u>	51	4.62	10	2.59			34	5.72	20	4.72
<u>Elliptio dilatatus</u>	41	3.71	14	3.62			12	2.02		
<u>Pleurobema cordatum</u>					1	2.00			2	0.47
<u>Pleurobema decisum</u>	14	1.26	1	0.25	14	28.00	32	5.38	52	12.29
<u>Plagiola lineolata</u>	41	3.71	8	2.07			10	1.68	9	2.12
<u>Lampsilis ovata</u>	2	0.18								
<u>Lampsilis teres</u>	1	0.09	7	1.81					2	0.47
<u>Lampsilis excavata</u>									6	1.41
<u>Lampsilis radiata</u>	1	0.09	16	4.14	3	6.00			2	0.47
<u>Lampsilis fasciola</u>	3	0.27								
<u>Ligumia recta</u>	2	0.18								
<u>Obovaria unicolor</u>	22	1.99	10	2.59	2	4.00	8	1.34	19	4.43
<u>Proptera purpuratus</u>	2	0.18	3	0.77			4	0.67		
<u>Truncilla truncata</u>	1	0.09	1	0.25						
<u>Obliquaria reflexa</u>	24	2.17	6	1.55	1	2.00	18	3.03	23	5.43
Total	1103	99.93	386	99.92	50	100.00	594	99.96	423	99.86

Table 5
A List of the Naiads in the Tombigbee River Exclusive
of its Tributaries (from Yokley 1975)

Species	Hinkley 1906	Van der Schalie 1939	Yokley & Gooch 1974
<u>Strophitus tombigbeensis</u> Lea	Yes	Yes	Yes
<u>Arcidens confragosus</u> Say	Yes	Yes	Yes
<u>Lasmigona complanata</u> Barnes	Yes	No	Yes
* <u>Megalonia gigantea</u> Barnes	No	Yes	Yes
* <u>Plectomerus dombeyana</u> Val.	Yes	Yes	Yes
* <u>Tritogonia verrucosa</u> Raf.	No	Yes	Yes
* <u>Quadrula aspera</u> Lea	Yes	Yes	Yes
* <u>Quadrula rumphiana</u> Lea	Yes	Yes	Yes
* <u>Quadrula metanevra</u> Raf.	Yes	Yes	Yes
* <u>Quadrula stapes</u> Lea	Yes	Yes	Yes
* <u>Quadrula asperata</u> Lea	Yes	Yes	Yes
* <u>Amblema plicata perplicata</u> Conrad	Yes	Yes	Yes
* <u>Fusconaia ebena</u> Lea	Yes	Yes	Yes
* <u>Fusconaia rubida</u> Lea	Yes	Yes	Yes
<u>Pleurobema decium</u> Lea	Yes	No	Yes
<u>Pleurobema marshalli</u> Frierson	No	Yes	Yes
<u>Pleurobema nucleopsis</u> Conrad	Yes	No	Probably
<u>Pleurobema bulbosum</u> Lea	Yes	No	Yes
<u>Pleurobema nux</u> Lea	Yes	No	Yes
<u>Pleurobema taitianum</u> Lea	Yes	No	Yes
<u>Pleurobema curtum</u> Lea	Yes	No	Yes
* <u>Elliptio crassidens</u> Lam.	Yes	Yes	Yes
<u>Elliptio arctatus</u> Conrad	Yes	Yes	Yes
<u>Elliptio dilatatus</u> Raf.	Yes	Yes	Yes
* <u>Obliquaria reflexa</u> Raf.	Yes	Yes	Yes
* <u>Plagiola lineolata</u> Raf.	Yes	Yes	Yes
* <u>Obovaria unicolor</u> Lea	Yes	Yes	Yes
<u>Obovaria</u> sp.	Yes	Yes	Yes
<u>Truncilla truncata</u> Raf.	Yes	Yes	No
* <u>Truncilla donaciformis</u> Lea	Yes	Yes	Yes
* <u>Leptodea fragilis</u> Raf.	Yes	Yes	Yes
<u>Potamilus inflatus</u> Lea	No	Yes	No
* <u>Potamilus purpuratus</u> Lam.	No	Yes	Yes
<u>Toxolasma parva</u> Barnes	Yes	No	No
<u>Medionidus acutissimus</u> Lea	Yes	No	Yes
<u>Medionidus moglameriae</u> Van der S.	No	Yes	No
* <u>Ligumia recta</u> Lam.	Yes	Yes	Yes
<u>Villosa lienosa</u> Conrad	Yes	Yes	Yes
* <u>Lampsilis anodontoides</u> Lea	Yes	Yes	Yes
* <u>Lampsilis radiata claibornensis</u> Lea	Yes	Yes	No
<u>Lampsilis affinis</u> Lea	Yes	No	No
<u>Lampsilis apicina</u> Lea	Yes	Yes	Yes
* <u>Lampsilis excavata</u> Lea	Yes	Yes	Yes
<u>Epioblasma penita</u> Conrad	No	No	Yes
<u>Epioblasma metastriata</u> Conrad	No	Yes	No
<u>Anodonta imbecillis</u> Say	No	No	Yes
Total Number of Species	37	34	40

* Species collected alive

Table 6
Modern Naiads Found in the Tibbee River Drainage
and Lubbub Creek

<u>Species</u>	<u>Total Number Collected</u>	
	<u>Tibbee River</u>	<u>Lubbub Creek</u>
<u>Anodonta grandis</u>	7*	1
<u>Anodonta imbecillis</u>	2*	-
<u>Strophitus subvexus</u>	5*	-
<u>Tritogonia verrucosa</u>	2*	17*
<u>Quadrula rumphiana</u>	7*	-
<u>Quadrula asperata</u>	7*	59*
<u>Amblema plicata perplicata</u>	20*	-
<u>Fusconaia cerina</u>	1	21*
<u>Pleurobema decium</u>	-	21*
<u>Pleurobema perovatum</u>	-	9*
<u>Elliptio crassidens</u>	2	1*
<u>Elliptio arcus</u>	4	15
<u>Unio merus tetralasmus</u>	4*	-
<u>Obovaria unicolor</u>	-	31*
<u>Obovaria jacksoniana</u>	-	6*
<u>Leptodea fragilis</u>	33*+	1
<u>Medionidus acutissimus</u>	-	5
<u>Potamilus purpuratus</u>	1*	-
<u>Toxolasma paulus</u>	7	-
<u>Villosa iris nebulosa</u>	7*	6
<u>Villosa lienosa lienosa</u>	24*+	49*
<u>Lampsilis teres teres</u>	13*+	1*
<u>Lampsilis straminea straminea</u>	208*+	-
<u>Lampsilis straminea clai bornensis</u>	-	85*
<u>Lampsilis ornata</u>	-	4*
<u>Lampsilis perovalis</u>	-	2*

* One or more found live

+ Others observed

A SURVEY OF MUSSELS ALONG THE OHIO RIVER*

by

John C. Williams**

I have just completed the field work on a mussel survey of the Ohio River. Our work involved 664 river miles, from the city of Ashland, Kentucky, mile 317, all the way to the mouth of the Ohio River at mile 981. This is actually a follow-up study of our earlier work on the mussel beds of the Ohio River which was completed in 1967. The present study was funded in part by the U. S. Army Engineer District, Louisville.

First of all, I would like to emphasize that studies such as this should be done about every 4 or 5 years on the larger rivers. As you know, the Ohio River has undergone some drastic changes with development of high-level dams and increase in navigation traffic over the last few years. For example, currents which used to move along the shoreline are now being concentrated more in the middle of the river. This has permitted silt to settle in some areas and is probably responsible for the loss of some mussel beds along the shoreline.

We are now in the process of completing our report, and it should be finished in June of 1983. Right now I can say that we have noted some species composition changes in the Ohio River when we compare our most recent data to the 1967 survey.† In addition, some mussel beds have disappeared, and in some cases new ones have actually appeared.

* Transcribed from a tape, reviewed by the author.

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A SURVEY OF THE FRESHWATER MUSSEL FAUNA OF THE
LITTLE KANAWHA RIVER BASIN

by

John E. Schmidt,* Michael A. Zeto,** and Ralph W. Taylor

Acknowledgements

This survey was a cooperative effort between Marshall University, Department of Biological Sciences, and the West Virginia Department of Natural Resources, (WVDNR) Division of Water Resources. The authors would like to thank Jack Numaw, WVDNR, and graduate students Karen Horn and Beverly Spurlock and undergraduate student Karla McCloud for their assistance in the field and lab.

Introduction

The West Virginia Department of Natural Resources, Division of Water Resources, is currently undertaking a statewide survey of West Virginia's freshwater mussel resources. Although some work has been done recently in the State by Drs. Stansbery (Stansbery 1980), Taylor (Taylor 1980), and others (Taylor and Hughart 1981; Morris and Taylor 1978; Taylor and Horn 1982; Zeto 1982; Schmidt, Fisher and Kain 1982; Bates 1979), a large portion of the State and several of its large river systems remain unstudied.

The purpose of this statewide survey is to identify where healthy populations of freshwater mussels exist. This will provide baseline data for future wastewater management decisions. Once identified, these populations will be sampled periodically for changes in diversity and/or for tissue and shell analyses of pesticides and metals. Areas not found to have mussels in initial surveys will be checked periodically to determine if improved water quality has brought about a return of the mussels.

The Little Kanawha River Basin was surveyed for freshwater mussels as part of the statewide survey. This basin was chosen first because it is an important tributary ($\bar{x}$ flow = 3100 cfs) of good water quality to the Ohio River, and Dr. Ralph Taylor of Marshall University had previously sampled portions of the study area.

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Description of the Basin

Location and Size

The Little Kanawha River meanders for approximately 169 miles from its headwaters in Upshur County in north-central West Virginia to its confluence with the Ohio River at Parkersburg. The drainage area includes 1,479,447 acres, or about 2,312 square miles.

Physical Description

The Little Kanawha River Basin lies entirely within the Appalachian Plateau Physiographic Province and displays the typical steep hills, narrow ravines, and ridges of a maturely dissected plateau. The Little Kanawha River and its numerous tributaries have cut deep channels into the ancient plateau forming a dendritic pattern across the basin. Rail and vehicular transportation routes follow the meandering streams, occupying most of the level land of the narrow stream flood plains.

Along the Ohio River and the lower reaches of the Little Kanawha River, terraces and broad lowlands are distinctive topographic features. The valleys consist of broad bottoms and terraces of gravel, sand, silt, and clay. The terraces rise above the river channel, forming narrow to wide strips of fertile land.

Upstream, the basin becomes successively more rugged and inaccessible, rising to elevations of 2,390 feet above sea level in the headwaters of Upshur County. At Burnsville, 120.5 miles upstream from its mouth at Parkersburg, the Little Kanawha River is approximately 750 feet above sea level. The river's average rate of fall from its source to Burnsville is 33.8 feet per mile. In contrast, along the lower 120.5 miles of the river the rate of fall is only 1.3 feet per mile.

Tributaries

The major tributaries of the Little Kanawha River are the Hughes River, Reedy Creek, West Fork, Leading Creek, and Steer Creek. The Little Kanawha River system comprises about 415 miles of main tributaries.

Water Quality

The streams and rivers of the basin are turbid the majority of the year. While water quality is considered good, major problems include sedimentation due to soil conditions aggravated by timbering and oil and gas exploration and elevated fecal coliforms due to inadequate domestic wastewater treatment (West Virginia Department of Natural Resources 1982).

Methods and Materials

A total of 29 stations were sampled for freshwater mussels between June 1981 and September 1982 (Figure 1). These stations were selected from the 923 sites sampled for water quality in the basin (West Virginia Department of Natural Resources 1982). During water quality sampling, stations having mussel populations were noted. All stations, except those sampled by brailing, had at least one riffle and one pool. Water-willow (Justicia americana) was the predominant aquatic vegetation at each station. Table 1 provides exact location information. Station 13 was omitted due to the small amount and poor quality of the material collected.

All stations were examined during low-flow conditions. Stations 1 through 9, 21, and 22, were sampled by walking the banks looking for shells and using a waterscope to locate live specimens. Stations 20 and 23 through 28 were sampled by walking the banks. Station 29 was sampled with a 10-foot dovetail brail.

Brailing was performed at fifteen locations on the Little Kanawha River from Little Kanawha River Mile (LCRM) 1.9 to LCRM 15.0. Each brail drag was approximately 200 meters in length. After each drag the brail was raised and cleaned of mussels and debris.

As material was collected in the field, a preliminary species list was compiled for each station. Live specimens were retained only if suitable dead material was not found. Live specimens were sacrificed in the field and their soft parts removed and discarded. All collected material was then bagged, labeled, and returned to the lab for positive identification. Dr. David Stansbery (Ohio State University) aided in the identification of difficult specimens and confirmed all others. Voucher specimens have been accessioned in the Ohio State University Museum of Zoology or the Marshall University collection.

Results and Discussions

A total of 27 species of freshwater mussels was collected from the Little Kanawha River drainage basin (Table 2). The asiatic clam, Corbicula sp., was also collected, but not with the regularity expected. A total of 19 species was recorded from the Hughes River system, the largest tributary to the Little Kanawha River. One species, Lasmigona complanata, was found only in the Hughes River (Station 2) and not in the remainder of the Little Kanawha River system.

Only two specimens were collected by brailing on the Little Kanawha River. These were collected at LCRM 14.4 below the first riffle at Slate, West Virginia. Below this point the river bottom may have been too soft and the current too slow for abundant freshwater mussel populations to exist. This section of the Little Kanawha River is also affected by Ohio River backwater which causes heavy sediment deposition in this lower area.

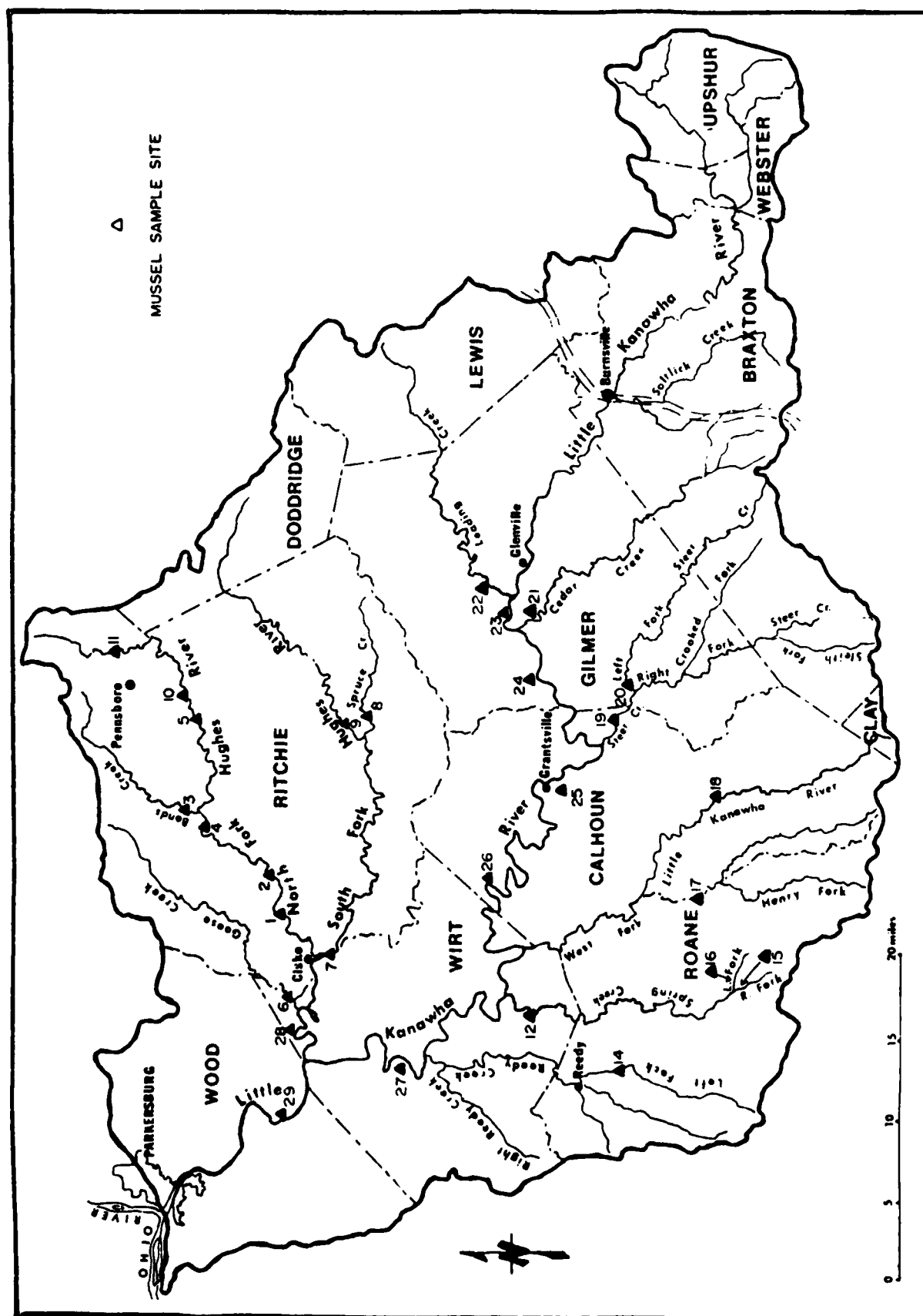


Figure 1. Sites sampled for freshwater mussels in the Little Kanawha River Basin, West Virginia

Freshwater mussels were abundant at many stations (Table 2). As expected, species diversity generally increased with increasing stream order. This trend has been noted by other researchers (Harman 1974, Schmidt 1982). The diversity exhibited in some of the small tributaries--Station 21 (Cedar Creek), 10 species; Station 22 (Leading Creek), 14 species--was surprising.

Lampsilis radiata luteola was collected at 27 of the 28 stations sampled in the basin. This mussel is the most abundant species in the small and medium-sized tributaries of the Ohio River in West Virginia. Fusconaia flava was represented at 24 stations and Obovaria subrotunda and Lasmigona costata at 19 stations each. These three species, in addition to Lampsilis radiata luteola, typically comprised a significant portion (40-60 percent) of the material collected at each sampling station.

Due to its widespread distribution and abundance, the Water Resources Division considers Lampsilis radiata luteola an important indicator species. By using Lampsilis radiata luteola in our pesticide and metal analyses, greater accuracy in comparing results between stations can be made.

Several species were represented at only one or two stations: Anodontoidea ferussacianus, Simpsonia ambigua, Lasmigona complanata, Cyclonaias tuberculata, Pleurobema clava, Truncilla truncata, and Villosa lienosa (Table 2). Taylor and Horn (1982) included Pleurobema clava and Villosa lienosa in their list of rare, threatened, and endangered freshwater mussels in West Virginia.

The Little Kanawha River system appears to have healthy freshwater mussel populations. The Division of Water Resources should be able to utilize one or two of the 28 stations for its freshwater mussel water quality monitoring network. These stations will be chosen as baseline data stations and/or to monitor an upstream pollution point source.

Table 1
List of Stations Sampled

Station	Latitude	Longitude	Location
1	39° 10' 19"	81° 10' 38"	North Fork Hughes River off County Route 15, 3.2 km S Cairo (Ritchie Co.)
2	39° 11' 51"	81° 10' 04"	North Fork Hughes River off County Route 31/12 @ Cairo (Ritchie Co.)
3	39° 13' 47"	81° 06' 57"	Bonds Creek of North Fork Hughes River off County Route 8 @ Cornwallis (Ritchie Co.)
4	39° 13' 32"	81° 07' 13"	North Fork of Hughes River off County Route 8 @ Cornwallis (Ritchie Co.)
5	39° 13' 12"	81° 05' 06"	North Fork Hughes River off County Route 12, 1 mi. NE Harrisville (Ritchie Co.)
6	39° 08' 42"	81° 20' 12"	Goose Creek of North Fork Hughes River off State Route 47 @ Freeport (Wirt Co.)
7	39° 06' 28"	81° 16' 19"	South Fork of Hughes River @ State Route 47, 2.4 km NW of Girta (Ritchie/Wirt Co.)
8	39° 04' 38"	81° 01' 08"	Spruce Creek of the South Fork of Hughes River off County Route 19, 6.4 km E Smithville (Ritchie Co.)
9	39° 06' 28"	81° 00' 16"	South Fork of Hughes River off County Route 28 @ Prunty (Ritchie Co.)
10	39° 13' 33"	81° 00' 38"	North Fork of Hughes River off County Route 12 near Hannahdale (Ritchie Co.)
11	39° 18' 40"	80° 56' 15"	North Fork of Hughes River off County Route 74/9, 3.2 km NE Pennaboro (Ritchie Co.)
12	38° 57' 15"	81° 20' 17"	Spring Creek of Little Kanawha River off County Route 36, 1.6 km S Sanoma (Wirt Co.)
13	Spring Creek at Beaver Dam - omitted		
14	38° 52' 05"	81° 24' 23"	Left Fork of Reedy Creek of Little Kanawha River off State Route 14, 4.8 km S Reedy (Roane Co.)
15	38° 47' 05"	81° 21' 42"	Right Fork of Spring Creek @ U. S. Route 119, 8.0 km S of Spencer (Roane Co.)
16	38° 47' 23"	81° 21' 05"	Left Fork of Spring Creek @ State Route 36, 0.4 km S Spencer (Roane Co.)
17	38° 47' 47"	81° 13' 20"	Henry Fork of Little Kanawha River @ U. S. Route 119, 1.6 km SE Triston (Roane/Calhoun Co.)
18	38° 46' 08"	81° 06' 35"	West Fork of Little Kanawha River off State Route 16, 3.2 km SW Millstone (Calhoun Co.)
19	38° 52' 30"	81° 02' 25"	Steer Creek of Little Kanawha River @ County Route 7, 1.6 km N Dodrill (Calhoun Co.)
20	38° 51' 56"	80° 59' 33"	Left Fork of Steer Creek off U. S. Route 119 near Stumptown (Gilmer Co.)
21	38° 56' 28"	80° 54' 50"	Cedar Creek off County Route 17, 8.0 km W Glenville (Gilmer Co.)
22	38° 57' 37"	80° 52' 27"	Leading Creek off County Route 12, 4.0 km NW Glenville (Gilmer Co.)
23	38° 57' 13"	80° 53' 09"	Little Kanawha River off State Route 5, 5.2 km W Glenville (Gilmer Co.)
24	38° 56' 01"	80° 58' 13"	Little Kanawha River off State Route 5, 4.8 km E of Calhoun/Gilmer County line (Gilmer Co.)
25	38° 54' 31"	81° 05' 09"	Little Kanawha River off County Route 7, 0.8 km SE Grantsville (Calhoun Co.)
26	38° 58' 42"	81° 21' 03"	Little Kanawha River off County Route 1, 0.8 km S Industry (Calhoun Co.)
27	39° 00' 38"	81° 20' 29"	Little Kanawha River off State Route 5, 2.4 km E Enterprise (Wirt Co.)
28	39° 08' 19"	81° 21' 00"	Hughes River off State Route 47, 1.2 km W Freeport (Wirt Co.)
29	39° 08' 50"	81° 27' 22"	Little Kanawha River off County Route 14, 2.4 km NW Leachtown (Wood Co.)

Table 2

A List of the Freshwater Mussels Collected at Each Station in the Little Kanawha River Basin, West Virginia

Species	Stations																												
	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
<u>Anodonta g. grandis</u>	X	X								X	X	X		X	X	X													
<u>Anodontoides ferussacianus</u>																					X								
<u>Strophitus u. undulatus</u>	X	X	X	X	X			X	X	X	X	X	X	X		X			X	X	X	X	X	X					
<u>Simpsoniopsis subigua</u>			X									X																	
<u>Lasmigona complanata</u>																													
<u>Lasmigona costata</u>	X	X	X	X	X	X	X	X		X		X			X	X	X	X	X	X	X	X	X	X					
<u>Tritigonia verrucosa</u>	X	X														X													
<u>Quadrula quadrula</u>												X										X						X	
<u>Quadrula p. pustulosa</u>												X								X	X	X	X	X				X	
<u>Amblopus p. plicata</u>	X	X					X		X	X		X				X	X	X		X	X	X	X	X	X	X	X		
<u>Fusconia flava</u>	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
<u>Cyclonaias tuberculata</u>																													
<u>Pleurobema clava</u>								X																					
<u>Pleurobema sintoxia</u>		X						X										X				X	X	X	X	X	X		
<u>Elliptio dilatata</u>		X			X	X	X	X	X	X		X						X	X	X	X	X	X	X	X	X	X		
<u>Pychobranchus fasciolaris</u>	X						X		X	X								X		X	X	X	X	X	X	X	X		
<u>Actisonaias ligamentina carinata</u>												X						X				X	X	X	X	X	X		
<u>Obovaria subrotunda</u>	X	X	X	X	X	X	X	X	X	X		X					X	X	X	X	X	X	X	X	X	X	X		
<u>Truncilla truncata</u>																													
<u>Leptodes fragilis</u>	X	X																											
<u>Potamilus alatus</u>	X																												
<u>Villosa i. iris</u>	X	X			X		X	X	X											X	X								
<u>Villosa lienosa</u>																													
<u>Lampilis radiata luteola</u>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
<u>Lampilis ventricosa</u>	X	X		X				X	X	X		X					X	X	X	X	X	X	X	X	X	X	X		
<u>Lampilis fasciola</u>																		X			X	X	X	X	X	X	X		
<u>Epiblasma triquetra</u>	X						X									X				X	X	X	X	X	X	X	X		
<u>Corbicula sp.</u>							X		X			X				X		X	X	X	X	X	X	X	X	X	X		

Discussion

Question: How did you chose your sampling stations? From your map it looks as though certain stations are quite far apart, and I wonder if some species could have been missed during the survey.

Schmidt: My colleague, Mike Zeto, is a basin planner for our state. He had done extensive work on water chemistry and benthic studies throughout the Basin, in excess of 900 sites, before we established our stations for mussel sampling. Our sampling stations were placed only at locations where Mike Zeto had previously noted the presence of mussels.

Question: Did you save any of the tissues of the animals you sacrificed during your survey? Could you use these tissues for bioassay work related to water quality problems?

Schmidt: We only collected live material when suitable shells were not found. In addition, our lab requires about 1/2 lb of mussel tissue for its work; this could mean 10 to 15 individuals would be needed for an assay. We never collected that many live individuals. Our work was primarily to determine what species of mussels were inhabiting the river. Later, mussels will be collected for tissue analysis.

Question: So you really did not sacrifice any animals for test purposes?

Schmidt: No.

Question: Is there much coal mining in that area?

Schmidt: There is coal mining in just about every county in West Virginia. We noticed coal fines in almost all of the streams. However, in this particular area, oil and gas exploration is the major problem, along with inadequate sewage treatment. There are no sewage treatment plants in Wood, Wirt, Ritchie, Roane, and Calhoun counties.

Question: Did you have any other records of Villosa lienosa from your part of West Virginia?

Response by Dr. Ralph Taylor: It is common in some streams of the state, although it is considered a Midwestern species. We found it in the Pocatalico River and Twelvepole Creek.

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NAIAD RESEARCH IN MISSOURI

by

Alan C. Buchanan*

Naiad research in Missouri has had an "on-again, off-again" history. The amount and types of research conducted have been directly related to the general interest in naiades commercially and environmentally. During the pearl button industry in the early 1900's, intensive research was conducted on the distribution and reproduction of naiades. Later, as the industry declined, so did the amount of research. The Endangered Species Act of 1973 revived interest in naiad research.

William I. Utterback conducted the first distributional research on Missouri naiades during the early 1900's. He published "The Naiades of Missouri" in 1915 and 1916, in which he described 100 species and subspecies of naiades from Missouri and presented limited information on their distribution. His "Naiadgeography of Missouri," published in 1917, contained more complete distributional information.

From Utterback's early research until the early 1950's, little formal research was conducted on Missouri naiades. During the 1950's two sisters, Frieda Schilling and Hessie Kemper, began to collect naiades from Missouri streams while their husbands fished. As the years passed, their proficiency at identifying naiades increased, and they eventually assembled a reference collection of all of the species then known in Missouri. Dr. David Stansbery, a well-known malacologist from Ohio State University, provided expert assistance to Schilling and Kemper.

Beginning in the 1960's, Ron Oesch also began collecting naiades from Missouri streams. With the help of Schilling, Kemper, and Dr. Stansbery, Oesch set out to document the distribution of naiades in the major streams of Missouri. The results of his work, "The Naiades of Missouri," is being published by the Missouri Department of Conservation and will be available in mid-1983.

The Missouri Department of Conservation's formal involvement in naiad research began in 1977 when a biologist was hired to survey the naiades of the Meramec River Basin. Prior to that time, several Department biologists collected naiades incidentally while conducting research on other aquatic organisms and water quality, but no naiad-specific research was conducted. Since 1977 the Missouri Department of Conservation has conducted a number of naiad studies, each designed to provide specific information for proper management of naiad populations.

All studies we have conducted fall into one or more of the following categories: (a) endangered species studies, (b) general species composition and distribution surveys, or (c) impact assessment. Endangered species studies involved determining the distribution, relative abundance, and/or habitat requirements of either the pink mucket pearly mussel (Lampsilis orbiculata) or

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the Curtis pearly mussel (Epioblasma florentina curtisi) in one or several Missouri streams. General species composition and distribution studies involved determining the species composition and distribution of all naiad species in one or more streams. Impact assessments involved determining the species composition, particularly of endangered species, at one or more sites in a reach of stream likely to be impacted by dam construction, channelization, bridge construction, gravel dredging, sewage plant modernization (upgrading), or pollution of various types. Most of our naiad research falls under at least two of the above categories. A survey of the naiades of the Lower Osage River Basin conducted in 1980, for example, not only identified areas where endangered species might be impacted by gravel dredging, but also delineated the distribution of the pink mucket pearly mussel, an endangered species, and other naiad species in the Lower Osage River Basin.

Each study has been designed according to (a) information needs, (b) study objectives, (c) stream characteristics, and (d) funds available. The study objectives are based on information needs, and the sampling design is selected according to the types of information needed. For example, the design of a study to determine the impact of dredging on a short section of stream would be much different from a study to determine the distribution of a number of species in an entire stream system, or a study to determine the life history of one or more species of naiades. If more than one agency is involved, the study must meet the objectives and fill the informational needs of all agencies.

Characteristics such as stream size and depth, flow velocity, water and air temperature, water clarity, and bottom type, of the lake, stream, or stream segment being sampled directly affect the sampling design. Some collecting techniques may be used under a wide variety of conditions and water types, while others are best suited for very specific conditions. We collect naiad shells along shore and from muskrat and raccoon middens on all streams. Large middens have contained over twenty naiad species. In shallow stream reaches, such as headwaters, living naiades are collected from the stream bottom while wading. Collection by sight works well in clear waters, but collection by feel is necessary in turbid water. In water 3 to 8 feet deep, snorkeling is a more effective method in slow current. In deeper waters, or where the current is strong, SCUBA diving is the best collecting technique. A crowfoot bar (brail) can be very effective in streams with relatively even bottoms. Missouri's Ozark streams, however, generally have irregular bottoms composed of gravel, cobble, and boulder, which do not lend themselves well to brailing.

Water temperature also impacts the types of sampling gear which can be used. A crowfoot bar is relatively ineffective when the water temperature is less than approximately 55°F, due to the slow response time of naiades. Water and air temperatures also affect collecting since wading in shorts can become rather uncomfortable in the Midwest during late fall and winter.

The effects of funding on a sampling scheme are obvious. Funding affects not only the types of gear you can afford to use, but also the frequency, intensity, and duration of the sampling effort. While sampling in shallow streams in tennis shoes and shorts is relatively cheap, collecting naiades with SCUBA in a large river is possible only after acquisition of the appropriate gear and training.

As an example of what is involved in planning and conducting a naiad research project, I will discuss two studies which the Missouri Department of Conservation conducted during the past 5 years.

Meramec River Basin

We conducted a survey of the naiades of the Meramec River Basin during 1977 and 1978 to provide information needed to evaluate the potential impacts of five Corps of Engineers' reservoirs proposed for the Meramec River Basin (Fig. 1). Of primary concern was the pink mucket pearly mussel (Lampsilis orbiculata), an endangered species known to occur in the lower Meramec River. The objectives of the study were to: (a) determine the distribution, relative abundance, and ecological requirements of the federally classified "Threatened" or "Endangered" naiad species found in the Meramec River Basin and (b) determine the distribution, relative abundance, and ecological requirements of all other naiad species which occur in the Meramec River Basin. The study was funded by the U. S. Army Engineer District, St. Louis.

The Meramec River Basin, approximately 4,000 square miles in area, is located in east-central Missouri (Fig. 1). The river flows 236 miles northeast from its origin in southern Dent County to empty into the Mississippi River south of St. Louis. It has a mean annual flow of approximately 3,000 cfs, and its principal tributaries are the Bourbeuse and Big Rivers and Huzzah, Courtois, and Dry Fork Creeks.

We collected naiades at 198 sites (Fig. 1) at approximately 5-mile intervals in order to systematically sample the entire Meramec Basin. The sampling techniques used at each site depended on the stream characteristics at each site. All habitat types were sampled at each site until we were confident that we had collected representatives of all the species present.

Forty-five species of naiades were found in the Meramec River Basin; 42 in the Meramec River, 39 in the Bourbeuse River, and 34 in Big River (Table 1). Of the 45 species found, 9 common species comprised nearly 80 percent of the living naiades found (Table 2). Lampsilis orbiculata, the species of primary concern for this project, was found only in the downstream 5 miles of Big River and downstream 55 miles of Meramec River, and comprised only 0.1 percent of the living naiades found. Of the 11 species classified as rare or endangered in Missouri, or federally, only Cumberlandia monodonta comprised more than 0.2 percent of the living naiades found.

Our results illustrate the importance of sampling at regular intervals over the length of a stream or basin. Two species found in the Meramec River Basin during this study, the salamander mussel (Simpsonaias ambigua) and the cylindrical paper shell (Anodontoidea ferussacianus), were found at only one and three sites, respectively, of the 198 sites sampled. They had not been previously reported from Missouri. Had we sampled only a few sites less, both species could have been missed.

The distribution of each naiad species in the Meramec River Basin reflected its habitat requirements (Fig. 2). Each bar in Figure 2 represents the

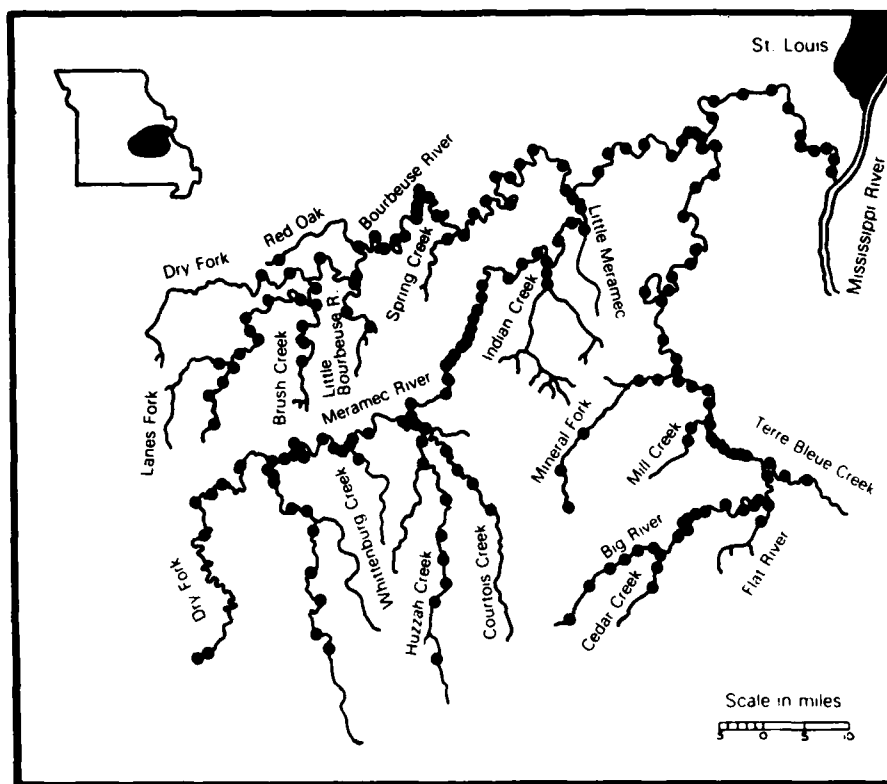


Figure 1. Sampling sites in the Meramec River Basin

Anodontoides ferussacianus
Simpsonaias ambigua
Ligumia subrostrata
Alasmidonta viridis
Lampsilis reeviana brittsi
Quadrula pustulosa
Cyclonaias tuberculata
Lampsilis t. teres
Corbicula leana
Cumberlandia monodonta
Plethobasus cyphus
Obliquaria reflexa
Truncilla truncata
Ligumia recta
Leptodea leptodon
Elliptio c. crassidens
Plagiola lineolata
Megalonaia nervosa
Arcidens confragosus
Truncilla donaciformis
Potamilus ohioensis
Lampsilis t. anodontoides
Lampsilis orbiculata
Fusconaia ebena
Quadrula quadrula
Anodonta g. corpulenta
Anodonta imbecillus
Anodonta g. grandis
Strophitus u. undulatus
Alasmidonta marginata
Lasmigona complanata
Lasmigona costata
Tritogonia verrucosa
Quadrula metanevra
Amblema p. plicata
Fusconaia flava
Pleurobema coccineum
Elliptio dilatata
Actinonaias l. carinata
Venustaconcha e. ellipsiformis
Leptodea fragilis
Potamilus alatus
Lampsilis r. luteola
Lampsilis ventricosa
Epioblasma triquetra
Toxolasma parvus

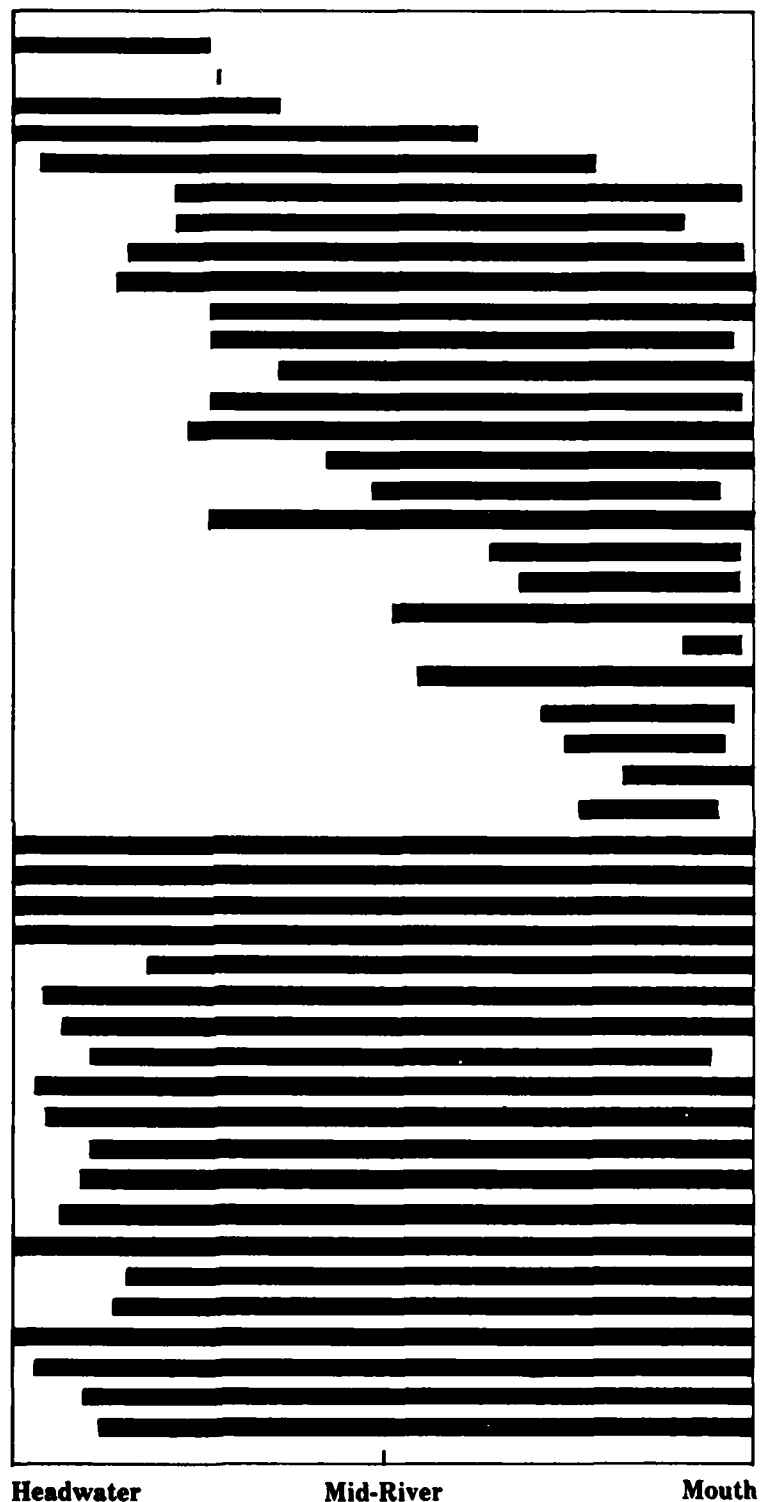


Figure 2. Respective distribution of naiades in reference to river reach in the Meramec River Basin (from Buchanan 1980)

distribution of a species over the length of the Meramec River Basin. While some species, such as the pond mussel (Ligumia subrostrata) and the cylindrical paper shell (Anodontoides ferrussacianus), were found only in headwaters, others, such as the ebony shell (Fusconaia ebena) and the maple leaf (Quadrula quadrula), were found only in the lower, large river portions of the basin. Twenty of the forty-five species found had a cosmopolitan distribution and occurred from headwaters to mouth.

The information gathered during this study is being used by a number of agencies, including the U. S. Army Corps of Engineers, U. S. Fish and Wildlife Service, Missouri Department of Conservation, and Missouri Department of Natural Resources, to manage and protect naiad populations in the Meramec River Basin.

Epioblasma florentina curtisi in the Upper Little Black River

The second study, conducted during 1980 and 1981, was called "Study of the Curtis Pearly Mussel, Epioblasma florentina curtisi, in the Upper Little Black River." This study was a followup to a 1979 survey of the naiades of the Little Black River Basin in southeastern Missouri. The 1979 survey was conducted to determine if any federally classified "Threatened" or "Endangered" naiades were present which might be impacted by 25 dams, a stream diversion structure, and 3.1 miles of channelization proposed for the Little Black River Basin (Fig. 3). During the 1979 study the Curtis pearly mussel was found at three sites in approximately 5 miles of the upper Little Black River. Once E. f. curtisi was found, a second study was conducted to evaluate the potential impacts of the two largest proposed impoundments, which were located approximately 4 and 6 miles upstream from the populations. Both the 1979 and 1980-81 studies were funded by the Missouri State Office of the U. S. Soil Conservation Service.

The primary objective of the 1980-81 study was to determine the distribution, abundance, habitat preference, and age structure of populations of E. f. curtisi in the upper Little Black. A secondary objective was to determine, if possible, the reproductive success of E. f. curtisi. The first step in the study was to further delineate the distribution of E. f. curtisi within the study reach. Ten sites were sampled in the Little Black River at approximately 1-mile intervals upstream and downstream from the reach in which this species had been found previously. Two sites were also sampled on Flat Creek, a tributary which empties into the Little Black in the area where E. f. curtisi occurs.

We found the Curtis pearly mussel 1.2 miles further upstream in the Little Black River than we found it previously (Fig. 4). It was not, however, found any further downstream. Therefore, this species only occurred in 6.1 miles of the upper Little Black River.

Once we knew its distribution, we set out to determine the abundance, age structure, and habitat requirements of populations of E. f. curtisi in the upper Little Black River and to compare sites where this species occurs to sites where it does not. Five sites, three sites where E. f. curtisi occurred

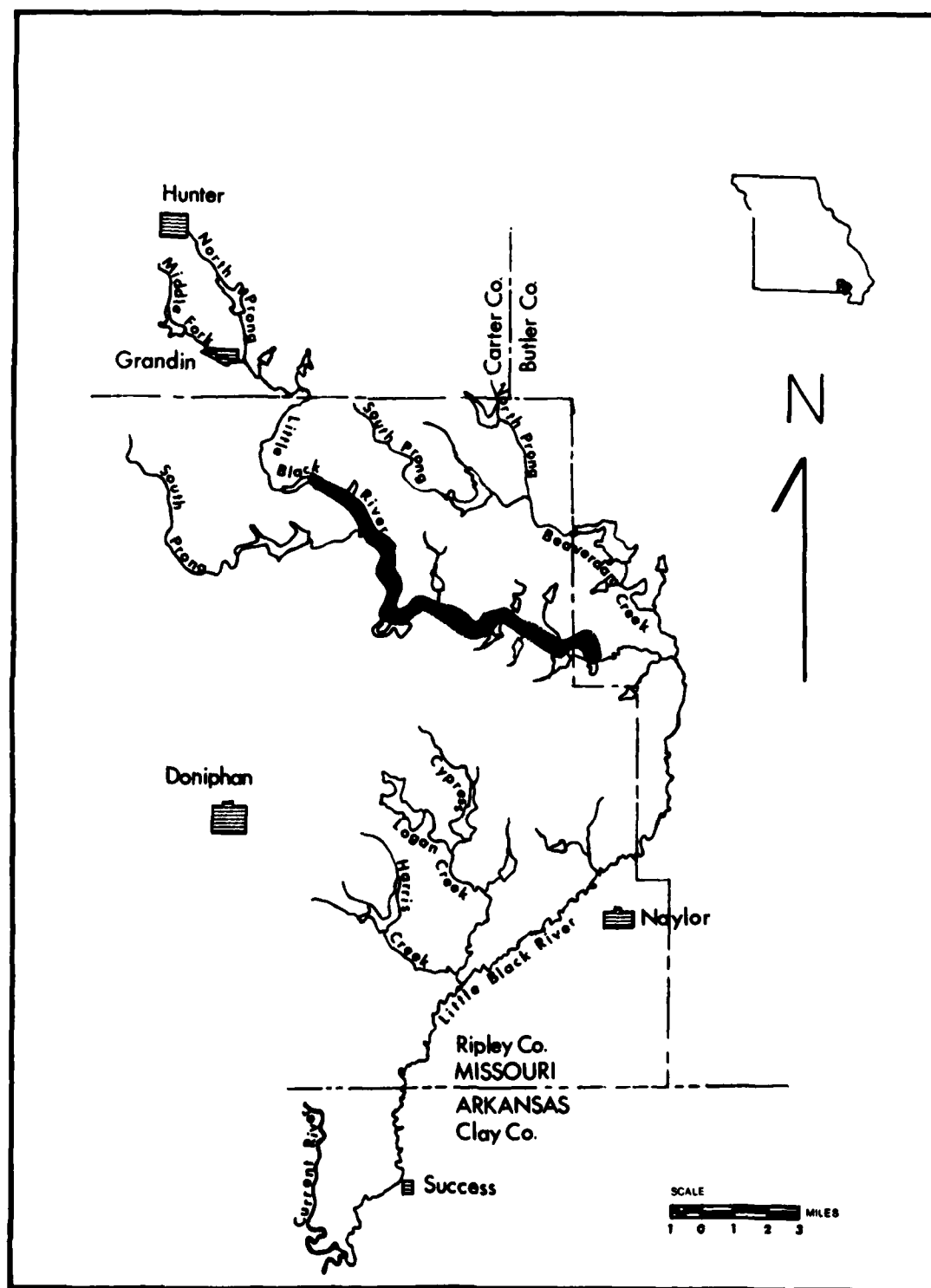


Figure 3. Study area on the Little Black River, Missouri

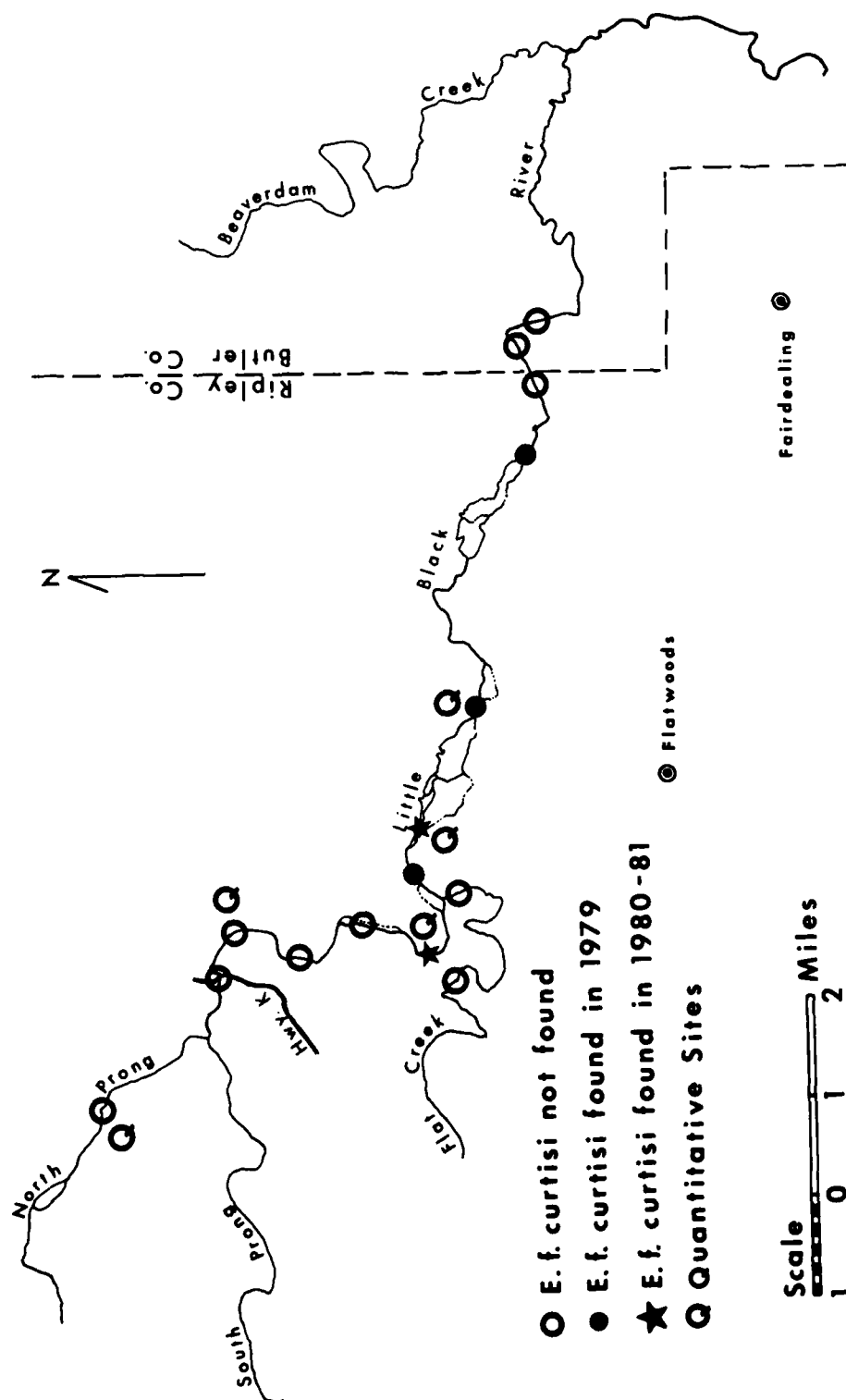


Figure 4. Location of sampling sites on the Little Black River

and two sites where it did not occur, were selected for further study. At each site, 35 to 100 m of riffle which appeared to provide suitable habitat for E. f. curtisi was selected. Randomly selected transects were marked off, and 2 to 7 quadrats ($1/2 \text{ m}^2$), depending upon the width of the stream, were sampled in each transect. Approximately 5 percent of the bottom area was sampled at each site in order to make statistically reliable estimates of naiad numbers. The substrate was sampled twice to a depth of 4 to 6 inches in each quadrat and all the naiades and Asiatic clams (Corbicula leana) counted. Six hundred quadrats were sampled at the five sites.

Water quality measurements, including dissolved oxygen, temperature, pH, total hardness, alkalinity, total phosphorus, and total nitrogen, were made quarterly at each site. Substrate samples were taken at each site by forcing a 1-gallon can into the bottom and removing a portion of the substrate. Substrate samples were analyzed to determine mean particle size and organic content. At each point where a living specimen of E. f. curtisi was found, the current velocity was measured and the water depth and substrate type were noted. All living E. f. curtisi found were aged, sexed, measured, marked, and returned unharmed to the habitat.

We found little difference in the abundance of naiades or dominant naiad species present among the three sites where E. f. curtisi occurs and two sites where it does not occur (Table 3). At the three sites where E. f. curtisi occurs, 6.4 naiades/ m^2 were found, while at the two sites where it does not occur, 5.5 naiades/ m^2 were found. The ladyfinger (Elliptio dilatata) was the most abundant species at the E. f. curtisi sites, while Britt's shell (Lampsilis reeviana brevicula) was the most abundant species at the non-E. f. curtisi sites. The same six species (Elliptio dilatata, Pleurobema coccineum, Fusconaia flava, Lampsilis reeviana brevicula, Ptychobranchus occidentalis, and Villosa lienosa lienosa) comprised over 85 percent of the living naiades found both at sites where E. f. curtisi occurs and sites where it does not occur. Lampsilis reeviana brevicula, typically a headwater species, was most abundant at the upstream-most site and least abundant at the downstream-most site.

The Curtis pearly mussel comprised only 0.9 percent of the living naiades found at the three sites where it occurs. Twenty-five of the thirty specimens were found at the site with the greatest diversity and density of all naiades. Based on my experience in other Missouri River basins, endangered species typically occur at sites where the habitat is suitable for a wide variety of naiad species.

There was no significant difference in the substrate composition between sites, or substrate composition where E. f. curtisi was found and where it was not found. This may have been due to too few substrate samples being taken. We also found no significant differences in the water quality parameters among sites and no trends from upstream to downstream ends of the study area.

Thirty specimens of the Curtis pearly mussel, including three females and twenty-seven males, were aged, sexed, measured, and marked during this study. They ranged in length from 15 to 38 mm, and in age from just over 4 years old to 12 years old. Females were 4+ to 5+ years old and males 6 to 12+ years old (Fig. 5). The ratio of males to females was 9 to 1 during both 1980 and 1981,

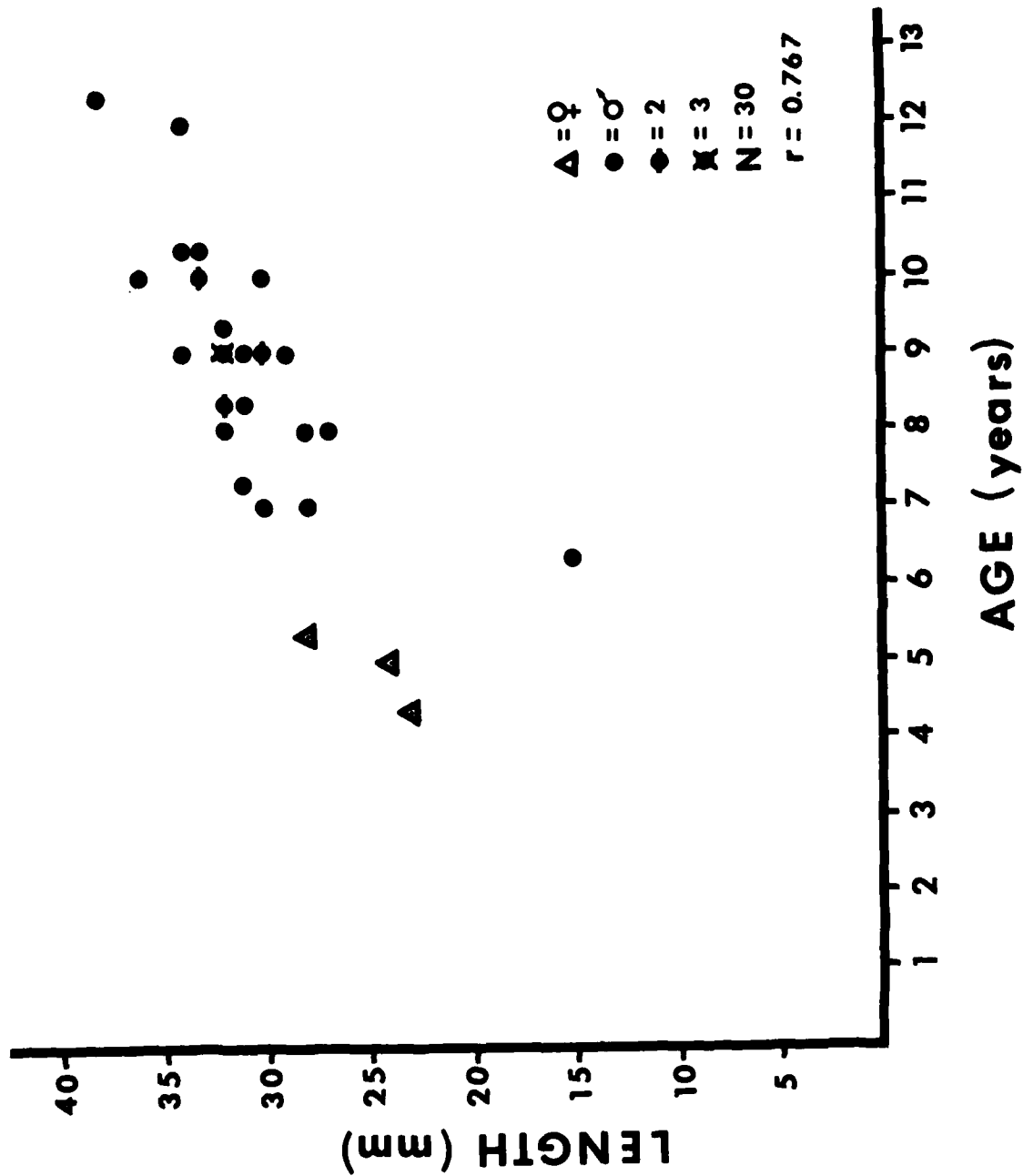


Figure 5. Length and age of *E. f. curtisi* in the Little Black River

and there was generally a linear relationship ($r=0.767$) between age and length of the specimens examined.

A comparison of the historic information on the Curtis pearly mussel and information from the Little Black River indicates that this species occurs in 4 to 30 inches of water, in slow current in or near a riffle, in stream segments of order 4 to 7 with gradients of 1 to 8 feet per mile (Table 4), in a sand and gravel to gravel and cobble substrate. Where E. f. curtisi occurs, the Little Black River is an order 4 stream with a gradient of 5.5 to 7.7 feet per mile and has substrate with an average particle size of gravel. (Since we have data on more specimens from the Little Black River than from all other localities, Little Black data are separated within parenthesis from other data in the gradient and stream order rows under the range column (Table 4). The "Most Common" column usually reflects Little Black data.) This species has never been reported outside Missouri.

Based on the results of the Little Black River study and a survey of E. f. curtisi in southern Missouri, we recommend that the two largest impoundments not be built in the Little Black River Basin. Most of the remaining E. f. curtisi occur in the Little Black River. Loss of the Little Black populations would ultimately result in the extinction of this species.

Naiad research in Missouri is mushrooming. The studies described are just two of a number of studies which are completed or in progress. Two biologists in the Missouri Department of Conservation are using naiades to monitor levels of pollutants in Missouri streams: Jim Czarnecki is using naiades to monitor lead levels in Big River, and Ron Crunkilton is using naiades to monitor dioxin levels in Spring River. We are also conducting a survey of the naiades of the Salt River Basin in Missouri. Dr. Marc Imlay of the Columbia National Fisheries Research Laboratory, U. S. Fish and Wildlife Service; Dr. Gerald Summers of the University of Missouri; and Mark Gordon of the University of Arkansas are also doing research on Missouri naiades. The more we know about naiades the more aware we are of their value to the aquatic ecosystem and as biological monitors. Because of their long lives and relative immobility, naiades may eventually become our most valuable indicators of stream quality.

Discussion

Question: What mussels do you use for monitoring?

Buchanan: Amblema plicata because it is very common in Missouri and it is a good monitor organism.

Question: How much time do you spend sampling with the circular ($1/2\text{-m}^2$ -area) frame?

Buchanan: Quantitative sampling is very time-consuming. On the Little Black River it took two people 2 to 3 days to sample 150 quadrats. We sampled approximately 5 percent of the bottom area at a site. The Little Black River where we sampled averages about 25 meters in width. In large streams it might

take 1 to 2 weeks to quantitatively sample a site with only two people working.

Question: When using the circular frame do you physically remove substrate from it or simply push it to one side while searching for mussels?

Buchanan: We remove all of the larger (3-inch-diameter or greater) substrate from the frame as we work. This keeps the rock out of the way when we search the framed area for mussels a second time.

Question: Why did the U. S. Soil Conservation Service (SCS) fund your work?

Buchanan: They have 25 impoundments, 3.1 miles of stream channelization, and a stream diversionary structure planned for the Little Black River Basin. The two largest impoundments are 4 and 6 miles upstream from the area where the Curtis pearly mussel occurs. We are trying to predict what impacts these two impoundments will have on that species.

Question: So your survey of the Meramec River was published and is available?

Buchanan: Yes. The St. Louis District funded the study and paid half of the publication costs of the final report.

Question: What other reports have you published on your mussel research in Missouri?

Buchanan: Besides the Meramec River study, nothing else has been published. However, if you contact me I can send you photo copies of our unpublished reports.

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Table 1
Number of Species Found in the Meramec River Basin

	<u>No. of Species</u>
Meramec River Basin	45
Meramec River	42
Bourbeuse River	39
Big River	34
State rare & endangered	10
Federally endangered	1

Table 2
The Relative Abundance of the Dominant Species and the Rare and Endangered Species of Naiades Found in the Meramec River Basin

<u>Dominant Species</u>		
<u>Species</u>	<u>Relative Abundance (%)</u>	<u>Number of Sites Where Found</u>
<u>Amblema plicata plicata</u>	18.1	103
<u>Actinonaias ligamentina carinata</u>	17.4	81
<u>Lampsilis radiata luteola</u>	11.6	53
<u>Elliptio dilatata</u>	6.9	95
<u>Lampsilis ventricosa</u>	6.3	133
<u>Lampsilis reeviana brittsi</u>	5.9	72
<u>Quadrula pustulosa</u>	3.9	81
<u>Fusconaia flava</u>	3.7	101
<u>Venustaconcha e. ellipsiformis</u>	3.1	93
Total of Dominant Species	76.9	
<u>Rare & Endangered Species</u>		
<u>Species</u>	<u>Relative Abundance (%)</u>	<u>Number of Sites Where Found</u>
<u>Cumberlandia monodonta</u>	2.2	31
<u>Anodonta grandis corpulenta</u>	0.2	6
<u>Anodontoides ferussacianus</u>	*	3
<u>Arcidens confragosus</u>	*	11
<u>Simpsonaias ambigua</u>	*	1
<u>Fusconaia ebena</u>	*	6
<u>Plethobasus cyphus</u>	0.2	40
<u>Elliptio c. crassidens</u>	*	6
<u>Leptodes leptodon</u>	*	14
<u>Lampsilis orbiculata</u>	0.1	13
<u>Epioblasma triquetra</u>	0.1	21
Total of Rare & Endangered Species	2.8	

** = less than 0.1%

Table 3
Numbers and Dominant Species of Naiades Found at Sites Where Epioblasma florentina curtisi
Occurs and Sites Where It Does Not Occur in the Little Black River

	<u>E. f. curtisi Sites (3)</u>	<u>Non-E. f. curtisi Sites (2)</u>
Number/m ²	6.4	5.5
Dominant Species (Rel. %)	<u>Elliptio dilatata</u> (30.8) <u>Pleurobema coccineum</u> (28.2) <u>Ptychobranhus occidentalis</u> (8.3) <u>Villosa l. lienosa</u> (7.4) <u>Lampsilis reeviana brevicula</u> (7.0) <u>Fusconaia flava</u> (4.1)	<u>Lampsilis reeviana brevicula</u> (30.6) <u>Elliptio dilatata</u> (26.7) <u>Pleurobema coccineum</u> (15.7) <u>Ptychobranhus occidentalis</u> (8.5) <u>Fusconaia flava</u> (3.7) <u>Villosa l. lienosa</u> (2.7)
<u>Epioblasma f. curtisi</u>	Less than 0.1/m ² (0.9%)	0

Table 4
Characteristics of the Habitat Where Epioblasma florentina curtisi Has Been Found

	<u>Range</u>	<u>Most Common</u>
Depth	4 to 30 inches	Same
Current	Slow (less than 0.2 m/Sec. to 0.22 m/Sec.)	Same
Substrate	Sand and gravel to gravel and cobble	Gravel
Gradient	1 to 8 ft./mi. (5.7 - 7.7 ft./mi.*)	5.7 to 7.7 ft./mi.
Stream Order	4 to 7 (4*)	4

* - Little Black River.



THE STATUS OF FRESHWATER MUSSEL RESEARCH IN VIRGINIA

by

Richard J. Neves*

Acknowledgements

I thank Richard Johnson, David Stansbery, Sally Dennis, and Steve Ahlstedt for sharing their taxonomic expertise. Most of the research described constitutes thesis projects of graduate students Alexander Zale, Lynn Weaver, James Widlak, Lisie Kitchel, Steve Moyer, Paul Pajak, Sally Dennis, and Richard Ayers. Paul Eschmeyer, Garland Pardue, and Doug Smith kindly reviewed the manuscript.

Introduction

Virginia has a diverse molluscan fauna, consisting primarily of riverine species in the eastern and southwestern part of the state. The occurrence and zoogeography of approximately 20 species of freshwater naiades (mussels) that occur in the rivers of the Atlantic drainage species were summarized by Johnson (1970). In southwestern Virginia, the Clinch, Powell, and Holston Rivers are major tributaries of the upper Tennessee River and contain roughly 50 species of freshwater mussels. This extremely diverse faunal group consists of many endemic species and forms unique to the Cumberland Plateau Region, an area that includes portions of seven states bordering the southern Appalachians. A detailed description of this important geographic area and its geologic history was provided by Hayes and Campbell (1894) and Ross (1971). The Cumberland Plateau was one of the major centers of naiad speciation, and endemic fauna are generally referred to as Cumberlandian species (Ortmann 1924). Along with these endemics are mussel species common to the larger Ohio-Mississippi River Basins. Currently nine species of freshwater mussels in Virginia's Cumberland Plateau Region are included on the U. S. Department of the Interior's Endangered Species List (Table 1).

Only limited data existed on the mussels of southwestern Virginia prior to 1970. The most significant work on the Cumberlandian fauna was Ortmann's (1918) monograph on naiades of the upper Tennessee River. This work contained the best available data on mussel taxonomy and distribution in the Clinch, Powell, and Holston Rivers before dams were constructed on lower sections of these rivers. Since then, several works have provided updated species lists and documented faunal declines in these river basins (Stansbery, 1972, 1973; Stansbery and Clench 1974, 1975, 1978; Bates and Dennis 1978;

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Table 1
Freshwater Mussels on the Federal Endangered Species
List Which are Reported for Virginia

Ambleminae*

<u>Fusconaia cuneolus</u>	Fine-rayed pigtoe
<u>Fusconaia edgariana</u>	Shiny pigtoe
<u>Quadrula intermedia</u>	Cumberland monkeyface
<u>Quadrula sparsa</u>	Appalachian monkeyface

Unioninae

<u>Pleurobema plenum</u>	Rough pigtoe
<u>Conradilla caelata</u>	Birdwing pearly
<u>Dromus dromas</u>	Dromedary
<u>Dysnomia (=Epioblasma) torulosa gubernaculum</u>	Green-blossom
<u>Dysnomia (=Epioblasma) walkeri</u>	Tan riffle shell

* Subfamily designations according to Burch (1975).

Ahlstedt and Brown 1980; Dennis 1981; Ahlstedt 1982; Neves and Zale 1982). An extensive bibliography on the mollusks of the entire Tennessee Valley was compiled by Shoup (1974); however, no information was available on the biology of Cumberlandian mussels, other than a few anatomical descriptions by Ortmann (1921). Knowledge on these endemic and/or endangered species was therefore limited, providing a myriad of opportunities for basic biological research.

Completed Projects

Endangered Mussel Survey

The Virginia Commission of Game and Inland Fisheries (VCGIF) expressed concern for the nine endangered mussel species (Table 1) and exercised its responsibility and authority to protect and conserve these and other mussel populations in southwestern Virginia. With this goal, VCGIF initiated a 3-year study in 1977 through the Virginia Cooperative Fishery Research Unit, the Biology Department at Virginia Polytechnic Institute and State University (Virginia Tech), and the Tennessee Valley Authority (TVA) to (a) develop a literature digest and distribution maps for the endangered species and (b) conduct a mussel survey to locate these species and their habitats in southwestern Virginia. The Virginia Cooperative Fishery Research Unit, which consists of two U. S. Fish and Wildlife Service employees stationed at Virginia Tech through a cooperative agreement between the Service, VCGIF, and Virginia Tech, coordinated this literature and field survey effort. Results of the mussel survey verified the occurrence of seven endangered species in Virginia; shiny pigtoe, fine-rayed pigtoe, Cumberland monkeyface, Appalachian monkeyface, birdwing pearly, dromedary, and tan riffle shell (Neves et al. 1980). An intensive survey in one section of the Clinch River in 1982 collected subfossil shells and one live specimen of the green-blossom mussel. Hence the only endangered species listed for Virginia that has not been found is the rough pigtoe. Six of these species are at such critically low numbers in Virginia that preservation of habitat appears to be the only feasible means of maintaining their continued survival in these rivers. The shiny pigtoe and fine-rayed pigtoe are in less danger of extirpation because of their wider distribution and relatively greater abundance. Based on these survey results and recent TVA surveys (TVA 1979a, 1979b), there are a minimum of 40 river miles in the Clinch, Powell, and Holston Rivers that are considered of utmost importance for the continued survival of most of the endangered mussel populations in Virginia. An assessment of environmental conditions and water quality in southwestern Virginia leads me to be somewhat optimistic about the future of freshwater mussels in the Clinch River and North Fork Holston River above Saltville. However, endangered populations in the Powell River appear headed for extirpation due to accumulated coal-washer wastes and water quality degradation from mining activities.

After this initial study, VCGIF designated the Virginia Cooperative Fishery Research Unit as their agent for research on endangered mollusks in Virginia. Subsequent mussel projects conducted by the Unit are described and summarized in the following sections.

Mussel Life Histories

The glochidia of naiades are obligate parasites on the gills or fins of fish and exhibit at least some degree of host specificity. Fish hosts are known for only 25% of the Unionidae (Fuller 1974), and most of these associations were determined at least 60 years ago by the U. S. Bureau of Fisheries on commercially important species in the Mississippi River (Coker et al. 1982). This facet of mussel research lay dormant for 50 years and was finally resurrected in the last decade (Kakonze 1972; Wiles 1975; Weir 1976; Stern and Felder 1978; Tompa 1979). Since no published data existed on fish hosts of Cumberlandian mussels, the Unit initiated two projects in 1978 to describe the reproductive cycles and identify fish hosts of five species in southwestern Virginia.

Four species of the Lampsilini, which are long-term (bradytictic) breeders, and one species of the Pleurobemini, which are short-term (tachytictic) breeders, were studied in Big Moccasin Creek, a major tributary of the North Fork Holston River. Through integrated laboratory and field studies on Medionidus conradicus, Villosa nebulosa, Villosa vanuxemi, Lampsilis fasciola, and Pleurobema oviforme, gametogenesis, spawning period, embryonic development, glochidial release periods, and fish hosts were described for each of these species (Zale 1980; Weaver 1981; Zale and Neves 1982; Zale and Neves 1982). Results showed that long-term breeders exhibited active gametogenesis throughout the year and spawned in July and August. Glochidia required 8 weeks postfertilization to develop and were released by gravid females over a period of several months. Each species displayed a high degree of fish host specificity. Host fishes among the 24 fish species in the stream were as follows: M. conradicus, redline darter (Etheostoma rufilineatum) and fantail darter (E. flabellare); V. nebulosa, smallmouth bass (Micropterus dolomieu) and rock bass (Ambloplites rupestris); V. vanuxemi, banded sculpin (Cottus carolinae); and L. fasciola, smallmouth bass.

For the short-term breeder P. oviforme, gametogenesis occurred between late spring and early fall and spawning took place in spring. Embryonic development required 3 to 5 weeks, and glochidia were released by gravid females between mid-April and July. Confirmed host fishes for this species included whitetail shiners (Notropis galacturus), river chubs (Nocomis micropogon), common shiners (N. cornutus), and stonerollers (Campostoma anomalum). Although Fuller (1974) did not list cyprinids as known hosts for species of the Unioninae, it appears that minnows (Cyprinidae) are major host species for Pleurobema spp. (Yokley 1972; Weaver 1981) and other short-term breeders in southwestern Virginia.

From these studies, it is apparent that nongame fishes are important hosts for at least some Cumberlandian mussels and that the integrity of the native fish fauna must be maintained to ensure the continuation of these species. The decline in some mussel populations may very well be linked to a changing fish taxocene (species composition or abundance) and not to the often cited, but rarely documented, degradation of physical habitat or water quality. If significant progress is to be made in expediting the restoration of mussel populations, fish host identifications must be considered essential to any overall conservation or recovery program.

Assessment of Project Impacts

The Virginia Fishery Unit, in addition to its research function, serves the State in the capacity of advisor on Section 404 permit applications that are forwarded to the VCGIF for approval. Most proposed projects that could adversely affect aquatic habitats in sections of the Clinch, Powell, and Holston Rivers in which endangered species live are referred to the Unit for review and comment, either by VCGIF or the local endangered species office of the U. S. Fish and Wildlife Service.

The Unit has conducted mussel surveys at sites with old bridges on the Clinch River for the Virginia Department of Highways and Transportation. Our maps of mussel distribution and abundance at these sites have been used by that Department to reduce adverse impacts on mussels and to avoid directly impacting endangered species when the old bridges are removed and replaced. Common freshwater mussels have even been moved out of coffer dam and causeway construction areas, and additional siltation barriers have been erected when critical habitats have been identified downstream. The Unit provides similar service-oriented activities and advice to the Virginia State Water Control Board, the U. S. Soil Conservation Service, Forest Service, National Park Service, and Army Corps of Engineers, and other governmental agencies with responsibilities in or along rivers. The working relationship established between the Virginia Fishery Unit and these agencies has been invaluable in preventing the needless destruction of mussel fauna and habitat in southwestern Virginia.

Projects Underway in 1982

Shiny Pigtoe Life History

Life history research on the endangered shiny pigtoe was begun in 1980 through a contract with the Endangered Species Office and a permit from the Wildlife Permit Office of the U. S. Fish and Wildlife Service. The objectives of this study are to (a) describe the reproductive cycle of this short-term breeder, (b) identify the fish host(s), and (c) determine growth rate and age class structure of a relatively undisturbed population. The field component of this project is being conducted at North Holston Ford, North Fork Holston River at McCrady, Virginia. Field and laboratory studies are nearing completion. Preliminary results indicate that this species releases conglomerates in July. Conglomerates from gravid females contain a low percentage of mature glochidia (30%) and mostly unfertilized eggs. Successful fertilization appears to be a problem in this population, the mean density of which is only 1 shiny pigtoe per 2m² of river bottom. Through microscopy and morphometric work on the glochidia of short-term breeders at this location (Fusconaia barnesiana, F. edgariana, Pleurobema oviforme, and Lexingtonia dolabelloides), the Unit has been able to identify natural infections on 12 cyprinid species by glochidia of these four mussel species. Incidence of infection was not correlated with abundance of fish species. Laboratory studies are being directed toward determining whether induced infections of glochidia on suspected fish hosts of the shiny pigtoe will confirm the field observations.

Techniques for Aging Mussels

Counts of external growth rings on mussel shells have been used most often to estimate age. However, shell erosion, spawning checks, environmental stress, and other extraneous factors may affect the accuracy of this method, and the age of old specimens can only be approximated. This project of aging mussels, which is being funded by the Endangered Species Office, has three objectives: (a) to describe the nature and periodicity of growth lines, (b) to compare ages derived from the external ring method with three other aging techniques (thin sectioning, acetate peel, ashing), and (c) to identify the asymptotic growth model that best fits mussel growth patterns. To follow the chronology of growth line deposition, Unit personnel conducted a mussel-marking program in 1981, using several species in different streams. A low-speed diamond blade saw is being used to provide shell sections for internal aging, and separation of organic growth bands in the shell is being attempted with a muffle furnace. The most reliable aging technique that can be developed will be used to obtain data on size at age and growth rate for several mussel species, including the shiny and fine-rayed pigtoes. A computerized growth model has been developed, consisting of four growth submodels frequently used to describe growth in animal populations (Schnute 1981):

$$Y(t) = Y_{\infty}(1 - e^{-g(t-t_0)}) \quad \text{von Bertalanffy}$$

$$Y(t) = Y_{\infty}e^{-g(t-t_0)} \quad \text{Gompertz}$$

$$Y(t) = Y_{\infty}(1 + e^{-g(t-t_0)})^{-1} \quad \text{logistic}$$

$$Y(t) = Y_{\infty}(1 + 1/p e^{-g(t-t_0)})^{-p} \quad \text{Richards}$$

where $Y(t)$ represents mussel size at age t , and Y_{∞} , g , p , and t_0 are population parameters. Sets of species growth data are to be analyzed by using these growth equations in an Apple II microcomputer to select the most appropriate submodel that describes mussel growth.

Experimental Translocations

Several drastic perturbations have occurred on the North Fork Holston River and Clinch River, Virginia, that have eliminated endangered mussels and dramatically reduced other molluscan species. The North Fork Holston River below Saltville was subjected to a variety of inorganic pollutants (especially chlorides and mercury) over several decades from a now defunct chemical plant. These chemicals eliminated the mussel fauna in 120 km of river below Saltville (Hill et al. 1974). Similarly, the Clinch River below Carbo, Virginia, was adversely affected by 198 million m³ of caustic alkaline slurry (pH 12) in June 1967, when a fly ash holding pond collapsed at the Appalachian Power Company generating plant. The fly ash spill killed fish downstream for 105 river km in Virginia and 38 km in Tennessee (Cairns et al. 1971). All benthic organisms were eliminated for 7 km downstream, and the mussel fauna was eliminated for about 24 km below Carbo. In June 1970, a sulphuric acid spill at the same plant caused another massive kill of aquatic organisms between Carbo and St. Paul (24 km). Ortmann (1918) reported a diverse mussel fauna in these sections of river, and excellent mussel habitat still exists for recolonization.

A translocation study was initiated to identify several sites within each of these river sections that have suitable substrate, water quality, and the appropriate fish hosts for the translocation of several mussel species. In 1981 a total of 1,692 adult mussels of three species, Medionidus conradicus, Villosa nebulosa, and V. vanuxemi, were marked and moved to three sites on the North Fork Holston River below Saltville. Sites were selected that would not interfere with a previous mollusk translocation (Ahlstedt 1980). In addition, a total of 1,359 adult mussels of six species—M. conradicus, V. nebulosa, V. vanuxemi, Amblema costata, Actinonaias carinata, and A. pectorosa—were marked and moved to three sites on the Clinch River below Carbo. Wire baskets made of 0.5-inch hardware cloth were implanted flush with the river bottom and used for the translocation of small species (M. conradicus, V. nebulosa, V. vanuxemi) in both rivers. The other species were planted directly into the substrate. These mussels are being monitored quarterly to document movement, survival, and gravidity of females.

In addition to the translocation of adults, four sites have been selected for an induced propagation experiment. Gravid females of the three small mussel species will be transported to these sites and sacrificed to obtain glochidia; and up to 100 fish hosts for each mussel species will be collected by electrofishing, anaesthetized, infected with glochidia, allowed to recover, and then released. This long-term experiment will be evaluated by quadrant sampling, first in 1985 and again in later years.

Cooperative Work with TVA

The Virginia Cooperative Fishery Research Unit has assisted TVA on two major mussel-related projects in Virginia. One of these is progressing on the Clinch River at St. Paul. The St. Paul Redevelopment Project was conceived by several State and Federal agencies ostensibly to improve the economic future and safety of St. Paul residents from periodic flooding. The Clinch River at St. Paul was modified as follows: a new 1500-ft channel was cut across a narrow meander; part of the old river channel (3,000 ft) is to be filled and used for highway construction, industrial sites, and residential development; and the remaining channel (3,700 ft) will be converted into a shallow fishing lake of 9 acres. The primary effect of this project was the destruction of approximately 2,000 ft of habitat for 25 mussel species including 3 endangered species, the fine-rayed pigtoe, shiny pigtoe, and birdwing pearly mussel.

As a special condition of the Section 404 permit, specimens of endangered species were to be removed from the project area. Some mussels were removed during the early construction phase (fall-winter 1981), but the major relocation effort occurred on May 12, 1982 (the day after diversion). Virginia Fishery Unit personnel and graduate students from Virginia Tech assisted a TVA-coordinated crew of biologists in the collection and relocation of mussels to other suitable habitats in the Clinch River, Virginia. Unfortunately, this salvage effort appeared insufficient to recover all endangered species, and many freshwater mussels perished in the dewatered channel.

The second project deals with life history research on the genus Quadrula. In association with TVA's Columbia Dam Project on the Duck River, life history research on Quadrula intermedia is expected to begin in 1983. To prepare for this project, TVA contracted with the Virginia Fishery Unit to prepare a short

course on laboratory techniques for fish host research and to assist TVA biologists in applying these techniques on a surrogate species, Q. cylindrica, in 1982. A portable laboratory is being maintained by TVA for this research on the Clinch River below Speer's Ferry. The Virginia Fishery Unit is proceeding with a histological study of the reproductive cycle of Q. cylindrica to complement the fish host identification work recently completed by TVA. The field and laboratory experiences gained in this pilot study will provide TVA with the necessary expertise for fish host research in 1983.

Ecology of Juvenile Mussels

Two of the most critical stages during the unique life cycle of naiades are thought to be those of (a) attachment to the appropriate fish host and (b) release of newly metamorphosed juveniles onto a suitable substrate. The place where fish shed young mussels is largely a matter of chance, and only those juveniles that reach favorable habitat will survive (Howard 1922). Although early studies of life histories and habitat requirements recommended specific investigations on the juvenile stage, none were ever conducted. The location and habitat of juvenile mussels (< age 3) has been debated among malacologists for the past 60 years, but without resolution.

The objectives of this new 2-year study, funded by VCGIF, are to (a) locate juveniles in the substrate of a study stream and (b) describe the habitat and ecology of the juvenile stages. Core samples will be taken from various benthic habitats in Big Moccasin Creek, North Fork Holston River, and carefully sorted in search of juveniles. This stream has a diversity of habitat types and an abundance of adult mussels in several sections (Neves and Zale 1982). Successful completion of this labor-intensive project would fill a void in current knowledge of mussel ecology and provide an essential element in critical habitat designation for all ages of endangered species.

Recovery Plans

The U. S. Fish and Wildlife Service is required by the 1973 Endangered Species Act and its amendments to develop recovery plans for all threatened and endangered species under its jurisdiction. To assist in the development of recovery plans for endangered species in Virginia, the Virginia Fishery Unit is working with the Fish and Wildlife Service, Asheville Office, to prepare and submit draft recovery plans for the fine-rayed pigtoe, shiny pigtoe, and tan riffle shell in fiscal year 1983. Most of the endangered Cumberlandian species will have draft recovery plans and critical habitats designated by the end of 1983. These draft documents should lead to Service-approved recovery plans and serve as a basis for future recovery efforts.

Other Mussel Research

I am aware of two additional research projects on freshwater mussels in Virginia. A PhD candidate in the Biology Department at Virginia Tech is completing her dissertation on the influence of habitat on mussel distribution in the Tennessee River drainage, Virginia and Tennessee. The objectives of this project are to characterize the mussel assemblages, to examine faunal changes in recent years and present possible explanations for these changes, and to

evaluate the effects of siltation as a potential limiting factor to mussel occurrence.

The other project is being conducted by an MS candidate at Virginia Commonwealth University. His thesis research centers on the biology of Elliptio complanata in the Pamunkey River, Virginia, and includes fish host identification, gametogenesis, growth rate, age class structure, and population densities in this river. Both of these graduate research topics will contribute to the available data on naiades in Virginia.

+to Tennessee Valley
Conclusion rit

In addition to the previously described mussel research projects in Virginia, (TVA) has undertaken a wide-ranging Cumberlandian Mollusk Conservation Program to (a) accumulate information on the present distribution, life histories, and ecological requirements of the Cumberlandian mussel fauna and (b) conserve or increase populations of these species in the Tennessee River drainage (Jenkinson 1981, 1982). This TVA program has contributed greatly toward a better understanding of species status, water quality problems, and research needs for this unique faunal group. The attention currently being given to freshwater mussels in the upper Tennessee River system is unprecedented, and participating State and Federal agencies are to be commended for supporting conservation activities far beyond what is legally required.

The success of a mollusk conservation effort will depend on public awareness, not of mussels in and for themselves but as indicators of riverine degradation and its effect on environmental health and recreational opportunities for man. It is my perception that malacologists rarely concur on taxonomic issues, but that they unanimously recognize the decline in many taxa throughout the United States. A greater effort is therefore needed to educate and 'sell' the endangered species concept to the general populace. At a recent symposium on the endangered and threatened species of Virginia (Linzey 1979), most of the mussel species in the Clinch, Powell, and Holston Rivers were listed as endangered in the State of Virginia. To an outsider, it appears that an alarmist view was taken by a panel of malacologists to protect their entire faunal group. In my opinion, these intemperate actions have tended to (a) alienate many supporters of the endangered species concept in the State natural resource agencies and (b) weaken the designation of endangered status for truly endangered species, i.e., those in danger of extinction. Biologists must maintain their credibility with society if they are to serve as spokespersons for the silent majority of animal life and convince people of their worth in a healthy environment.

Discussion

Question: How were your measurements made from the glochidia?

Neves: They were made with a binocular microscope and an ocular micrometer.

Question: Did you use a mark and recapture method for the fish you were studying in the North Fork Holston River?

Neves: No, we preserved infected fish from our representative sample. We did not want to intensively sample the fish populations at the sites, since we were concerned about sampling impact on resident populations. Most of the fish sample with glochidia attached were cyprinids. The cyprinids are easily damaged by electrofishing techniques, and we did not want to impact their population numbers and interrupt mussel recruitment by overcollecting. Removal of fishes was therefore kept to a reasonable number.

Question: What about the fish that were artificially infected with glochidia?

Neves: That work was done in the laboratory.

Question: Do you have any indication that Lampsilis sp. ever use darters as host for their glochidia?

Neves: No.

Question: How do you explain the differences between the results of your studies versus those of Billy Isom concerning the question of host-fish specificity from mussels?

Neves: Based on our studies (and I think that John Jenkinson would support this) and studies that TVA has done with Quadrula cylindrica and Conradilla caelata, there is definite host-fish specificity among mussel species. However, I am not sure how to explain these results versus Billy Isom's results. I think that there is a difference in a whole fish being used as a test organism as opposed to serum alone being used as a medium. The treatment of a culture medium as described with fungicides, bacteriocides, etc., may be doing something to the natural immunology of the system; or perhaps limiting factors (chemical concentrations) were not present. I am sure that there can be experiments designed to determine that. In addition, there may be something, such as antibodies, not included in Billy Isom's medium that naturally occurs in fish and accounts for the host specificity. Based on my results I am convinced that there is definitely fish host specificity in most mussel populations.

Question: In the case of glochidia not transforming on a fish, what actually happened? Were the glochidia sloughed off the fish, or did the glochidia attach and then not grow?

Neves: We know they were sloughed off because we could collect them from the bottom of the tanks. This poses a question: are they actively rejected by the fish or is the required biochemical trigger missing so that the glochidia simply die and slough off the fish?

Question: Do the glochidia always attach to the gills of the fish, or are they found on other parts of the body?

Neves: We examined all parts of the fish during the field survey. We did find some glochidia attached to the inner linings on the gill arches of the

sculpins. We did not find any attached to any other parts of the body since we were working with mussel species without hooked glochidia.

Comment by unidentified individual: I have actually seen glochidia on the tail or the dorsal fins of some fish.

Neves: I think that TVA biologists have found glochidia attached around the lips and eyes of some fish.

Comment by John Jenkinson, TVA: Yes, especially on sculpins. We have found glochidia on the scales or anywhere on the body.

Comment by Dr. David Stansbery, Museum of Zoology, Ohio State University: In our observations over the years there seems to be a pattern that Anodontine glochidia (that is the triangulate ones) are typically attached outside and encapsulated on fins, or tissues over the scales, and around the mouth, whereas the smaller glochidia are found on the gill filaments.

Comment by Dr. Paul Yokley, University of North Alabama: I believe that the serum that Billy Isom (TVA) is using is an all-encompassing set of amino acids with no antibodies that are usually present within each species of fish. A glochidium can survive in a mixture of darter or cyprinid amino acids without any antibodies. The glochidium will select and utilize the amino acids it can use and exclude the amino acids it does not need. At no time is the glochidium affected by antibodies which may not be present in the medium.

Neves: I think that there are some laboratory studies that can be designed to determine exactly what serum components produce the host-fish specificity, assuming of course that it does exist, and I am convinced that it does. I believe we could design some experiments to determine what is missing from the medium of Billy Isom that allows all species of glochidia to transform. I believe that there is something missing from the medium system that is present in specific fish which is the source of the host-fish specificity.

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UNIONID DISTRIBUTION AND ABUNDANCE RELATIVE
TO HABITAT CHARACTERISTICS

by

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Introduction

One of the first investigations of lake benthos in North America demonstrated the importance of substratum composition as boulder, gravel, sand, clay, or mud on the distribution and abundance of benthic invertebrates including mollusks (Baker 1918). Coker et al. (1921) emphasized the importance of the bottom sediment on the occurrence of freshwater mussels in their statement, "It may, therefore, be supposed that fresh-water mussels, like other animals, are adapted rather definitely to particular conditions of the environment, ... that a mud bottom supports certain species, while a firmer soil is required by others." They also point out the even more restrictive habitat requirements of young or juvenile mussels compared to adults, which may survive in a variety of habitats. Coker et al. (1921) listed 62 species of mussels along with the general composition of the substratum where they occurred. In the Altamaha River, Georgia, Clench (1962) reported finding Elliptio shepardiana at "mud stations" and Canthytia spinosa on shallow sandbars. In addition to differences in mussel density and species composition in different habitats, Kat (1982) has demonstrated experimentally the influence of substratum type on the growth rate of Elliptio complanata.

The data presented in the following three summaries were obtained in three independent studies in three different aquatic ecosystems: the Altamaha River, a free-flowing river in southeast Georgia (Sickel 1980), the Cumberland River in the tailwaters of Barkley Dam (Sickel 1982), and in Kentucky Lake, the last impoundment of the Tennessee River (Sickel and Chandler 1982). In each study varying efforts were made during sampling to describe the specific habitats where different species of mussels were located. The following summaries of each study indicate some generalizations which have been and are continuing to be formulated by a number of investigators regarding the interactions between unionid mussels and their environment.

Summary I: Altamaha River Unionidae

Seven collection sites in the Altamaha River north of Baxley, Georgia, were selected to include a range of sediment types from the coarse sand of the main

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channel to the fine silt and clay of backwater sloughs. Sediment samples were analyzed with soil sieves and hydrometers to determine the percent of each grain size at the seven sites. Unionid mussels were collected by hand, identified, and counted. Figure 1 presents the particle size distribution at each of the seven sites. A composite diagram showing relative abundance of mussel species with respect to sediment particle size distribution is presented in Figure 2.

Anodonta gibbosa and Anodonta couperiana were found only in a slough with fine sediment of silt and clay. Alasmodonta arcuata, Lampsilis spendida, Elliptio shepardiana, Elliptio dariensis, Elliptio hopetonensis, and Lampsilis dolabraeformis were abundant along the shorelines with sediments ranging from medium sand to medium silt. The only species abundant in the coarse sand of the main channel were Canthyria spinosa and L. dolabraeformis. Other species were occasionally found as young individuals in the coarse sand on sandbars, but not as adults. There is an apparent migration of older mussels to near-shore habitats, which are more stable than the mainstream sandbars or channel, although host fish distribution and behavior are probably the most significant factors in the initial distribution of juvenile mussels.

Summary II: Kentucky Lake, Kentucky, Unionidae

The Kentucky portion of Kentucky Lake was divided into five major habitat types: embayments, shorelines, overbanks, old river levees and the main Tennessee River channel, and sampling with SCUBA was conducted to determine unionid species composition of each habitat (Fig. 3). Species found within each habitat type are given in Table 1.

Embayments were areas of relatively calm, shallow water generally unaffected by the main river currents. Substrates a short distance from shore were typically soft silt although a few embayments on the east side of the lake were primarily sand. Over 70% of the embayment mussel community was composed of Quadrula quadrula, with eleven other species found in much smaller numbers. Carunculina parva was found only in embayments.

Shoreline sites were sampled from the edge of the water toward the river channel. As the lake floor sloped toward the main channel, there was a transition from cobble and large gravel to smaller gravel to sand and then silt. Because of wind and wave action there was constant water movement in this habitat except on very calm days. A total of eleven species was found at shoreline sites, with Tritogonia verrucosa being found only at shoreline sites.

The old river levees, which border the main river channel, were influenced by the river currents. The levee substrates were primarily compact clay that was often covered by a thin layer of silt, sand, or scattered gravel. Plectomerus dombeyanus was found only on the levees, while Fusconaia ebena was found both on the levees and in the main channel, indicating the preference of these species for the more riverine environments or their failure to exploit lake habitats.

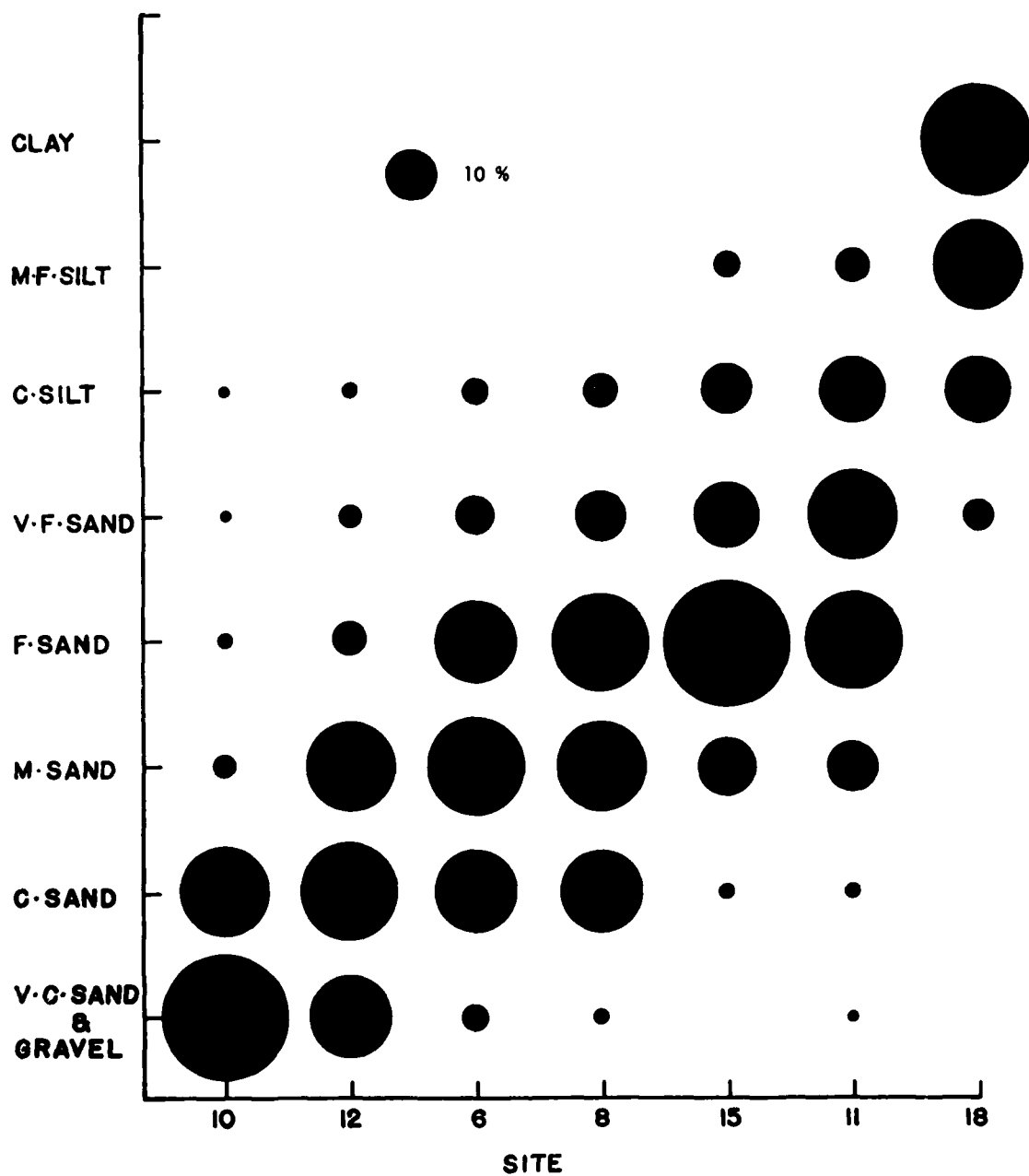


Figure 1. Sediment particle size distribution for the Altamaha River collection sites. The area of each dot represents the percentage of the sediment by weight having the indicated particle size. A standard area is indicated by the dot marked 10%. The abbreviations VF, F, M, C, and VC represent very fine, fine, medium, coarse, and very coarse particle size designations, respectively

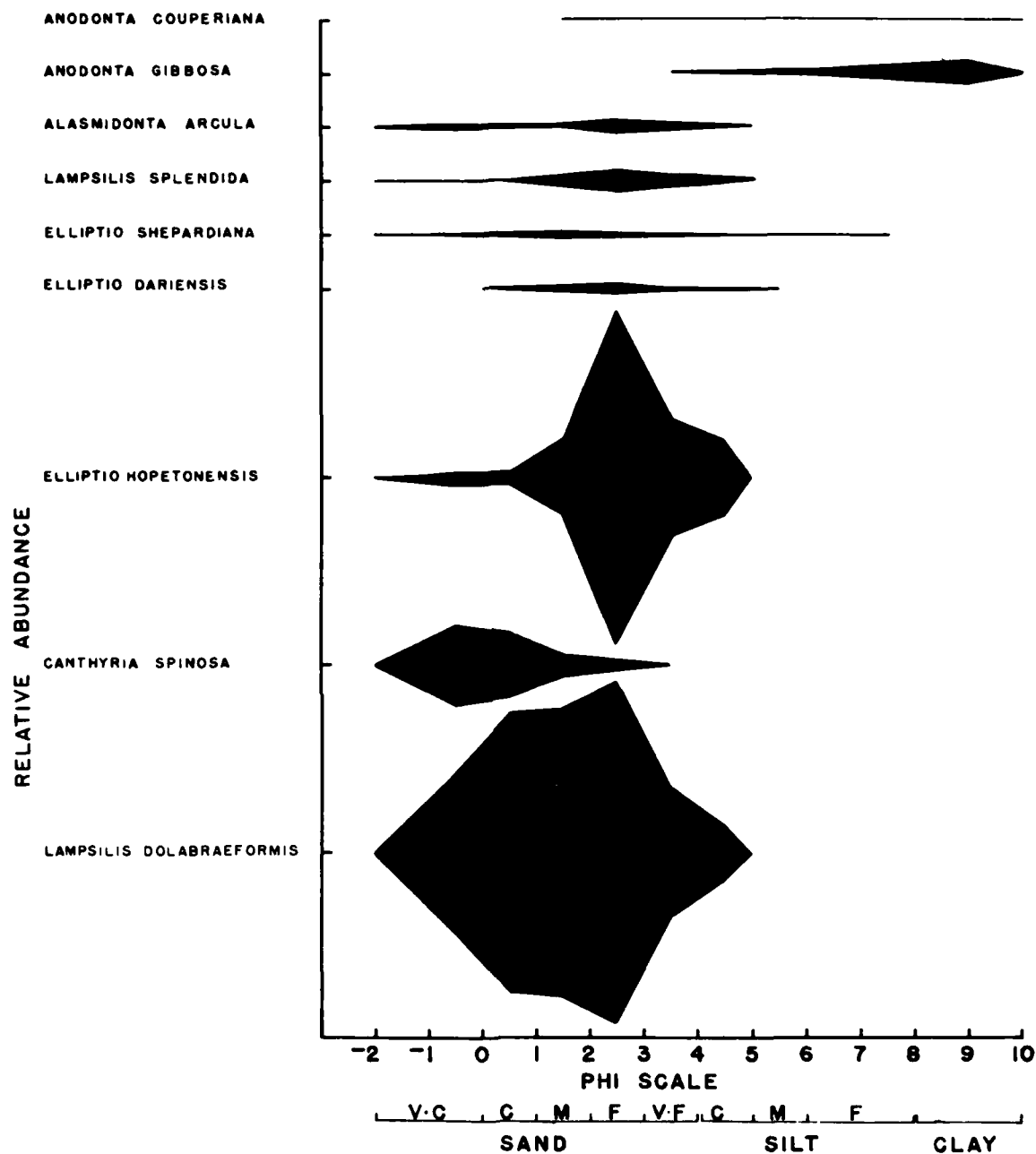


Figure 2. Relative abundance of freshwater mussels with respect to sediment particle size in the Altamaha River. Particle size is indicated on the Phi scale where Phi is the negative base 2 logarithm of the particle diameter in mm. Sand and silt are subdivided into very coarse, VC; coarse, C; medium, M; fine, F; or very fine, VF

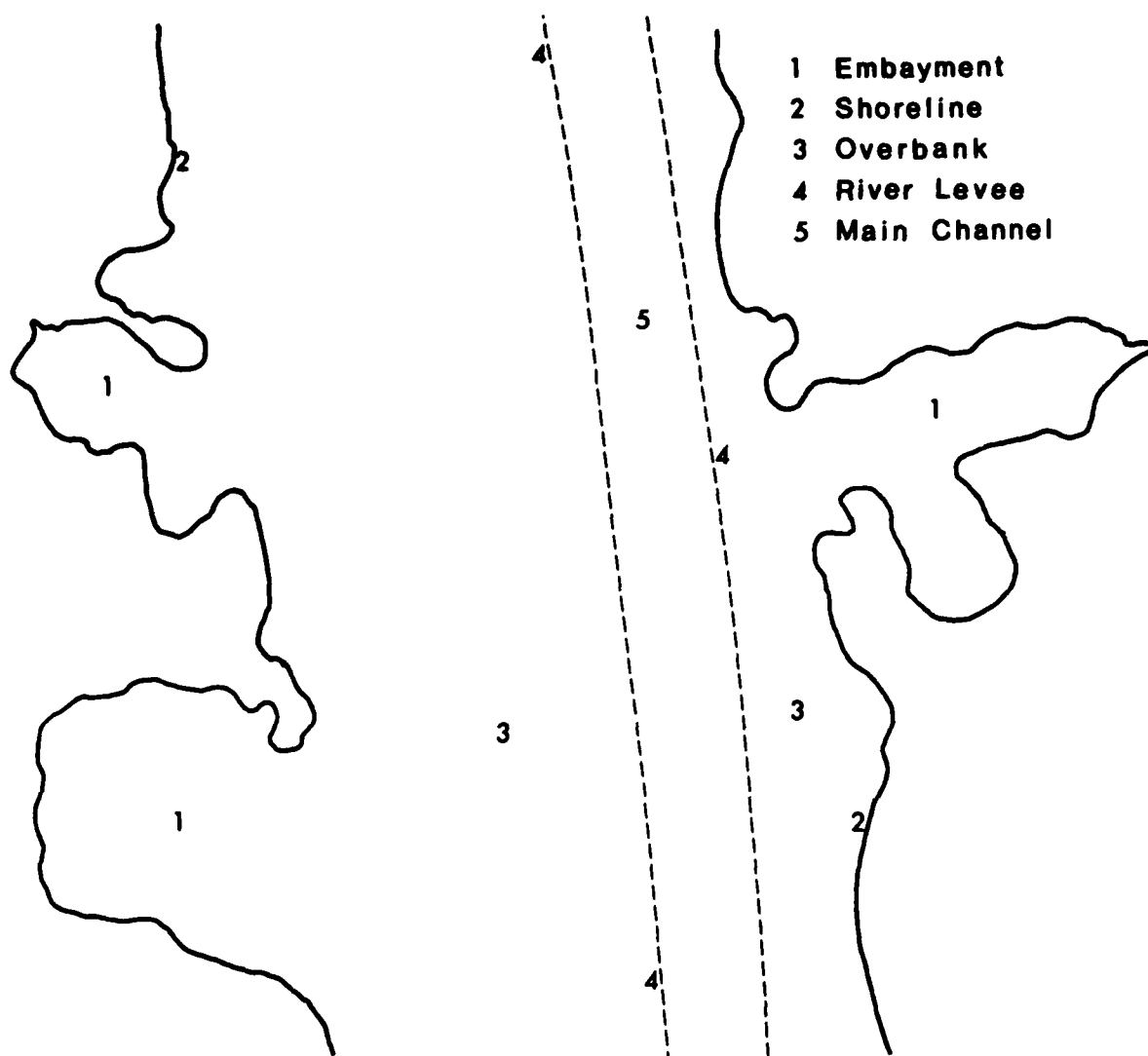


Figure 3. Kentucky Lake habitat types

The overbank areas, located between the levees and the shorelines, were affected by wind and wave action because of their shallow depth. River currents also exerted some influence on these areas. Thin layers of silt, sand or gravel were often found over compact clay. Species found on the overbanks tended to be generally distributed throughout the lake, with no species showing a definite preference for this habitat type.

The sediments of the main Tennessee River channel were composed of silt and fine organic detritus characteristic of copropel; however, during calm summer periods, the bottom was often anaerobic with a tendency toward sapropelic

sediments. Only four species were collected from the main channel, with all except F. ebena being found throughout the lake.

While some species showed a definite tendency toward habitat preference, other species apparently have adapted well to a variety of habitats within the lake ecosystem. In each habitat type those species showing definite habitat preferences were found in smaller numbers than widely distributed species. The restricted species are probably more susceptible to environmental and competitive pressures and may not be able to survive outside their present habitat type, whereas the widely distributed species are apparently able to withstand ecological changes encountered in different habitats.

Summary III: Barkley Tailwater Unionidae

This study was conducted in conjunction with an endangered species survey for the U. S. Army Engineer District, Nashville. The purpose was to determine if any endangered mussels remained in the last 30 miles of the Cumberland River, Kentucky, which historically contained mussels now included on the Federal endangered species list. To sample the 30 miles, both mussel brails and SCUBA divers were used. Brails were used throughout the 30-mile section to locate mussel beds, then SCUBA divers sampled each bed to ensure a more complete faunal characterization. Divers also examined proposed dredge and disposal sites even if mussels were not found by brails, and sediment characteristics were noted at all dive sites.

Mussel Habitat Description

The map of the lower 30 miles of the Cumberland River (Fig. 4) shows the locations of all mussel beds (large crosshatched areas) and locations where occasional mussels were found (crosshatched ellipses).

Mussel beds in the Cumberland River were locations of stable substrate, usually of gravel and sand held firmly in place by compact silt and clay, in which mussels of various age classes and species occur in significant densities, generally more than $1/m^2$. The establishment of a bed requires many years since mussel recruitment is generally a slow process. Most beds had mussels ranging in age from 5-20 years and very few juveniles.

Dredging or other alterations of stream patterns often lead to unstable substrata resulting in the loss of mussel habitat. One example occurred at mile 24.2 where the left channel margin is a shifting sandbar. Only 2 small mussels were found on the bar. Another example was at mile 28.5 where a rock spoil along the left shore apparently altered the flow so that silt was deposited over the gravel along the right shore, resulting in an unstable habitat where only one young Proptera alata was found.

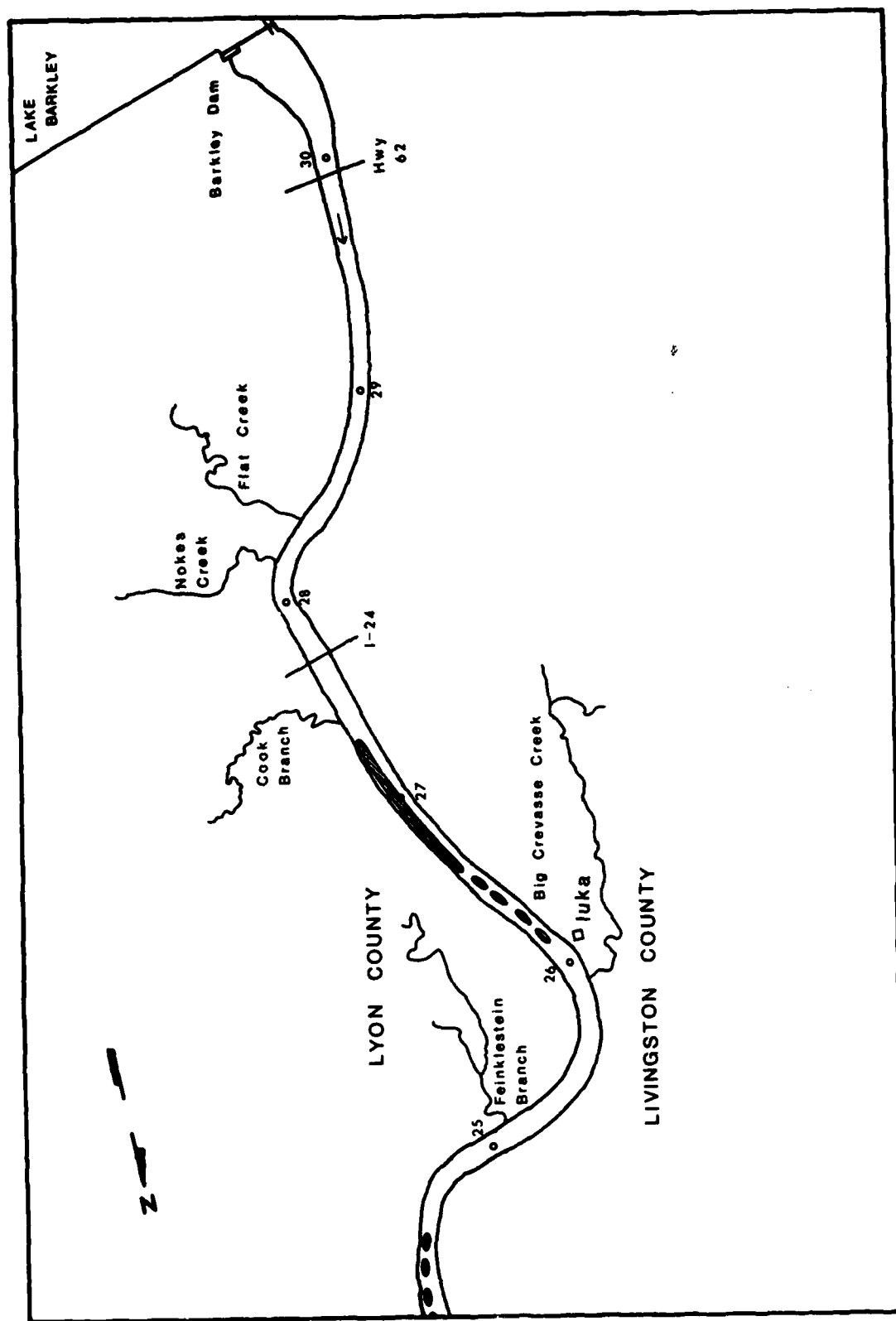


Figure 4. Map of the lower 30 miles of the Cumberland River, Kentucky, showing the location of mussel beds (large crosshatched areas) and locations where occasional mussels were found (crosshatched ellipses) (1 of 4)

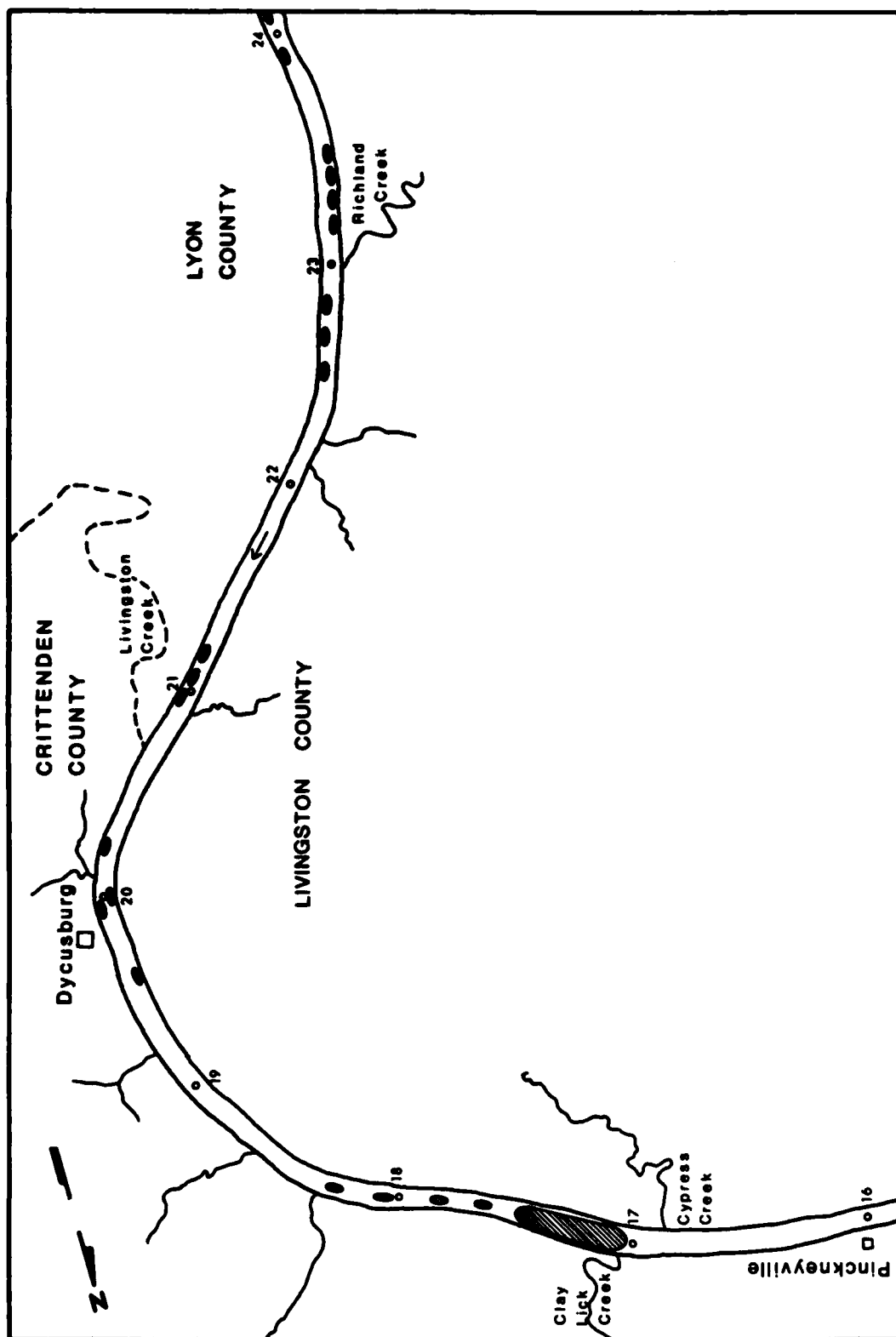


Figure 4. (2 of 4)

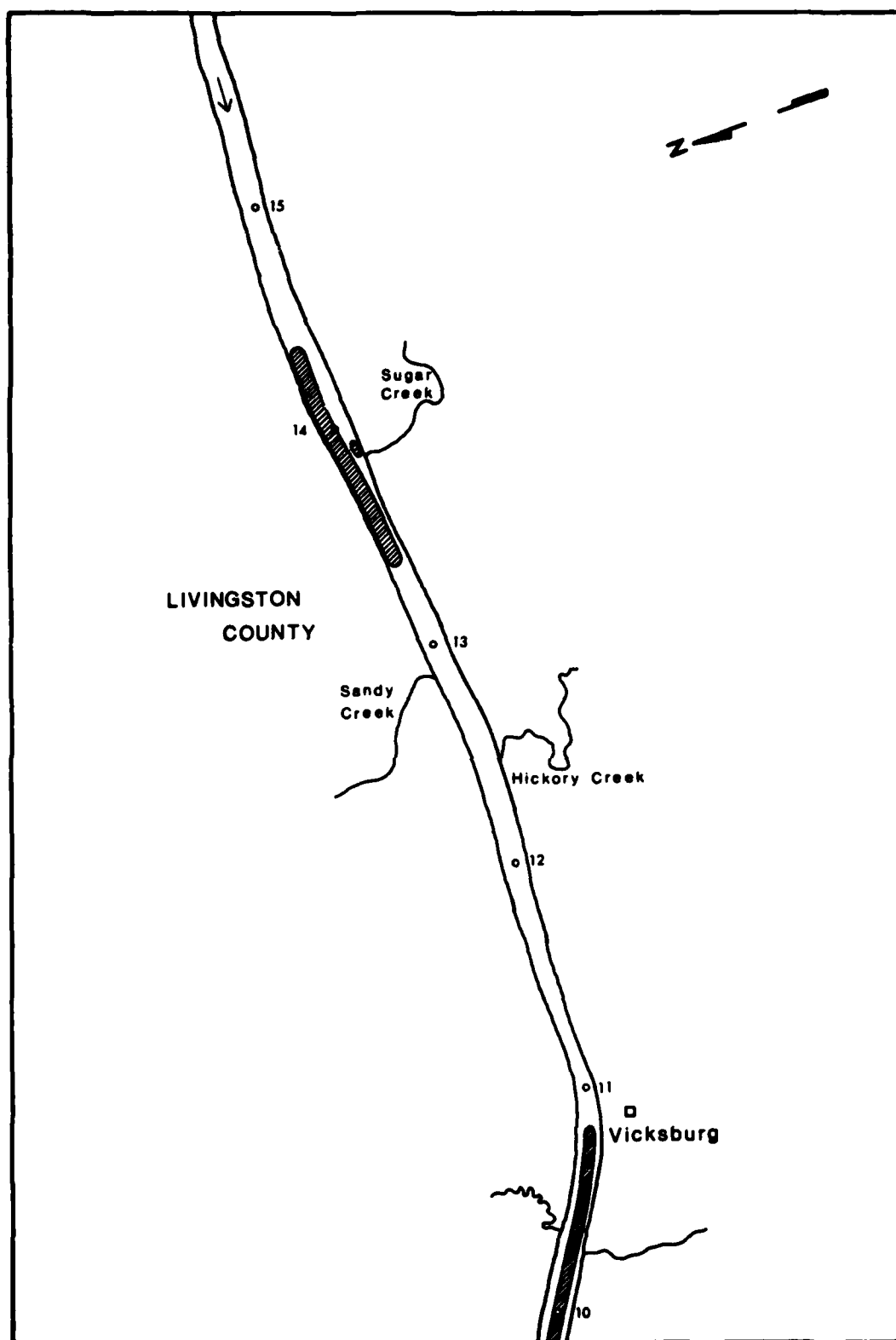


Figure 4. (3 of 4)

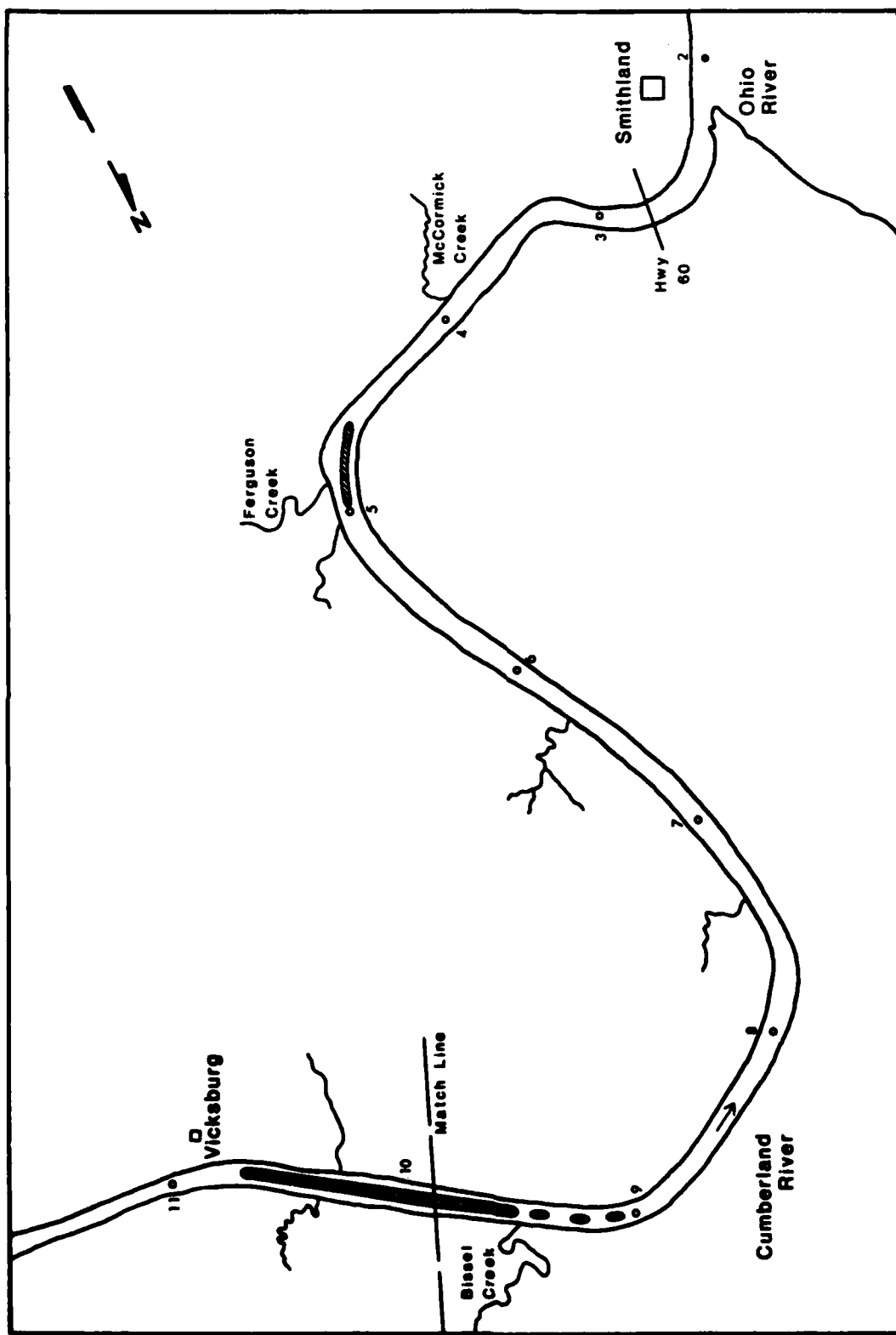


Figure 4. (4 of 4)

Effectiveness of Brails vs. SCUBA vs. Ponar Grab

Three brail boats with 5-m (16-ft) brails were used in this study, one boat brailing midchannel and the other boats working left and right of midchannel. Working 12-hour days each boat averaged 6 km/day, covering an area of 6 km x 5 m (30,000 m²) each. A SCUBA diver in good condition can survey approximately 1000 m²/day.

In this survey 21 species of mussels were found, 19 by brail and 20 by divers (Table 2). Only Truncilla donaciformis was found by brail and not by diving, while Anodonta grandis and Elliptio dilatata were found by divers but not by brail. These three species occurred as single individuals and constituted less than 0.5% of the total catch.

Ponar grabs (0.05-m² area) have been used in some surveys; however, to sample an area of 1000 m², which a SCUBA diver can accomplish in a day, would require 20,000 grab samples. With mechanized sampling equipment, a maximum of 200 grabs/day can be processed requiring 100 days to sample a 1000-m² area, which would result in a complete disruption of the habitat. Therefore, Ponar or other grabs are not suitable methods for sampling mussels in large rivers or lakes.

Creation of Mussel Habitat

Based on observations in the Cumberland River study, successful creation of new mussel habitat in altered or newly formed channels such as the Tennessee-Tombigbee Waterway would be a tenuous enterprise. The only habitats where mussels are abundant in the lower Cumberland River, which has a controlled discharge and barge traffic, are in nearly straight, wide stretches of the river where the sediments are gravel in compact sandy clay. These sediments have been stable for many years. Mussel recruitment is a slow process, and any habitat disturbance such as shifting substratum can only retard the recruitment process. If it is feasible to attempt to create mussel habitat, a thorough study of the hydraulic characteristics of the river section of interest should be conducted at all flow stages to determine locations where suitable substrata could be placed and remain stable. Perhaps dredging, filling, riprapping, or some other activity could be used to more or less permanently stabilize a section of river bed with a gravel bottom and sufficient current to prevent excessive siltation at all river stages; this would create a suitable habitat into which adult mussels could be transplanted. Suitable host fish might also have to be stocked if none were present naturally.

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Table 1

Species Found Within Each Habitat Type Sampled in Kentucky Lake
From Tennessee River Mile (TRM) 22.4 to 61.9

<u>Species</u>	<u>Embayment</u>	<u>Overbank</u>	<u>Shoreline</u>	<u>Levee</u>	<u>Main Channel</u>
<u>Amblema plicata</u>	X	X	X	X	X
<u>Anodonta grandis</u>	X	X	X	X	•
<u>A. imbecillis</u>	•	•	•	X	•
<u>A. suborbiculata</u>	X	•	X	•	•
<u>Arcidens confragosus</u>	X	X	X	X	•
<u>Carunculina parva</u>	X	•	o	•	•
<u>Fusconaia ebena</u>	•	o	•	X	X
<u>F. undata</u>	X	X	X	X	o
<u>Leptodea fragilis</u>	X	X	•	X	•
<u>Megalonaias gigantea</u>	X	X	X	X	X
<u>Obliquaria reflexa</u>	X	X	X	X	•
<u>Plectomerus dombeyanus</u>	•	•	•	X	•
<u>Proptera alata</u>	X	•	X	•	•
<u>P. laevissima</u>	•	X	•	X	•
<u>Quadrula nodulata</u>	X	X	X	X	•
<u>Q. quadrula</u>	X	X	X	X	X
<u>Q. pustulosa</u>	•	•	•	X	•
<u>Tritogonia verrucosa</u>	•	•	X	•	•
<u>Truncilla donaciformis</u>	•	•	•	X	•

X = present

Table 2

Distribution and Abundance of Mussels Found by Brailling and SCUBA Diving in the Lower
Cumberland River From Cumberland River Mile (CRM) 28.5 to the Ohio River

	CRM 4.7 - 5.0	CRM 9.0 - 9.3	CRM 9.4 - 11.0	CRM 10.6	CRM 11.0 - 12.4	CRM 13.5 - 14.0	CRM 13.9	CRM 13.9	CRM 14.3	CRM 14.5	CRM 17.0	CRM 17.3	CRM 17.3	CRM 17.3	CRM 17.5 - 19.6	CRM 19.6	CRM 20.0	CRM 20.0	CRM 20.0 - 20.2
<u>Anodonta grandis</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Arcidens confragosus</u>	3	1	•	•	•	•	1	•	•	1	•	•	•	•	•	•	•	•	•
<u>Lasimigona complanata</u>	•	•	•	•	•	1	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Megaloniaias gigantea</u>	41	3	19	•	2	31	10	•	18	4	13	•	•	8	3	•	•	•	•
<u>Tritogonia verrucosa</u>	•	•	1	•	•	5	•	•	•	1	•	1	•	•	1	•	•	•	•
<u>Quadrula quadrula</u>	3	3	3	•	1	4	•	•	1	5	1	4	•	•	1	1	•	•	2
<u>Q. metanevra</u>	1	•	3	•	1	6	•	•	•	1	•	•	•	•	1	•	•	•	•
<u>Q. nodulata</u>	1	1	2	•	•	4	•	•	•	1	•	1	•	•	1	•	•	•	1
<u>Q. pustulosa</u>	1	•	1	•	1	•	1	•	•	1	•	•	•	•	•	•	•	•	•
<u>Amblema plicata</u>	2	1	3	•	3	3	2	•	1	1	3	•	•	•	•	•	•	•	1
<u>Fusconaia ebena</u>	6	•	25	•	1	10	2	•	2	4	10	•	•	•	2	•	•	•	1
<u>F. undata</u>	1	•	1	•	•	•	1	•	•	•	•	•	•	•	X	•	•	•	1
<u>Pleurobema cordatum</u>	2	•	13	•	•	6	4	•	•	8	8	•	•	•	1	•	•	•	•
<u>Elliptio crassidens</u>	5	•	14	1	•	8	•	•	•	5	11	•	•	•	9	•	•	•	•
<u>E. dilatata</u>	•	•	•	•	•	•	1	•	•	•	•	•	•	•	•	•	•	•	•
<u>Obliquaria reflexa</u>	3	4	•	•	5	5	•	•	2	1	3	•	•	•	1	•	•	•	•
<u>Plagiola lineolata</u>	4	•	4	•	•	6	•	•	•	5	3	•	•	•	•	•	•	•	•
<u>Truncilla donaciformis</u>	•	•	•	•	•	1	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Leptodea fragilis</u>	•	•	1	•	•	•	•	•	•	•	1	•	•	•	1	•	•	•	•
<u>Proptera alata</u>	3	3	2	•	1	•	•	•	•	3	3	•	•	3	1	•	3	•	•
<u>Ligumia recta</u>	•	•	•	•	•	•	1	•	•	•	•	•	•	•	•	•	•	•	•
Totals	76	16	92	1	15	90	23	3	24	41	56	8	11	22	1	4	4	6	6

(Continued)

Table 2. (Concluded)

	CRM 20.9 - 21.2	right; brail	CRM 22.5 - 22.8	right; brail	CRM 23.1 - 23.4	left; brail	CRM 23.3	right; dive	CRM 23.8	middle; brail	CRM 24.1	middle; brail	CRM 24.2	left; dive	CRM 24.4	middle; brail	CRM 24.8	right; brail	CRM 25.5	right; dive	CRM 26.3	middle; brail	CRM 26.5	middle; brail	CRM 26.9	right; dive	CRM 27.1	right; dive	CRM 27.6	left; dive	CRM 28.5	right; dive
<u>Anodonta grandis</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Arcidens confragosus</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Lasmigona complanata</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Megalonaia gigantea</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Tritogonia verrucosa</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Quadrula quadrula</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Q. metanevra</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Q. nodulata</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Q. pustulosa</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Amblema plicata</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Fusconaia ebena</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>F. undata</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Pleurobema cordatum</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Elliptio crassidens</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>E. dilatata</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Obliguaria reflexa</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Plagiola lineolata</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Truncilia donaciformis</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Leptodea fragilis</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Proptera alata</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<u>Ligumia recta</u>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Totals	X	X	X	X	X	X	5	3	1	2	1	1	2	1	1	X	3	3	2	33	39	30	2	2	1							

THE HIGGINS' EYE MUSSEL RECOVERY PLAN: AN UPDATE

by

Edward M. Stern*

Currently there are recovery plans being written for six federally listed endangered species of freshwater bivalves. At the first mussel workshop sponsored by the CE in Vicksburg, in May 1981, the problems faced by the Higgins' eye team in drafting the plan and the approaches to these problems were discussed. The purpose of this presentation is not to repeat this information, but rather to update the status of the plan.

The Higgins' Eye Mussel Recovery Plan consists of three major sections and four appendices. Part I, The Introduction, is a discussion of what is known about the historical and recent distribution of the species, ecology and life history data, reasons for decline and threats confronting the species, and its endangered species status. Part II consists of the recovery plan objectives and rationale. Included is a detailed outline of proposed tasks along with an accompanying narrative. Part III is the implementation schedule. In tabular fashion, costs for each task are itemized, responsible agencies identified, and a priority assigned to each activity.

Of the four appendices, the two most important are Appendices A and B. Appendix A is a discussion of what the Team has chosen to call "essential habitat." Essential habitat includes those localities that we believe currently contain viable reproductive populations based upon the best available information to date. The Team initially considered 16 localities, seven of which were finally designated as essential habitat. Potentially, one or more of these may ultimately be designated as "critical habitat." Essential habitats include the following: St. Croix River at Hudson, Wisconsin, and in the upper Mississippi River at Whiskey Rock, Iowa, (Pool 9); Harper's Slough, Prairie du Chien, and McMillan Island, Wisconsin, (Pool 10); Cordova, Illinois, (Pool 14); and Sylvan Slough-Quad Cities, Illinois, (Pool 15).

Since the initial presentation 18 months ago in Vicksburg, the recovery plan has undergone both technical and agency reviews. The final draft was submitted to the Region 3 office of the FWS in September 1982. It is anticipated that the final draft will be approved and signed in the spring or early summer of 1983. It is hoped that partial funding for some of the activities will be available in FY 84.

It has been the recent policy of the FWS to disband some recovery teams following acceptance of the final draft. The Higgins' eye team has expressed a desire to continue to play an advisory role in any future decisions involving the species. At this point, the status of the team is uncertain.

* Team Leader, Higgins' Eye Mussel Recovery Team, Department of Biology, University of Wisconsin, Stevens Point, Wis.

COMPETITION OF NATIVE MOLLUSKS WITH EXOTIC SPECIES:
STUDIES ON CORBICULA*

by
Marc Imlay**

Introduced mollusks from Africa, Europe, and Asia (for example, the Asian clam Corbicula) are both an economic and ecological liability in this country. Some workers feel that Corbicula has been responsible for loss or at least decrease in numbers of some of our listed endangered bivalves, although this may or may not be true. However, a documented case of competition with exotics has occurred in Hawaii. The Hawaiian tree snail, Achatinella, was placed on the federal list of endangered species partly because of the competition and predatory behavior of introduced snails. In the northeastern United States, Bithynia tentaculata, the European fawcett snail, is replacing some native river snails (Pleuroceridae) which could ultimately cause the listing of these native gastropods. Of utmost importance are the exotic snails from Asia, South America, and Africa which carry the schistosome fluke responsible for the spread of Schistosomiasis. This disease affects 200 million people worldwide; if these snails were introduced to southern Florida, Louisiana, or Texas the results would be a dramatic reduction of our ability to enjoy our southern rivers. Currently none of our native snails carry the schistosome fluke.

Some people feel that the exotic mollusks could be eliminated or reduced by application of either biological or chemical control methods. However, I believe that habitat improvement is also a valuable tool for control of exotic species. It appears the native fauna can survive either competition from exotics or moderate pollution but not both at the same time. We have noticed this phenomenon in the case of introduced birds and plants. It seems that in the presence of competition from exotics, the native fauna can tolerate only a certain level of pollution; if the introduced mollusks were not present, the indigenous species could survive poorer conditions of water quality. My work, through literature reviews and field work, will compare concentrations of native species in areas experiencing various water quality conditions and pressures from exotic species.

For example, we (Fuller and Imlay 1976) noticed a polluted section of the Intercoastal Waterway Waccamaw River, North and South Carolina, where the water quality was degraded and native mussels were dead, but Corbicula numbered about 1000 individuals/sq ft. Where pollution was more moderate, Corbicula numbered about 100/sq. ft. Where the water quality was very good the Asian clam was found in numbers approximating 1/sq m. Another case was cited by Harman (1968a and b) in Maryland and New England: in streams that were only moderately polluted, and Bithynia tentaculata was not in evidence, native river snails were abundant; however, in similar streams in the same river basin, the exotic snail was present and had replaced the native fauna.

* Transcribed from tape, reviewed by the author.

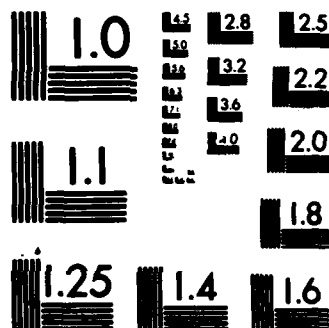
** Malacologist, Columbia, Mo.

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AD-A139 620 REPORT OF FRESHWATER MUSSELS WORKSHOP HELD AT ST LOUIS 3/3
MISSOURI ON 26-27 OCTOBER 1982(U) ARMY ENGINEER
WATERWAYS EXPERIMENT STATION VICKSBURG MS ENVIR.
UNCLASSIFIED A C MILLER OCT 83 F/G 6/3 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

THE GREATER ST. LOUIS SHELL CLUB

by

Alan Gettleman*

On behalf of the Greater St. Louis Shell Club, welcome to St. Louis, and we hope you enjoy your stay. We would like to compliment WES and all participants of this conference for their recognition that our freshwater molluscan fauna is a topic of interest and a subject worthy of continuing study. Many of you may be surprised to know that there is indeed a shell club in St. Louis. Although interest in shells and mollusks has never been greater among the general public, there are probably only a few thousand individuals in the entire nation who are active members of shell clubs. Therefore we welcome the opportunity to inform you that in shell clubs there is a resource of talented amateurs who are interested in the study and perpetuation of all forms of mollusca, who are eager to aid malacologists, and who are not just "shell collectors" who indiscriminately collect mollusks because they have "pretty shells." The club is extremely proud of our past and continuing efforts as an amateur scientific society dedicated to increased knowledge of all aspects of the molluscan phylum.

The Greater St. Louis Shell Club was formed in 1954 and, to our knowledge, is the oldest continuing shell club in the nation located away from a coastal area. Beginning in 1960, the Club has sponsored biennial shell shows, with exhibitors traveling from surrounding states and from as far away as Florida. The shows are competitively judged by professional malacologists, who in the past have included Dr. David Stansbery and Dr. R. Tucker Abbott, and by professional molluscan museum curators such as Russ Jensen (Delaware Museum), Bill Old (American Museum of Natural History in New York), and other prominently known malacologists. The shows acquaint St. Louisans with the varied forms of mollusca, including our rich native freshwater fauna. We have had a lecture series for over 20 years in which club members talk to school children or other groups on mollusks. Club members have staged displays on shells in libraries and other public buildings in an effort to increase local knowledge and appreciation of shells.

The Club has had a long and happy affiliation with the Museum of Science and Natural History in St. Louis, the descendant of the old Academy of Science of St. Louis. Club members are responsible for much of the Museum's small but growing collection of mollusks. Because the size of the Museum does not permit a curator for mollusks; knowledgeable club members have donated literally many thousands of hours in identifying and cataloging the museum's collection. Monies raised from our shell shows have often gone to the Museum for mollusk-related purchases. In addition, the club has purchased for the Museum many books and monographs on mollusks and shells and educational displays of mollusks. The Museum now has a small and solid core of well curated specimens which adds to the overall interest and value of the entire Museum.

* Member of the Greater St. Louis Shell Club, St. Louis, Mo.

The Club is also proud of its work in the conservation arena. We were vocal and active in our support to preserve the upper Meramec River and its tributaries from habitat destruction by development. The Club through petitions, exhibits at shows, etc., informed many Missourians that there was a local natural resource threatened with destruction. Club members provided specimens and data to professional malacologists to document the rare molluscan fauna which would be destroyed. This helped to marshal the scientific community to aid our Club's and other conservationist groups' successful efforts to save the Meramec.

Club members are interested in molluscan study. At each Club meeting, a member presents a paper on some aspect of the science of malacology. The Club is starting a speaker series; in February we will sponsor a visit to St. Louis by Dr. Alan Solem of the Field Museum of Natural History in Chicago to address Club members.

Most Club members begin their interest in shells by the collection of a few species. But the interest soon turns, even for the most nonscientifically oriented, to the animal and its relationship to its surroundings. Club members are acutely aware of the depletion and extinction of many fascinating molluscan species around the world by man's intervention. We realize that mollusks are often a fragile biological resource which can easily be depleted or destroyed. This Club, and other shell clubs stand as allies to the scientific community in the study and preservation of the mollusca. We are eager to assist those working with mollusks with data or specimen collection or, where we can, identification.

The Club thanks you for this opportunity to speak and hopes you will make use of club members in your own area in the preservation and enhancement of our beloved molluscan fauna.

MUSSEL IDENTIFICATION*

by

Thomas Freitag**

A field biologist attempting to identify mussels, especially endangered species, must depend on the use of shell features. This is not surprising since mussel species were and still are described by use of shell characteristics (Heard 1979). However, soft anatomy is also important in defining higher taxonomic groupings such as family and subfamily. Occasionally, characteristics of the soft anatomy are useful (in the field and laboratory) to separate mussels with similar shell features.

Guides such as Parmalee (1967), Burch (1973, 1975), Heard (1979), and Clarke (1981), as well as similar keys, use mainly shell characteristics. Such references are invaluable to those beginning the identification of mussels. Probably of equal value is a collection of specimens of several species for comparison; i.e., a synoptic collection. Series of specimens of a species might also be kept as examples showing variation within a species.

In any group of organisms, variation of identifiable features causes difficulties for beginners as well as professionals. In the mussels, variation in shell morphology can be caused by several factors including varying genetic stocks, age, sex (shell sexual dimorphism), stream station, and differences in physical or chemical parameters. With experience, however, a field biologist should be able to accurately identify mussels despite shell variation. Certainty of identification is needed not only for scientific accuracy, but also because of legal requirements of the Endangered Species Act.

Many salient external and internal shell features important in identifying mussels are included in the attached outline. Figure 1 displays major morphologic features; Figure 2 presents beak sculpture of some common mussels.

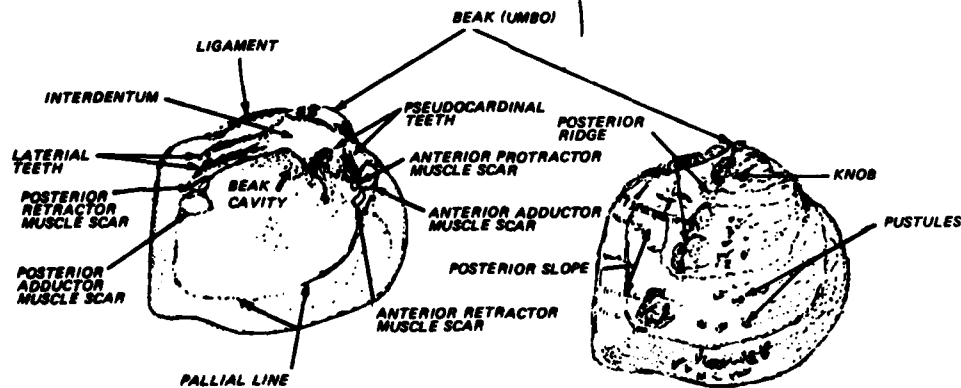


Figure 1. External and internal view of a typical mussel shell

* This paper was prepared for the display session of the workshop and modified slightly for this report.

** Biologist, U. S. Army Engineer District, Detroit, Mich.



Anodontoides ferussacianus (Lea)
($\times 4.5$)



Uniomerus tetralasmus (Say)
($\times 4$)



Strophitus undulatus (Say)
($\times 3$)

a. Concentric ridges or loops



Lasmigona complanata (Barnes)
($\times 1$)



Anodonta grandis (Say)
($\times 1.5$)



Lampsilis r. siliquoidea (Barnes)
($\times 3$)

b. Double loops

Figure 2. Examples of beak sculpturing (continued)



Amblema plicata (Say)
($\times 2$)



Fusconaia flava (Raf.)
($\times 2$)



Quadrula nodulata (Raf.)
($\times 3$)



Q. Pustulosa (Lea)
($\times 5$)

c. Bars or ridges

Loops parallel to growth lines

Zig-zag sculpturing



Elliptio dilatata (Raf.)
($\times 2$)



Cyclonaias tuberculata (Raf.)
($\times 2.5$)

d. Other types of sculpturing

Figure 2. (Concluded)

External and Internal Shell Characteristics

A. External characteristics

1. Shell Outline

- a. Oval: Obovaria olivaria and Obliquaria reflexa
- b. Quadrate: Fusconaia flava and Quadrula quadrula
- c. Rhomboidal: Q. metanevra, Tritogonia verrucosa, and Alasmidonta viridis
- d. Elliptical: Anodontoides ferussacianus, Actinonaias ellipsiformis, and Villosa iris
- e. Triangular: Fusconaia flava undata, Truncilla truncata (nearly triangular), Corbicula fluminea (adult)
- f. Round (circular): Obovaria subrotunda, F. ebena, Anodonta suborbiculata

2. Variation of shape within a species according to

- a. Age. Note: check growth lines to determine early shape of old mussel
- b. Station. Varies with stream size
- c. Shell sexual dimorphism. Some species show greater or lesser dimorphism
- d. Genetic structure. May be difficult to separate from environmentally induced changes

3. Periostracum color

- a. Rayed: Lampsilis radiata siliquoidea, Villosa iris (most species)
- b. Unrayed: Cumberlandia monodonta, Arcidens confragosa
- c. Basic colors of shells
 - (1) Yellow
 - (2) Brown
 - (3) Green
 - (4) Black

4. Periostracum sheen

- a. Shiny: Ligumia recta, Lampsilis o. ventricosa
- b. Dull: Examples: Elliptio dilatata, Plagiola lineolata

5. Shell "decoration"

- a. Shell roughened by pustules, nobs, or ridges: Amblema plicata, Cyclonaias tuberculata, Obliquaria reflexa, Lasmigona costata
- b. Shell smooth: Anodonta grandis, Leptodea fragilis
- c. Beak sculpturing

- (1) Concentric: Strophitus undulatus, Uniomerus tetralasmus,
Anodontoides ferussacianus
 - (2) Double loop: L. o. ventricosa, Megaloniaias gigantea,
Lasmigona compressa
 - (3) Ridges and bars: F. flava, Amblema plicata, Q. pustulosa
 - (4) Zig-zag bars and loops: Cycloniaias tuberculata, Q. quadrula
6. Beak positioning
 - a. Beaks appear turned anteriorly: Pleurobema cordatum complex,
Plagiola lineolata
 - b. Beaks not appearing to be greatly turned anteriorly: Fusconaia
flava undata, Obovaria subrotunda
 - c. Beaks far anterior: Obovaria olivaria, Plethobasus cyphus,
Cycloniaias tuberculata
 - d. Beaks located centrally: Obovaria subrotunda, Anodonta
suborbicula
 7. Obesity changes (within a species)
 - a. Increase in obesity with increasing stream size (some species):
Quadrula metanevra, Cycloniaias tuberculata, Fusconaia flava
 - b. No difference in obesity with stream size: Strophitus undulatus,
Dynomia triquetra, Ligumia recta
 8. Development of posterior ridge
 - a. Posterior ridge rounded and indistinct: Obovaria olivaria,
Fusconaia ebena, Ptychobranhus fasciolare
 - b. Distinctly angled: Fusconaia flava undata, Truncilla truncata
 9. Sulcus development (i.e., having a defined sulcus or furrow anterior
of posterior ridge): Pleurobema cordatum, Fusconaia flava, Quadrula
quadrula
 10. Alate extension of shell
 - a. Extension of posterior dorsal margin: Proptera alata, Lasmigona
complanata, Leptodea fragilis
 - b. Extension of posterior and anterior margins: Proptera (= Leptodea)
laevissima

B. Internal Characteristics

1. Hinge development

- a. Toothless or with reduced or vestigial pseudocardinal teeth:
Anodonta grandis, Anodontoides ferussacianus, Strophitus undulatus
- b. Well-developed pseudocardinal teeth, but with lateral teeth repre-
sented only as thickening of hinge: Lasmigona complanata,
Alasmidonta marginata, Arcidens confragosa
- c. With lateral and pseudocardinal teeth: Lampsilis spp., Lasmigona
compressa, Obovaria spp., Leptodea spp., most species

2. Shell thickness
 - a. Thin shell (papershell) (these shells usually crack as they dry): Leptodea fragilis, Anodonta grandis, A. imbecillis, Cumberlandia monodonta
 - b. Thick, solid shells: Obovaria spp., Actinonaias carinata, Megalonaias gigantea
3. Shell color. Shell color often varies from species to species and within a population. The basic colors are:
 - a. White
 - b. Blue-white
 - c. Pink
 - d. Salmon
 - e. Orange
 - f. Purple
4. Orientation of lateral and pseudocardinal teeth
 - a. Teeth roughly parallel with hinge margin: Leptodea fragilis, Proptera (=Leptodea) laevissima
 - b. Teeth appear to form an angle between the posterior ventral margin and the anterior dorsal margin of shell (sometimes the line is dorsal-ventral). Note: this is the usual condition in most mussels: Cyclonaias tuberculata, Fusconaia flava, Pleurobema cordatum, Actinonaias carinata, Lampsilis higginsii
 - c. Pseudocardinal teeth appear to be roughly parallel with lateral teeth. Fusconaia ebena, Obovaria olivaria
5. Interdentum
 - a. Interdentum wide and shelflike: Quadrula metanevra, Cyclonaias tuberculata, Plagiola lineolata
 - b. Interdentum moderately wide: Elliptio dilatata, Actinonaias carinata, Lampsilis higginsii
6. Beak cavity
 - a. Beak cavity shallow: Obovaria olivaria, Ptychobrancus fasciolaris, Elliptio dilatata, Actinonaias ellipsiformis
 - b. Beak cavity deep (often compressed): Fusconaia ebena, Cyclonaias tuberculata, Quadrula metanevra, Fusconaia flava
7. Muscle scars and mantle attachment points: These features should be compared from individual to individual when other features are not sufficient for identification. This is often necessary in working with archaeological material

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ADDENDUM

by

Andrew C. Miller*

I finished packing and transporting specimens and equipment to the car late in the afternoon of the last day of the workshop. The majority of the details relating to the meeting were over. Now I was looking forward to a change of pace and an interesting evening. A young man from the catering office of the Henry VIII Inn and Lodge stopped by to talk for a few minutes.

"I see you are about finished. Where do you go from here?" I replied that my car was already pointed toward Vicksburg, Mississippi.

He was obviously surprised. "Why, I thought you were heading for another city."

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