BACKGROUND
In 1994 the first author, Henry W. Robison, and his staff completed the first tests of a data entry module to capture recent and historical fish distributional information on Arkansas fishes that existed only in manual files. The second author, L. Gayle Henderson, developed the module with assistance from the third author, Melvin L. Warren, Jr. The pilot study was completed in September 1995, and the module proved to be time-efficient and flexible. Data entry of Robison’s Arkansas fish collections was begun in the fall of 1995 under a Challenge Cost-Share (CCS) agreement with the Ouachita National Forest (ONF), Southern Research Station, and The Nature Conservancy. This CCS agreement was extended later in partnership with The Nature Conservancy, the ONF Ecosystem Management Program, the ONF Fisheries Program, and Robison.

Data entry proceeded with records of fishes from within the proclamation boundaries of the ONF. Initially, the records entered were those of Robison; however, permission was secured subsequently from Neil H. Douglas, Northeast Louisiana University (NLU), to add the data from fish collections housed in their museum. This data was primarily from the fieldwork of Douglas and NLU graduate students. Later, data on Arkansas fishes from the large holdings of the Tulane University fish museum were added to the fish database.

The USDA Forest Service effort focused primarily on fishes living within or immediately downstream of the forest proclamation boundaries. Initial data entry concentrated on that subset of fish collections but also included collections from river systems in Arkansas that drain the ONF. In a subsequent CCS in 1997, fish collection data from the proclamation boundaries of the Ozark National Forest and the St. Francis National Forest were added to the expanding fish database. More recently, information from field collections made by Tom M. Buchanan, John L. Harris, Betty Crump, George L. Harp, and others in the national forest areas and elsewhere in Arkansas were added. The addition of other national forests and field collections of these individuals substantially increased coverage of federal and surrounding lands in Arkansas.

In 1998-99, supplemental funding was granted from the Arkansas Game and Fish Commission AGFC to include fish collections from all drainages in Arkansas. The result is a database covering the entire state of Arkansas which can be used by the USDA Forest Service, The Nature Conservancy, the AGFC, the Department of Arkansas Natural Heritage, and others in future planning, monitoring, and management efforts.

PERTINENT LITERATURE
The site-specific information now contained in the fishes of Arkansas database formed the basis of several scientific contributions that increased our knowledge of fish distribution, fish conservation status, and fish assemblage association with watershed characteristics. Robison and Buchanan (1988) published “Fishes of Arkansas” with dot distribution maps depicting over 3,000 fish collections within the state. These localities were located by hand on paper maps that are currently in the possession of Robison. None of the more than 3,000 collections was in a digital format, decreasing their utility for rapid manipulation, analysis, planning, and monitoring. This manually compiled information was later used by Matthews and Robison (1988), Matthews and others (1992), and Matthews and Robison (1998) for studies analyzing the distributions of Arkansas fishes and the geological, climatological, and water quality correlates that described faunal patterns across the state. Recently, the
maps of Robison and Buchanan (1988), in part, formed the basis for an assessment of fish distribution, diversity, and conservation status for hydrologic units in the Ozark-Ouachita Highlands Assessment led by the USDA Forest Service (Standage 1999; Warren and Clingenpeel 1999; Warren and Hlass 1999; Warren and Tinkle 1999).

OBJECTIVES
The computerization of the distributional data for the fishes of Arkansas was premised on information needs in four specific areas. First, there was a need to establish a Geographic Information System (GIS)-compatible fish research database for the state of Arkansas to document historical and present fish distributions. Second, a digital database would allow identification of unique ecological or taxonomic fish community assemblages and centers of fish diversity within and across drainages of Arkansas. Third, historical changes in stability and persistence of community assemblage patterns and historical trends in species distributions needed to be easily associated with land use. Finally, there was a need for geo-spatial tools to assess conservation status of individual Arkansas fish species. The primary objective of this paper is to describe the development and design of the database used to capture collection records for fishes across Arkansas and that can be used to meet these information needs.

DATABASE DESIGN
The initial design goal was to create a database structure that could incorporate diverse sources of data on fishes into a standardized central, digital repository and that would be flexible and extensible enough to meet anticipated future needs. Additional design considerations included standardization, portability, integration with GIS, ease of use, available PC platforms, and support. These factors together with the one-to-many nature of the primary data dictated the need for a relational database system (e.g., for each fish collection, many species were sampled). A relational system provided the needed master-detail database structures. Importantly, a relational database system also provided programming tools for developing modular code units for data entry, queries, and reports, user-friendly graphical user-interfaces (GUI), data entry validation procedures, and on-screen help displays.

Standardization of the fish collection data was a first step in the design process. The data originated from multiple sources with varying sampling techniques, measurement units, and recording methods. Agreement was reached on standardized values or value ranges for most fields. Attributes of standardized fields were stored in separate lookup tables and related to the main database tables as needed via a shared code. This approach provided standard variables, and standard categories for development of queries and analyses and reduced data redundancy and table sizes. Input errors were also reduced since users select values from a pick list rather than typing in the entry. In addition, comment fields were built into the design to capture field observations or specimen conditions that were important but not amenable to standardization.

Due to the magnitude of information related to each collection, data fields were grouped into four major categories, each with a separate data entry screen:
1. Location information (fig. 1), including county; physiographic region and section; river drainage and system; stream name; and exact locality of the sampling site...
2. Collection information (fig. 2), including collection or field identification number; collection date; collection interval, depth, and methods; and collectors

3. Habitat information (fig. 3), including 11 environmental variables: turbidity; vegetation; substrate; geology; shore-line condition; percent riffle; water depth and width; current; stream width; and water and air temperatures

4. Species information (fig. 4), including scientific name and family; number of individual species sampled; museum number; total length, standard length, and notes concerning sex, weight, spawning colors, and spawning condition.

Figure 2—Data entry screen for collection information.

Figure 3—Data entry screen for habitat information.
To enhance accuracy and ensure standardization, the user extracts most field entries from pull-down tables of master lists. Scientific names and respective families for fish species are selected as single entries from a standardized list of all fishes known to occur in Arkansas as documented by Robison and Buchanan (1988) and updated to reflect subsequent taxonomic changes (table 1). A hierarchical list of river drainages and stream systems was adopted from drainage units defined by (Matthews and Robison 1988) (table 2). Similar master lists provide standard political subdivisions (Arkansas county names) and physical and geologic divisions of the state (physiographic region and section, surface geology), (table 3). Others indicate the capture method or provide descriptors of conditions at the collection site and include: air and water temperature, current category, percent riffle habitat, water depth, substrate type, turbidity category, stream size, shore classes, and types of aquatic vegetation (table 4). As needed the master lists may be updated or expanded to accommodate other categories of information or create additional entry fields.

Table 1—Sample from species master list

<table>
<thead>
<tr>
<th>Species</th>
<th>Family</th>
<th>Species code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acipenser fulvescens</td>
<td>Acipenseridae</td>
<td>1</td>
</tr>
<tr>
<td>Alosa alabamae</td>
<td>Clupeidae</td>
<td>2</td>
</tr>
<tr>
<td>Alosa chrysochloris</td>
<td>Clupeidae</td>
<td>3</td>
</tr>
<tr>
<td>Ambloplites arionmus</td>
<td>Centrarchidae</td>
<td>4</td>
</tr>
<tr>
<td>Ambloplites constellatus</td>
<td>Centrarchidae</td>
<td>5</td>
</tr>
<tr>
<td>Ambloplites rupestris</td>
<td>Centrarchidae</td>
<td>6</td>
</tr>
<tr>
<td>Amblysopsis rosae</td>
<td>Amblysopidae</td>
<td>7</td>
</tr>
<tr>
<td>Ameiurus catus</td>
<td>Ictaluridae</td>
<td>8</td>
</tr>
<tr>
<td>Ameiurus melas</td>
<td>Ictaluridae</td>
<td>9</td>
</tr>
<tr>
<td>Ameiurus natalis</td>
<td>Ictaluridae</td>
<td>10</td>
</tr>
<tr>
<td>Ameiurus nebulosus</td>
<td>Ictaluridae</td>
<td>11</td>
</tr>
<tr>
<td>Amia calva</td>
<td>Amiidae</td>
<td>12</td>
</tr>
<tr>
<td>Ammocrypta clara</td>
<td>Percidae</td>
<td>13</td>
</tr>
<tr>
<td>Ammocrypta vivax</td>
<td>Percidae</td>
<td>14</td>
</tr>
<tr>
<td>Anguilla rostrata</td>
<td>Anguillidae</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 2—Sample from system-drainage master list

<table>
<thead>
<tr>
<th>Code</th>
<th>System</th>
<th>Drainage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0-Unknown</td>
<td>0-Unknown</td>
</tr>
<tr>
<td>1</td>
<td>Mississippi River-Blytheville</td>
<td>Mississippi River</td>
</tr>
<tr>
<td>2</td>
<td>Mississippi River-West Memphis</td>
<td>Mississippi River</td>
</tr>
<tr>
<td>3</td>
<td>Mississippi River-Helena</td>
<td>Mississippi River</td>
</tr>
<tr>
<td>4</td>
<td>Mississippi River-Eudora</td>
<td>Mississippi River</td>
</tr>
<tr>
<td>5</td>
<td>Upper St. Francis River</td>
<td>St. Francis River</td>
</tr>
<tr>
<td>6</td>
<td>St. Francis River</td>
<td>St. Francis River</td>
</tr>
<tr>
<td>7</td>
<td>Tyronza River</td>
<td>St. Francis River</td>
</tr>
<tr>
<td>8</td>
<td>L’Anguille River</td>
<td>St. Francis River</td>
</tr>
<tr>
<td>9</td>
<td>Fifteen Mile Bayou</td>
<td>St. Francis River</td>
</tr>
<tr>
<td>10</td>
<td>Upper White River</td>
<td>White River</td>
</tr>
<tr>
<td>11</td>
<td>War Eagle Creek</td>
<td>White River</td>
</tr>
<tr>
<td>12</td>
<td>Kings River</td>
<td>White River</td>
</tr>
<tr>
<td>13</td>
<td>Long Terrapin-Dry Creek</td>
<td>White River</td>
</tr>
<tr>
<td>14</td>
<td>Bull Shoals-White River</td>
<td>White River</td>
</tr>
<tr>
<td>15</td>
<td>Crooked Creek</td>
<td>White River</td>
</tr>
</tbody>
</table>
Help screens were used to clarify instructions and provide examples of valid entries. Techniques for field-entry validation (e.g., numeric range checking) were employed as appropriate, and printable summary reports (fig. 5) aided verifying entry accuracy. An export routine for creating delimited-text files (ASCII) was provided to ensure the database could later be moved to other systems. The export routine also served as a secondary backup mechanism.

SOFTWARE EVOLUTION AND SYSTEM REQUIREMENTS
The custom application, ONF FISH, has undergone a series of revisions since its inception. The database was originally developed for the DOS platform using Paradox, a relational database development product of Borland (now Inprise). Factors in the selection of Paradox over other relational database systems included PC system requirements (Paradox requires less resources than other products, such as PC Oracle), Borland's reputation in database development and programming arenas, and previous developer experience with Paradox. The application includes four basic modules accessible from a single, menu-driven, graphical interface: Data, Reports, Queries, and Utilities. Emphasis to-date has been on data entry and editing, but each module can easily be further expanded as user needs evolve.

The last major revision converted the application to object-based Paradox for Windows 5.0 and the Windows 3.1 platforms. The application now functions under Windows '95 and Paradox for Windows 7.0 (a Corel product). It is currently being ported to Delphi 5.0, a Windows '9x object-oriented development package originally developed by Borland and now owned by Corel as a result of their recent acquisition of Inprise. The new application will have the look-and-feel of a Windows '95 or Windows '98 application. Although still based on Paradox tables, the new application will not require Paradox as an underlying package at runtime. It will allow the use of tables created in any relational database system.
# Inventory Summary

**Printed:** 03/21/00  
**Inventory #:** 1121  

**Collection Information**  
- **ID:** HWR72-15  
- **Date:** 04/23/1972  
- **Interval:** 60  
- **Depth:** 1.22M  
- **By:** H.I.V. Robison; Calhoun; Beene; Tipton  
- **Method:** Seine

**Location Information**  
- **County:** Lafayette, AR  
- **Region:** West Gulf Coastal Plain  
- **Section:** Southwestern Arkansas  
- **Drainage:** Red River  
- **System:** Lower Red River  
- **Stream:** Red River  
- **Locality:** At Hwy. 160 ferry, 200 yds. N of ferry; on sand bar on east side of the river; T19S, R27W, Sec.13; Doddridge SE Quad  

**Habitat Information**  
- **Turbidity:** Moderately turbid  
- **Vegetation:** No vegetation present  
- **Substrate:** Sand-gravel mixture  
- **Geology:** Alluvium or terrace deposits  
- **Shore:** 0-24% Wooded  
- **Water Depth:** Large Rivers  
- **Stream Width:** 51-100 m  
- **Current:** Moderate  
- **Water Temp (F):** 75  
- **Air Temp (F):** 82

**Species Collected**

<table>
<thead>
<tr>
<th>Item</th>
<th>Species</th>
<th>Family</th>
<th>Quantity</th>
<th>Museum ID</th>
<th>TL</th>
<th>SL</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Unknown</td>
<td>Unknown</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>Lepisosteus sp. - skeleton</td>
</tr>
<tr>
<td>2</td>
<td>Cyprinella lutrensis</td>
<td>Cyprinidae</td>
<td>355</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Dorosoma cepedianum</td>
<td>Clupeidae</td>
<td>65</td>
<td></td>
<td></td>
<td></td>
<td>9 adults, 6 juveniles</td>
</tr>
<tr>
<td>4</td>
<td>Gambusia affinis</td>
<td>Poeciliidae</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Ictalurus furcatus</td>
<td>Ictaluridae</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td>Taken by commercial fishermen</td>
</tr>
<tr>
<td>6</td>
<td>Ictalurus punctatus</td>
<td>Ictaluridae</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td>Juveniles</td>
</tr>
<tr>
<td>7</td>
<td>Ictiobus bubalus</td>
<td>Catostomidae</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>Dead</td>
</tr>
<tr>
<td>8</td>
<td>Lepomis humilis</td>
<td>Centrarchidae</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Lepomis macrochirus</td>
<td>Centrarchidae</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Lepomis megalotis</td>
<td>Centrarchidae</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Menidia beryllina</td>
<td>Atherinidae</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Notropis atherinoides</td>
<td>Cyprinidae</td>
<td>31</td>
<td>TU93616</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Notropis buchanani</td>
<td>Cyprinidae</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Notropis potteri</td>
<td>Cyprinidae</td>
<td>12</td>
<td>TU93617</td>
<td></td>
<td></td>
<td>NEW STATE RECORD - Verified by Dr. G.A. Moore, OSU</td>
</tr>
<tr>
<td>15</td>
<td>Notropis shumardi</td>
<td>Cyprinidae</td>
<td>816</td>
<td>TU93619</td>
<td></td>
<td></td>
<td>Maies with small nuptial tubercles</td>
</tr>
</tbody>
</table>

Figure 5—Sample inventory report.
for which an Open Database Connectivity (ODBC) driver is
available (including Paradox, Access, Oracle, or others).
The new version will take advantage of the newest enhance-
ments of Delphi, one of the most powerful Rapid Application
Development (RAD) packages available today.

The current version requires at least an 80386-based PC
with Windows ‘95, Paradox for Windows 7.0, 32MB RAM,
and approximately 40MB free disk space for the ONF FISH
application. However, a Pentium or better system with 64MB
RAM is strongly recommended and will be required for
future Delphi-based versions.

INTEGRATION WITH GEOGRAPHIC INFORMATION
SYSTEM
In conjunction with development of the fish database appli-
cation, efforts were made to ensure the information could
be easily integrated into a GIS. As site-specific collections
were entered, they were also located on paper copies of
USGS 7.5 minute topographic maps (1:24,000) and coded
with a unique identification number. Those maps are being
maintained and continually updated by the first author as a
physical record of fish collection localities in Arkansas. In
late 1999, in an effort led by Alan Clingenpeel (ONF) and
Brian Wagner (AGFC), all sampling locations were geo-
referenced to state-wide coverages using PC ArcView, a
product of Environmental Software Research Institute. Each
sampling point on the paper maps was matched to the same
point on a 1:24,000 digital topographic coverage of Arkansas.
The resulting point coverage uses an ArcView table linking
collection identification numbers with point labels. This table
will be merged into the original fish database application
tables so that all the fish data attributes may be used in
map creation and geo-spatial analysis.

CONCLUSION
A digital, database repository linked to GIS is now developed
for over 3,500 collections of fishes covering all of Arkansas.
Importantly, the foundation of the database, the individual
collection records, were critically examined so that the
information is up-to-date and as error free as possible
(Robison and Buchanan 1998 and subsequent updates by
Robison). The abundance and distribution of the fishes of
Arkansas are linked intimately to the habitat and water
quality condition of streams and rivers these animals
inhabit (Matthews and Robison 1988, 1998; Matthews
and others 1992). As such, the database of fishes will be
extremely useful to natural resource agencies in manage-
ment, planning, and monitoring. The database gives natural
resource managers an enhanced ability to examine fish
distribution in association with rehabilitation, enhancement,
or remediation of the state’s running waters.

Future applications of the database are limited primarily by
one’s vision. The fish data application is currently extensible
and will be even more so after full conversion to Delphi,
which supports technologies such as Open Database Con-
nectivity (ODBC), Object Linking and Embedding (OLE),
and Active Data Objects (ADO) which would allow wide-
spread sharing of data with other applications. Uses may
ultimately extend well beyond management. Both Delphi
and certain GIS products could be used to extend database
products to the web. For example, web-based interactive
maps could be created that display recent versus historical
fish distributions. Guides to identification of fish species of
Arkansas could be developed complete with photographs
and detailed distributional maps for each species. Integrat-
on of the database with GIS provides managers with deci-
sion-making tools and visual communication modes that
assist in prioritizing allocation of scarce resource manage-
ment dollars, open the door to thoroughly examining
management alternatives, and help convey and justify
management decisions. In sum, the database is a powerful
natural resource tool for the USDA Forest Service, The
Nature Conservancy, the AGFC, the Department of Arkansas
Natural Heritage, and state, federal, and local entities in
future planning, monitoring, and management efforts.

ACKNOWLEDGMENTS
The assistance of a number of government agencies and
individuals who aided in the realization of a long-held dream
of Robison to computerize the fish collection records of
Arkansas is most graciously appreciated. First, thanks go to
the USDA Forest Service, primarily the Ouachita National
Forest and Ecosystem Management Large-Scale Research
Program, Southern Research Station (both in Hot Springs,
AR) and the Center for Bottomland Hardwoods Research,
Southern Research Station (Oxford, MS) and also The Nature
Conservancy, for supplying initial and continued funding in
the early phases of this project. Especially important in
recognizing the value and supporting the project were Alan
Clingenpeel, Jim Guldin, William Pell, and Richard Standage
(USDA Forest Service), and Douglas Zollner of The Nature
Conservancy. We also wish to thank the Arkansas Game
and Fish Commission, which in 1998-1999 funded the
addition of Arkansas fish records outside of the National
Forest. Brian Wagner of the Non-Game Section, Arkansas
Game and Fish Commission, was instrumental in support-
ing the effort.

Research support was provided through the “Ecosystem
Management Large-Scale Research Program” dated 1994
through September 1995 under Challenge Cost-Share (CCS)
agreement. Special thanks and appreciation is expressed to
Thomas M. Buchanan (Westark College, AR), for his will-
ingness to share important data on Arkansas fish collections
that he has made throughout the State. Other ichthyologists
who graciously shared field notes on fish collections include:
John L. Harris (Arkansas Highway and Transportation
Department), George L. Harp (Arkansas State University),
William J. Matthews and Edie Marsh-Matthews (University
of Oklahoma), and Betty Crump (Caddo Ranger District,
ONF).

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fish distribution and water quality patterns in streams of

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connectivity, drainage area, and regional species richness on
fishes of the Interior Highlands of Arkansas. American Midland


