Fishes of the Big Muddy River Drainage With Emphasis on Historical Changes

by

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Abstract. The Big Muddy River, a lowland stream located in southwestern Illinois and draining an area of about 6,182 km^2, contains a moderately diverse fish fauna of 106 species. The river is properly named, as the mainstem carried historically and continues to transport great quantities of silt. Historically, a large portion of the watershed was wooded, but much of the land has been cleared and put under cultivation. This has exacerbated siltation and eliminated former wetlands adjacent to and communicating with the mainstem and tributaries. Most of the drainage suffers from excessive siltation; dessication during drought periods; and oil-field, sewage effluent, strip-mine, and other industrial pollution. The construction of Crab Orchard, Little Grassy, Devil's Kitchen, Kincaid, Cedar, and Rend lakes effectively eliminated some of the highest quality streams in the drainage. One detrimental effect of these various stresses has been the disappearance of at least 10 native fish species over the past 100 years, including some of sport or commercial value (e.g., blue sucker, burbot). Suggested solutions to these problems include (1) a community ecology approach to future management of the drainage itself and the human made lakes; (2) maintenance or re-establishment of wooded riparian corridors, as well as wetlands adjacent to the river and tributaries, as spawning and nursery sites; (3) continued vigorous reclamation of abandoned mine lands and treatment of acid mine drainage; and (4) discontinuance of stocking of nonnative fishes (e.g., grass carp, bighead carp, striped bass, inland silverside) until their impact can be assessed.

Similar to most big river drainages in the largely agricultural state of Illinois, the Big Muddy River drainage, situated in the southwestern portion of the state (Fig. 1), has been subjected to an array of environmental stresses that have permanently disrupted its hydrological cycle, and ultimately altered its fish fauna. A century ago, the first fish collections were made in the Big Muddy River (Forbes and Richardson 1908), at about the time that the bottomland forests were beginning to be cleared for cultivation. In subsequent years, much of the well-drained, tillable ground was cleared, followed by

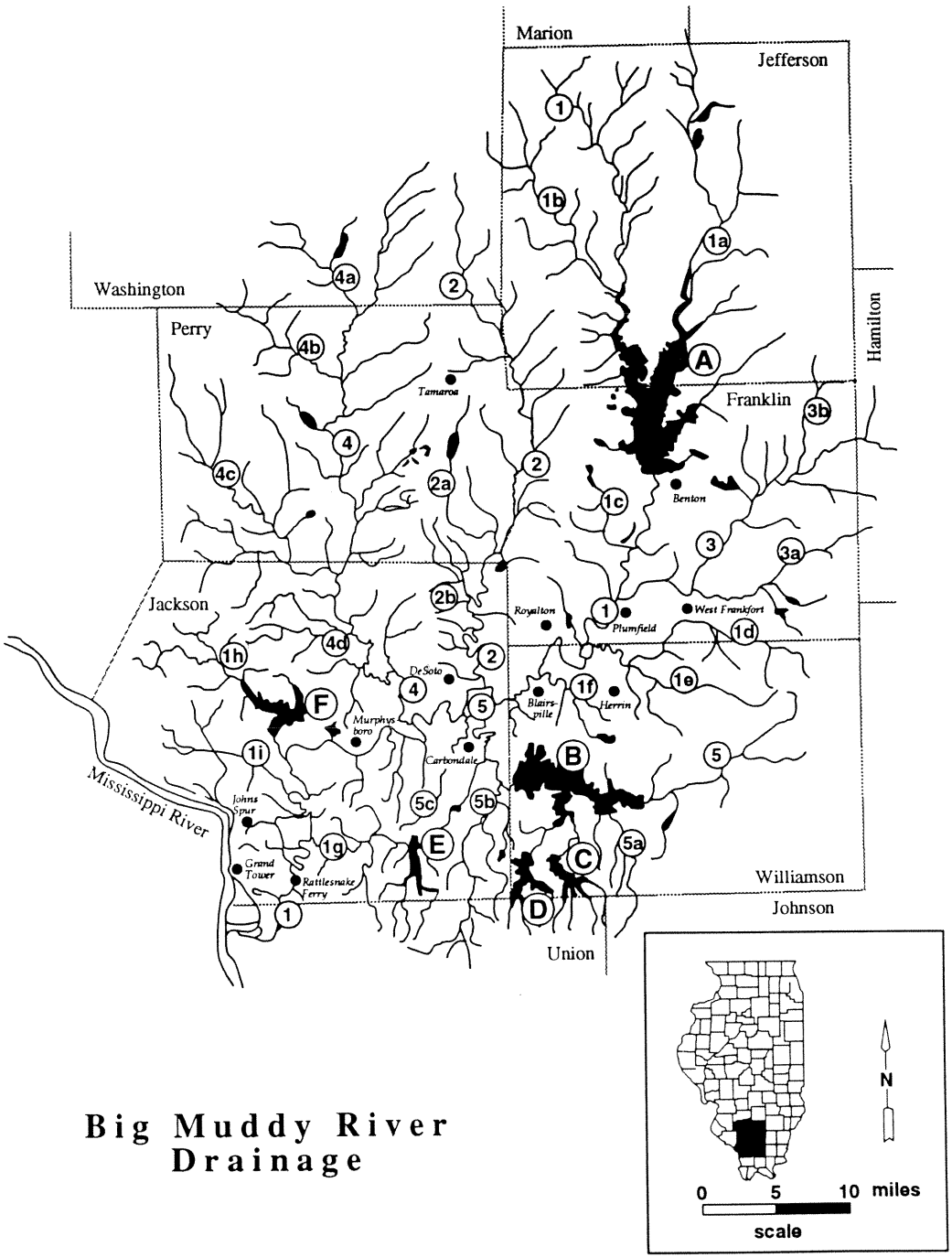

Fig. 1. Stream names, cities, counties, and reservoirs of the Big Muddy River drainage. A, Rend Lake; B, Crab Orchard Lake; C, Devil's Kitchen Lake; D, Little Grassy Lake; E, Cedar Lake; F, Kincaid Lake. 1, Big Muddy River; 1a, Casey Fork; 1b, Rayse Creek; 1c, Prairie Creek; 1d, Pond Creek; 1e, Long Creek; 1f, Hurricane Creek; 1g, Cedar Creek; 1h, Kincaid Creek; 1i, Worthen Bayou. 2, Little Muddy River; 2a, Reese C reek; 2b, Six Mile Creek. 3, Middle Fork Big Muddy River; 3a, Ewing Creek; 3b, Sugar Camp Creek. 4, Beaucoup Creek; 4a, Locust Creek; 4b, Swanwick Creek; 4c, Galum Creek; 4d, Rattlesnake Creek. 5, Crab Orchard Creek; 5a, Wolf Creek; 5b, Drury Creek; 5c, Little Crab Orchard Creek.

the draining of floodplain wetlands and clearing of riparian areas. Early in the 20th century, large-scale extraction of bituminous coal badly polluted tributaries of the upper and middle reaches of the river with silt and acid runoff; these problems plague the drainage to this day. More recently, construction of impoundments destroyed miles of stream habitat, altered natural discharge patterns, blocked migration of large-river fishes, and isolated many small-stream fish communities in headwaters of embayed tributaries.

Over 50% of the Big Muddy River drainage is in agriculture, much of which is under intensive tillage and subject to severe erosion. The drainage, nevertheless, serves as a major center in Illinois for water-based activities such as boating, fishing, waterfowl hunting, and camping. These activities are supported in part by three moderate to large reservoirs in the drainage—Rend, Crab Orchard, and Kincaid lakes—as well as numerous smaller impoundments. Rend Lake, in Franklin and Jefferson counties, is the second largest inland impoundment in the state. Recreational activity in the drainage is multifaceted and not strictly reservoir-based, being focused also around unique natural features or managed multiple-use areas such as the Shawnee National Forest (including Oakwood Bottoms), Crab Orchard National Wildlife Refuge, Giant City State Park, Little Grand Canyon, and Panther Den Wilderness.

In compiling our review of the drainage, we found (not surprisingly) that the fish fauna of the Big Muddy River drainage has been sampled systematically using standard methods in only a limited manner, but there is a considerable body of data on fisheries of the basin's reservoirs. We chose not to review the reservoir fisheries but refer the interested reader to Whitacre (1952), Allen and Wayne (1974), and Garver (1970, 1974). From a riverine standpoint, integrated, long-term ecological studies of the mainstem and large tributaries are noticeably lacking. In that vein, the work of Atwood (1988) and Hite et al. (1991) provides a much-needed foundation for beginning to understand the ramifications of anthropogenic change on the river's ecology.

Nevertheless, owing to a long history of collection of fishes in streams of the drainage, the native fish fauna is reasonably well-known and documented in regional and national fish collections. We assembled these data on the fish fauna of the Big Muddy River drainage into five eras of collecting activity. The first investigations date back to the classical work on Illinois fishes by Forbes and Richardson (1908), who reported on at least 12 collections made in the drainage during a period from about 1892 to 1900. From 1939 to 1940, A. C. Bauman, a former student of C. L. Hubbs, then at the University of Michigan, made 10 fish collections in the drainage. Beginning in the early 1950's, W. M. Lewis, Sr. and his students conducted several aquatic studies in the drainage and made at least 30 fish collections. The most comprehensive sampling of the Big Muddy River was by P. W. Smith and his colleagues, from 1963 to 1978, which resulted in 65 collections from throughout the drainage (Smith 1979). More recent efforts (1980–92), under the auspices of one of us (B. M. Burr), have resulted in 55 collections and the discovery of several fishes previously unreported from the drainage.

With this background, our primary objective is to present a description of the Big Muddy River drainage and its fish fauna, historically and today. We also identify impacts that have detrimentally affected the entire native aquatic community, provide a basic outline of management and monitoring needs for the river, and summarize requirements for restoration of the aquatic riverine resources in the drainage.

Sources and Methods

Information on the fish fauna of the Big Muddy River has been drawn from a variety of sources: (1) the primary literature—Forbes and Richardson (1908), Lewis (1955), Stegman (1959), Smith (1971, 1979), Burr and Page (1986), Warren and Burr (1988, 1989), and Burr (1991); (2) the gray literature—Whitacre (1952), Price (1965), Atwood (1988), Davin and Sheehan (1991), Hite et al. (1991), Burr et al. (1992), and Page et al. (1992); (3) vouchered specimen records in museum or university collections—University of Michigan Museum of Zoology, Illinois Natural History Survey, and Southern Illinois University at Carbondale; and (4) personal knowledge and field experience in the drainage over the past 20 years.

Physical, geological, and chemical features of the drainage were compiled from Rolfe (1908), Walker (1952), Schuster (1953), Price (1965), Smith (1971), Lopinot (1973), Illinois Environmental Protection Agency (1976), Ogata (1975), Hite and Bertrand (1989), Hite et al. (1991), and Illinois Environmental Protection Agency (1992). Streams, communities, and counties mentioned in the text are identified in Fig. 1.

Only limited standard sampling emphasizing catch per unit effort (CPUE) has been conducted on the fish fauna of the drainage. We assessed sampling effort from fish collections made over the past 100 years by competent fish biologists searching for maximum fish diversity in all available habitats at about 100 record stations in the drainage (Fig. 2). As already noted, we recorded sampling effort for different periods (eras), with credit given to the individuals making the most collections or directing the most effort during a given era (Table 1). Techniques used to sample fish over the years have included hook-and-line; wing, hoop, and gill nets; electrofishing; rotenone; and seining with various size nets and meshes. For purposes here, a collection is defined as thorough sampling of available habitats at a given locality using a variety of methods. Unfortunately, amount of effort and specific gear type at a given locality are largely unknown for collections made near the turn of the century and through the 1960's. It is therefore not possible to compare CPUE at a given site with the same gear type for one species.

The Big Muddy River Drainage

General Features

The Big Muddy River, one of the principal tributaries of the Mississippi River in southwestern Illinois, drains an area of 6,182 km^2 (Ogata 1975). The river's somewhat elliptical basin extends 168.9 km from north to south and 112.6 km from east to west (Lewis 1955), with a median length of 115.8 km and an average width of 53.1 km (Hite et al. 1991). Major tributaries within the Big Muddy River drainage include Casey Fork, Middle Fork, and Little Muddy River; and Crab Orchard, Galum, Kincaid, Cedar, and Beaucoup creeks (Fig. 1). The drainage includes the greater part of Franklin, Jackson, Jefferson, Perry, and Williamson counties; the southeastern portion of Washington County; the northern portions of Union and Johnson counties; the western edge of Hamilton County; and the southern part of Marion County (Fig. 1).

Four natural divisions are encompassed—Lower Mississippi River Bottomlands, Ozark, Shawnee Hills, and Southern Till Plain (Schwegman 1973). The Southern Till Plain composes most of the basin. The drainage lies at the extreme southwestern edge of the district covered by the Illinoisan drift sheet, lying in the low section just north of the Ozark ridge. The drainage is characterized by hilly upland topography and broad flat lowlands along the principal streams. The lower 32.2 km of the river flows through the Mississippi River Bottomlands. With the exception of the Ozark ridge on the southern border, which stands 182–243 m above mean sea level, the basin has few points rising above 167 m, the average level being 122–152 m. The immediate borders of the main valley fall below 122 m, and the mouth of the stream at low water in the Mississippi River is about 97 m. The bank-full channel of the mainstem throughout most of its course is 8–15 m wide and 15–21 m deep. A few sandstone outcrops, a common stratum in five of eight of the river's principal tributaries, and some patches of gravel are found in the main channel.

The Big Muddy River has the characteristics of an old stream, in an area long exposed to erosion (Rolfe 1908). Its bed has been cut down to drainage level, and its sinuous course runs over a broad floodplain. The river originates in northernmost Jefferson County and flows directly south and then generally southwest to empty into the Mississippi River about 8 km downstream from Grand Tower in Jackson County, at river km (rkm) 122 (Fig. 1). The length of the river, estimated from its point of origin, is about 248 km (Hite et al. 1991). Beaucoup Creek enters from the north about 40–48 km from the mouth, and Little Muddy River enters from the same side about 16 km farther upstream. These two streams together (2,222 km^2) drain about the same area as the mainstem above the Little Muddy River confluence. Beaucoup Creek (1,487 km^2) drains about twice the area of the Little Muddy River (736 km^2). An eastern tributary—Crab Orchard Creek—enters the mainstem from the south between the mouths of Beaucoup Creek and Little Muddy River and drains about 749 km^2 of the area bordering the Ozark ridge.

Hydrography

The Big Muddy River mainstem is at least as sluggish today as it was over a century ago (Rolfe 1908). Increased erosion and drainage of lowlands have exacerbated the silt load in the mainstem. Historically, in times of spring flood, Rolfe (1908) noted heavy silt loads that rendered the bottom a "creeping mass, shifting its contour with every change in rate of flow"; conversely, during summer drought the mainstem was reduced to a series of nearly stagnant pools. The river is properly named because with the exception of riffle areas the

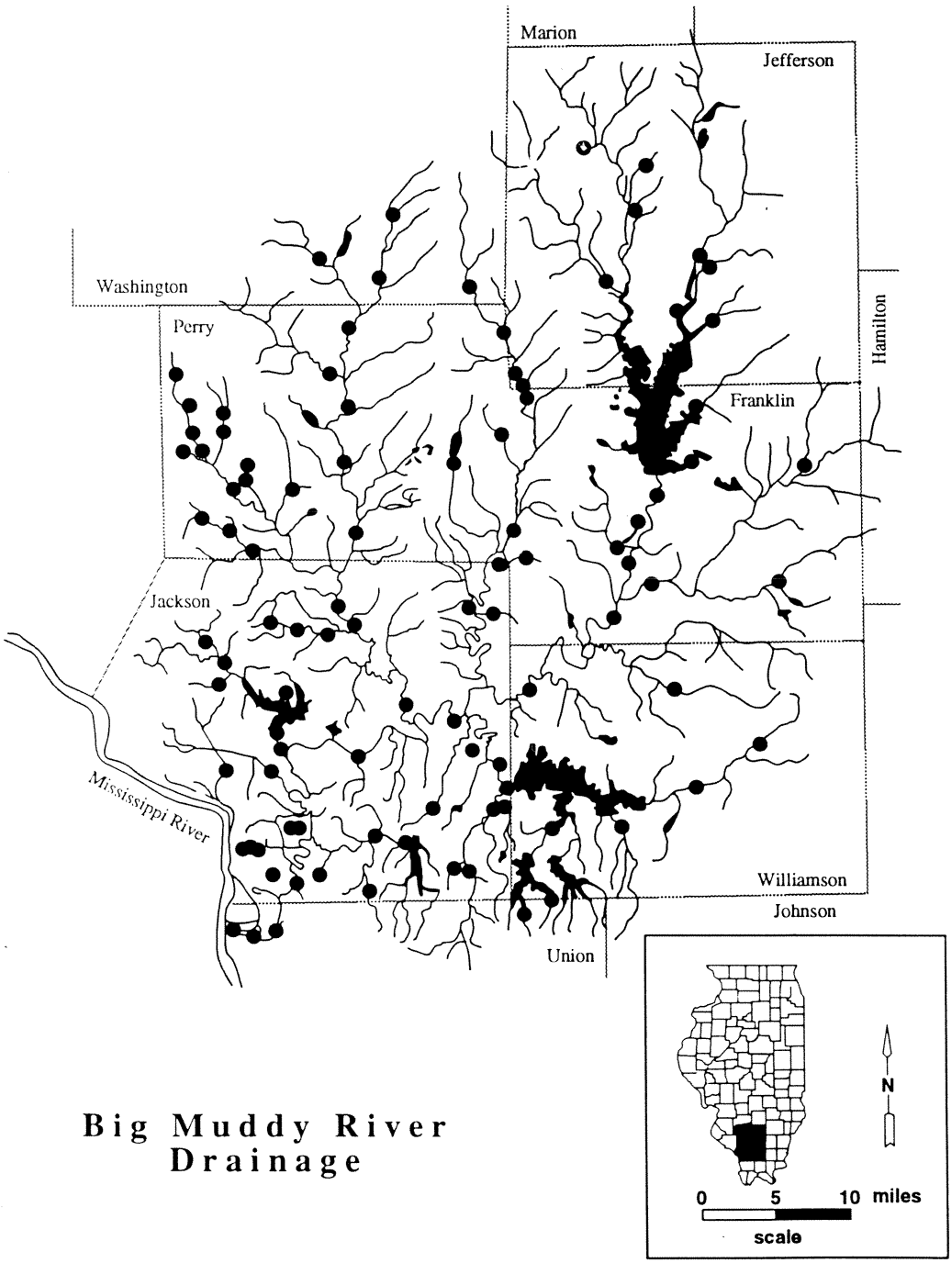

Fig. 2. Map of fish sampling sites in the Big Muddy River drainage represented in the Illinois Natural History Survey, University of Michigan Museum of Zoology, and Southern Illinois University at Carbondale ichthyological collections. Approximately 100 sites have been sampled at least once from 1892 to 1992.

Table 1. Fishes recorded from the Big Muddy River drainage, Illinois, in the period 1892–92, categorized by major historical periods of sampling. Classification and nomenclature of fish species follows Page and Burr (1991) VN = vouchered with a museum specimen and native to the drainage; I = introduced fish species deliberately or inadvertently moved into the drainage; L = literature record considered valid, species regarded as native; IE = introduced fish species with established population; IPE = introduced fish species without the status of a permanent population, but reproducing in an area where its elimination by humans would be impractical; R = record of an introduced fish species without evidence of reproduction, and vouchered with a museum specimen. Numbers in parentheses are number of collections made during a given period. SE = Illinois State Endangered; ST = Illinois State Threatened.

Family Species	S. A. Forbes and R. E. Richardson 1892–1900 (12)	A. C. Bauman 1939–40 (10)	W. M. Lewis 1950–59 (30)	P. W. Smith 1963–78 (65)	B. M. Burr 1980–92 (55)
Petromyzontidae					
1. *Ichthyomyzon castaneus*			VN		
Acipenseridae					
2. *Scaphirhynchus platorynchus*				VN	
Polyodontidae					
3. *Polyodon spathula*				VN	VN
Lepisosteidae					
4. *Atractosteus spatula* ST	L				
5. *Lepisosteus oculatus*					VN
6. *L. osseus*	L		L		
7. *L. platostomus*			L	VN	VN
Amiidae					
8. *Amia calva*	VN		VN	VN	VN
Anguillidae					
9. *Anguilla rostrata*			L		
Clupeidae					
10. *Alosa chrysochloris*			VN	VN	
11. *Dorosoma cepedianum*		VN	VN	VN	VN
12. *D. petenense*				VN	VN
Hiodontidae					
13. *Hiodon alosoides*			VN	VN	VN
Salmonidae					
14. *Oncorhynchus mykiss* I					IPE
Umbridae					
15. *Umbra limi*	L			VN	VN
Esocidae					
16 *Esox americanus*	VN	VN	VN	VN	VN
17. *E. lucius* I					IE
18. *E. masquinongy* I					IE
Cyprinidae					
19. *Campostoma anomalum*	L	VN	VN	VN	VN
20. *Ctenopharyngodon idella* I					IPE
21. *Cyprinella lutrensis*	VN	VN	VN	VN	VN
22. *C. spiloptera*					VN
23. *C. venusta*		VN			
24. *C. whipplei*	L	VN	VN		
25. *Cyprinus carpio* I	IE	IE	IE	IE	IE
26. *Ericymba buccata*		VN	VN	VN	
27. *Hybognathus hayi* SE		VN			
28. *H. nuchalis*	VN	VN		VN	VN
29. *Hybopsis amnis* SE	VN	VN			
30. *Hypophthalmichthys nobilis* I					IPE

Table 1. *Continued.*

Family Species	S. A. Forbes and R. E. Richardson 1892–1900 (12)	A. C. Bauman 1939–40 (10)	W. M. Lewis 1950–59 (30)	P. W. Smith 1963–78 (65)	B. M. Burr 1980–92 (55)
31. *Luxilus chrysocephalus*	L	VN			
32. *Lythrurus fumeus*		VN		VN	VN
33. *L. umbratilis*	L	VN	VN	VN	VN
34. *Macrhybopsis storeriana*	L				
35. *Notemigonus crysoleucas*	VN	VN	VN	VN	VN
36. *Notropis atherinoides*	VN	VN	VN	VN	VN
37. *N. blennius*	L				VN
38. *N. ludibundus*		VN	VN	VN	VN
39. *N. shumardi*		VN		VN	VN
40. *N. volucellus*		VN	L		VN
41. *Opsopoeodus emiliae*	VN	VN		VN	VN
42. *Phenacobius mirabilis*	L	VN	VN	VN	VN
43. *Pimephales notatus*	VN	VN	VN	VN	VN
44. *P. promelas*					VN
45. *P. vigilax*	VN	VN	VN	VN	VN
46. *Platygobio gracilis*				VN	
47. *Semotilus atromaculatus*	VN	VN	L	VN	VN
Catostomidae					
48. *Carpiodes carpio*		VN	VN		
49. *C. cyprinus*		VN	VN		VN
50. *Catostomus commersoni*		VN	VN	VN	VN
51. *Cycleptus elongatus*			L		
52. *Erimyzon oblongus*	VN	VN	VN	VN	VN
53. *E. sucetta*				VN	
54. *Hypentelium nigricans*				VN	
55. *Ictiobus bubalus*			VN	VN	
56. *I. cyprinellus*		VN	VN	VN	VN
57. *I. niger*				VN	VN
58. *Minytrema melanops*	L	VN	VN	VN	VN
59. *Moxostoma erythrurum*		VN	VN	VN	VN
60. *M. macrolepidotum*					VN
Ictaluridae					
61. *Ameiurus melas*	VN	VN	VN	VN	VN
62. *A. natalis*	L	VN	VN	VN	VN
63. *A. nebulosus*			VN		
64. *Ictalurus furcatus*			L		
65. *I. punctatus*	L	VN	VN	VN	VN
66. *Noturus gyrinus*	VN	VN	VN	VN	VN
67. *N. nocturnus*					VN
68. *Pylodictis olivaris*			VN		VN
Percopsidae					
69. *Percopsis omiscomaycus*		VN			
Aphredoderidae					
70. *Aphredoderus sayanus*	VN	VN	VN	VN	VN
Amblyopsidae					
71. *Forbesichthys agassizi*					VN
Gadidae					
72. *Lota lota*			L		
Fundulidae					
73. *Fundulus notatus*	VN	VN	VN	VN	VN
74. *F. olivaceus*	VN	VN		VN	VN
Poeciliidae					

Table 1. *Continued.*

Family Species	S. A. Forbes and R. E. Richardson 1892–1900 (12)	A. C. Bauman 1939–40 (10)	W. M. Lewis 1950–59 (30)	P. W. Smith 1963–78 (65)	B. M. Burr 1980–92 (55)
75. *Gambusia affinis*		VN	VN	VN	VN
Atherinidae					
76. *Labidesthes sicculus*					VN
77. *Menidia beryllina*					VN
Moronidae					
78. *Morone chrysops*	L		L	VN	VN
79. *M. mississippiensis*			L	VN	VN
80. *M. saxatilis* I				R	R
Centrarchidae (Percichthyidae)					
81. *Centrarchus macropterus*	VN		VN	VN	VN
82. *Lepomis cyanellus*		VN	VN	VN	VN
83. *L. gibbosus* I					R
84. *L. gulosus*	VN	VN	VN	VN	VN
85. *L. humilis*	VN	VN	VN	VN	VN
86. *L. macrochirus*	L	VN	VN	VN	VN
87. *L. megalotis*	L	VN	VN	VN	VN
88. *L. microlophus*				VN	VN
89. *Micropterus punctulatus*			L	L	VN
90. *M. salmoides*	VN	VN	VN	VN	VN
91. *Pomoxis annularis*	L	VN	VN	VN	VN
92. *P. nigromaculatus*	VN	VN	VN	VN	VN
Percidae					
93. *Etheostoma asprigene*	L	VN		VN	VN
94. *E. chlorosomum*	VN	VN	L	VN	VN
95. *E. flabellare*		VN	VN	VN	VN
96. *E. gracile*	VN	VN	L	VN	VN
97. *E. nigrum*	L	VN	VN	VN	VN
98. *E. proeliare*		VN		VN	
99. *E. spectabile*		VN	VN	VN	VN
100. *Perca flavescens* I					IPE
101. *Percina caprodes*		VN	VN	VN	VN
102. *P. maculata*	L	VN	VN	VN	VN
103. *P. shumardi*		VN	VN	VN	VN
104. *Stizostedion canadense*			VN	VN	
105. *S. vitreum*			VN	VN	
Sciaenidae					
106. *Aplodinotus grunniens*	L	VN	VN		VN
Total native species	45	58	65	68	71
Total introduced species	1	1	1	2	9
Total species	46	59	66	70	80

substrate of the mainstem and many tributaries is composed of thick layers of silt and mud. In the first 18 km from its origin the gradient is nearly 3 m/km, but ranges from less than 0.3 m/km in the middle reaches to 0.06 m/km at the confluence with the Mississippi River.

Major impoundments and the draining of wetlands have altered the hydrology of the watershed over the past 100 years. Flows have been decreased, especially on tributaries, and the timing and extent of flood pulses have been disrupted on the mainstem. Average daily stream flow for a 259-km^2 area ranges from 0.80 cubic feet per second (cfs) in the northwestern part of the drainage to 1.1 cfs in the southeastern part (Illinois Environmental Protection Agency 1976). Seven-day, 10-year low flows on

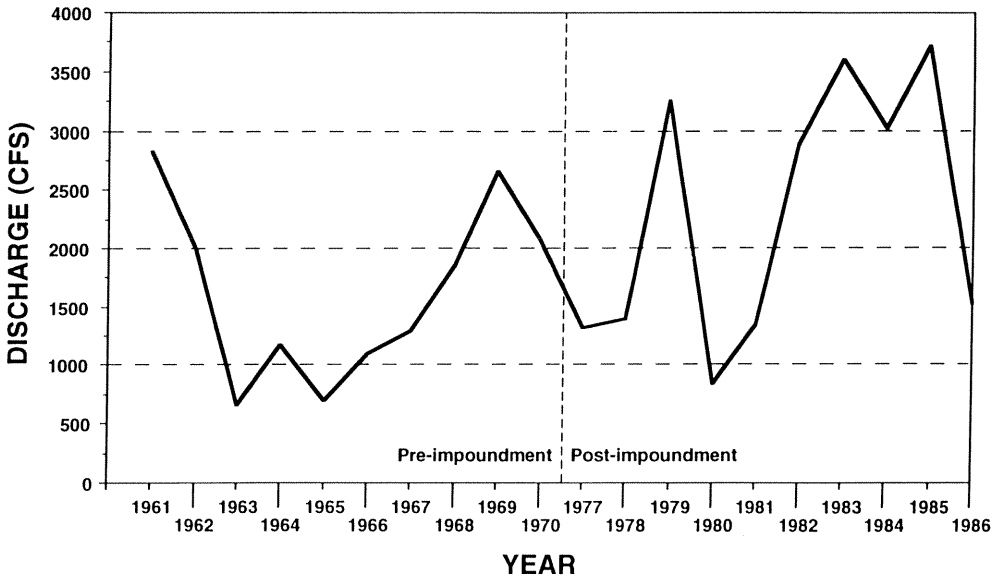

Fig. 3. Mean annual discharge pattern of the Big Muddy River as recorded by U.S. Geological Survey at the Murphysboro gaging station for a 10-year period (1961–70) before completion of Rend Lake and a 10-year period (1977–86) after completion of Rend Lake.

gaged streams in the drainage range from 0.0 cfs on several intermittent streams to 36.3 cfs on the mainstem near its mouth (Singh and Stall 1973). The rather extreme sinuosity of the Big Muddy River channel, a total fall of only 94 m, and an overall low gradient are the primary physical attributes collectively responsible for low stream velocities (U.S. Corps of Engineers 1968). Mean annual discharge recorded at the Murphysboro gaging station (Fig. 3) varied from 664 cfs in 1963 to 2,821 cfs in 1961 before completion of Rend Lake in 1970. After completion of Rend Lake, mean annual discharge varied from 839 cfs in 1980 to 3,599 cfs in 1983. Mean annual discharge does not appear to have stabilized since the lake was filled; however, this does not take into account the timing of the pulse and flow pattern during the spring.

Throughout the greater portion of its course, the Big Muddy River meanders about in a broad floodplain that is filled with drift and alluvium to a depth of 152–182 m or more above the bedrock. Upstream from Murphysboro (Fig. 1), the banks are neither abrupt nor high, and they and the bed of the stream are chiefly clay. Just below Murphysboro, the valley becomes constricted to a width of about 1.6 km as it breaches the elevated ridge that borders the Mississippi River. In its course through the Mississippi River Bottomlands its eastern shore hugs the ridge with a line of bluffs that rise 61–71 m above the river. On its west is the low, flat floodplain of the Mississippi River.

At Murphysboro (Fig. 1), where the channel is about 49 m wide, the water has sometimes risen 9 m, inundating the surrounding flats. Backwater from the Mississippi River is felt at that point and may even extend 138 km upstream to the vicinity of Plumfield (Hite et al. 1991).

Annual average rainfall of 106.7 cm and runoff of 31.8 cm, as well as soils of low permeability, make the Big Muddy River drainage suitable for surface water storage in reservoirs (U.S. Department of Agriculture 1968). Major impoundments in the drainage, all constructed since 1940, include Rend Lake (7,655 ha, completed in 1970), Crab Orchard Lake (2,821 ha, completed in 1940), Devil's Kitchen Lake (328 ha, completed in 1959), Little Grassy Lake (405 ha, completed in 1942), Cedar Lake (729 ha, completed in 1973), and Kincaid Lake (1,400 ha, completed in 1970). Numerous municipal reservoirs occupy smaller portions of the drainage. Rend Lake is an important source of flow in the Big Muddy River, providing a year-round flow of at

least 30 cfs as required by the U.S. Army Corps of Engineers.

Physiography

About 90% of the Big Muddy River drainage is located in the physiographic subdivision termed the Mount Vernon Hill Country of the Central Lowland Province (Leighton et al. 1948). Most of the remaining land area, the southwestern part of the basin, is in the Shawnee Hills section of the Interior Low Plateaus Province, which joins the Ozark Mountains in Missouri and Arkansas. A small portion of the drainage lies on the Mississippi River floodplain.

The Mount Vernon Hill Country is characterized by low rolling hills and broad alluvial valleys along the major streams. The relief in this region is not pronounced. Upland prairies are flat to moderately hilly, and the valleys are shallow. The land surface is controlled primarily by bedrock, which has been modified only slightly by glacial drift deposits. While the southern boundary of the Mount Vernon Hill Country lies within a few kilometers of the limits of glaciation, moraine ridges essentially are absent in the area.

The Shawnee Hills are south and southwest of the Mount Vernon Hill Country and provide striking contrast to that region. This section is unglaciated and characterized by rocky ridges and deep valleys. This area displays a complex, bedrock-controlled topography.

In its lower 32 km, the Big Muddy River flows on the Mississippi River floodplain. The floodplain is nearly flat except where it is broken by an outcrop of bedrock—Fountain Bluff—which rises about 122 m above the river channel at its base.

Geology

The entire Big Muddy River drainage lies in a preglacial valley. Over the greater portion of the area the drift is thin, and rock divides separating the preglacial drainages are plainly visible. During the Pleistocene, meltwaters from receding glaciers caused the Mississippi River to exceed its transporting capacity. The Mississippi valley filled with sediment deposits that closed the mouths of some tributary streams. The Big Muddy River, one of the impounded tributaries, formed a lake. When the Mississippi River was once more able to transport, the natural process of downcutting occurred, and the Big Muddy Lake was drained. Typical of a lake bed long subject to erosion, the soils of the Big Muddy River drainage contain little humus, are acidic, and consist of impervious clays and silts, interlaced with very fine sands (LeTellier 1971).

The Big Muddy River drainage is in the southern part of the geologic structure known as the Illinois Basin. Over most of the basin the bedrock lies nearly flat, sloping gently toward the east. The Pennsylvanian bedrock underlies about 80% of the basin and in places reaches thicknesses of 790 m. It generally is composed of shale, sandy shale, and sandstone interbedded with thin limestone layers and coal. A small area of Mississippian, Devonian, and Silurian bedrock occurs in the southwestern portion of the basin. The Devonian and Silurian bedrock consists of limestones and sandstones that, together with Pennsylvanian rocks, uplifted and formed portions of the Shawnee Hills.

Bedrock in the basin is overlain by discontinuous deposits of Pleistocene glacial till, a clay-rich slowly permeable material. Uplands may be mantled with up to 7.6 m of loess (a moderately to slowly permeable silty soil), the depth and permeability of which decrease from southwest to northeast across the basin. The loess, a highly erodible soil, is about 0.6 m thick at the upstream border of the basin and increases to 6 m near the mouth of the Big Muddy River (U.S. Department of Agriculture 1968). The stream valleys contain alluvium and lake clays, generally with low permeability and high water table levels. The Mississippi River floodplain, a small part of the drainage, contains deposits of outwash consisting of sand and gravel interbedded with layers of silt and clay. In addition, occasional small granular deposits such as alluvium, dune sand, and various types of glacial outwash deposits may be found in the basin.

Land Use

Cropland, forest, and pastureland are the predominant land uses in the central and lower Big Muddy River drainage, composing 51.5%, 24.5%, and 12.6%, respectively (U.S. Department of Agriculture 1968). The remaining 11.4% includes urban areas, industrial sites, residential areas, roads, coal mines, and oil fields. About 2% of the basin has been strip-mined for coal, and many areas have not been reclaimed. Gob and other waste materials are exposed on numerous old underground coal mine sites in Franklin County; these areas continue to contribute to water quality problems associated with acid runoff (Hite et al. 1991).

Substantial changes in the regional landscape have occurred since the time of settlement. In 1820, the five principal counties drained by the Big Muddy River were composed of 518,805 ha of forest and 124,132 ha of prairie (Iverson et al. 1989). By 1924 forested acreage was reduced to 109,796 ha (Iverson et al. 1989).

Mainstem Habitat

During August 1988, a period of near record low-flow conditions, the Illinois Environmental Protection Agency (Hite et al. 1991) collected a variety of habitat data that in our experience typifies the Big Muddy River mainstem. The mainstem averaged about 25 m wide and 0.73 m deep. Stream discharge ranged from 44 cfs west of Benton (just below the Rend Lake tailwaters) to 63 cfs at a downstream site near Murphysboro. Mean velocity at five sites was 0.12 m/s. The mean percentage of pool was 60.6 and of riffle 2.1. Average instream cover was about 8.8%; shading was sparse to moderate at 27%. Silt-mud (33.5%) was the predominant bottom substrate, followed by gravel (28.8%), plant detritus (10.6%), submerged logs (7.0%), cobble (6.9%), claypan-compacted soil (6.6%), sand (5.1%), boulders (1.2%), and other substrates. In comparison with other Illinois streams (e.g., Kaskaskia River to the north), the Big Muddy River had the highest means for width, depth, discharge, percent pool, and percent silt-mud—all characteristics of a low-gradient stream.

Natural Resources

The major natural resources available in the Big Muddy River drainage are soil, minerals, forests, and surface water. Groundwater supplies are scanty and of poor quality except along the extreme western edge of the drainage. The widespread construction of impoundments has provided adequate water supplies throughout the basin (Illinois Environmental Protection Agency 1976).

The principal mineral resources in the basin are coal and oil. These two commodities are in active production and are shipped from the area in quantities sufficient to make the Big Muddy River drainage a leading fuel-producing region. Pennsylvanian coal layers have been mined extensively for over a century, with production peaking from the late 1950's to the early 1970's. Coal reserves are substantial and probably exceed 15 billion metric tons.

Oil pools are known to exist in Franklin, Hamilton, Jefferson, and Washington counties. Most of the basin's oil production is from fields in Franklin and Jefferson counties. Estimated oil reserves in these two counties exceed 40 million barrels.

Other mineral resources in the basin are sand, gravel, limestone, sandstone, clay, and shale. These commodities are not recovered in large amounts, and production is used to supply local demands.

Water Quality and Environmental Impacts

As noted previously, pollution within the basin is associated with the various discharges and conditions inherent to coal mining and oil recovery as well as industrial and domestic effluent (Price 1965). The various forms of pollution and other environmental impacts (i.e., impoundments) are categorized below.

Drought

Extremely low flows during summer months and concomitant pooling of the mainstem were reported by early observers in the basin (Rolfe 1908). However, in recent decades the water table in Illinois has fluctuated more widely than it did before 1930 (Smith 1971). During some of the worst droughts affecting the basin (late 1980's), once permanently flowing streams dried up, seeps and springs ceased flow, and the mainstem temporarily became a medium-sized or even small stream. The effects of the most recent (1988) drought included massive fish kills in tributary streams primarily because of oxygen depletion.

Municipal and Industrial Discharges

Inadequate domestic sewage treatment, as well as discharges from various industries, accounts for poor water quality in some areas of the basin, particularly downstream of Rend Lake. Twelve communities have a population of 3,000 or greater, and 11 of these lie downstream of Rend Lake, discharging wastewater either directly into the mainstem or into tributaries (Hite et al. 1991). Numerous other point and nonpoint sources, including small wastewater treatment plants, industrial sites, and active and inactive coal mines, discharge nutrients, metals, and other constituents directly

or indirectly into the lowermost 167 km mainstem of Big Muddy River.

Historically, these discharges have degraded water quality and aquatic life in the river, particularly during periods of low flow. Early studies conducted by students of W. M. Lewis, Sr. at Southern Illinois University at Carbondale concluded that toxic pollution in the drainage was spasmodic and localized and that the most toxic conditions were confined to tributaries. The major pollutants in the early 1950's were sewage, creosols, silt, garbage wastes, iron, acid-mine drainage, and other coal-mine wastes (Walker 1952; Schuster 1953). Fish kills were documented on several occasions in the Crab Orchard Creek drainage near a railroad cross-tie plant, where creosote accumulation was washed into the creek during rainy periods (Lewis 1955). Price (1965) recorded a pH below 3.0, black water with frequent gas bubbles, and no fish near a municipal sewage discharge in Crab Orchard Creek about 8 stream km above the head of Crab Orchard Lake. Effluent sampling conducted in 1988 from 10 municipal wastewater treatment plants (Hite et al. 1991) revealed considerable variability in many parameters; however, phosphorus, un-ionized ammonia, and chemical oxygen demand were elevated more frequently than other constituents. In recent years, however, all major wastewater treatment plants that discharge to the lower Big Muddy River drainage have renovated or plan to upgrade treatment facilities through the state grant construction program (Hite et al. 1991). Because 70% of these plants have now made structural improvements in existing facilities, higher quality effluent would be expected in future studies.

Coal Mine Discharge

The presence of large waste piles from surface and underground mining presents a constant source of potential and oft-realized pollution in the drainage. Mining pollution was particularly acute during the 1950's and 1960's before the advent of regulation and reclamation. Although extensive mining activities are present in other Big Muddy River tributaries, including the Little Muddy River and Beaucoup Creek, the majority of mine drainage originates in Franklin and Williamson counties. Twenty-four mine discharges, permitted under the National Pollutant Discharge Elimination System, shunt effluent to the lower Big Muddy River or tributaries downstream from Rend Lake in Franklin and Williamson counties. Discharge types include surface runoff, reclamation runoff, pit pumpage, underground pumpage, untreated acid mine drainage, and treated acid mine drainage. At least nine known unpermitted and untreated mine discharges also release acid waters to the Big Muddy River in Franklin and Williamson counties (Hite et al. 1991). Runoff from the numerous spoil piles has resulted in water of undesirable quality flowing into the drainage. The pumping of water from old strip mines to rework the strip area for additional coal often results in even poorer quality water being discharged into waterways.

In 1964, Illinois Department of Conservation fishery biologist O. M. Price sampled Lake and Pond creeks, Williamson County (see Fig. 1) and recorded pH values of 3.5, a bright orange precipitate on the stream bottom and shoreline, and no fish at either station. In Lake Creek, a water velocity of over 0.15 m/s through a channel averaging 7.6 m in width and 0.6 m in depth, represented a considerable volume of polluted water flowing into the nearby mainstem. Fish kills from acidic waters continue to this day; the Illinois Environmental Protection Agency investigated a series of fish kills near Royalton on the Big Muddy River and in Prairie Creek from 1988 to 1990. The agency recorded pH values as low as 2.5 and high manganese concentrations in the Royalton drinking water (Hite et al. 1991). These problems are directly attributable to several mines just upstream of Royalton. Plans are underway for reclamation of these sites.

Water Quality

Water quality as measured at 27 sites on the mainstem and tributaries by Illinois Environmental Protection Agency personnel (Hite et al. 1991) during 1988 revealed that negative effects originated largely from municipal effluents and runoff from coal mines and agricultural activities. Water quality in 1988 generally was rated as borderline between fair/good and poor, although very good and very poor water also existed. Very good water was noted immediately downstream of Rend, Crab Orchard, and Kincaid lakes, which was indicative of reservoir trapping efficiency, specifically for nutrients and suspended solids. This effect was evident in the tailwaters of the major impoundments relative to water quality elsewhere in the basin. Very poor water was rare in the mainstem and more prevalent in tributaries. Middle Fork and its tributary, Ewing Creek, displayed

the poorest water. Water quality in these two streams was influenced largely by runoff from abandoned mines in the Middle Fork watershed. Illinois General Use Water Quality Standard violations were common in the Big Muddy River and tributaries but were not generally extreme. The standard most often violated was for manganese, followed by dissolved oxygen and then sulfate. The standard for pH was often violated; however, violations of these standards were limited to Big Muddy River tributaries (Hite et al. 1991).

Oil Pollution

Smith (1971) noted that oil-field pollution had been a problem in the Big Muddy River drainage for many years. There seems, however, to be little documentation of oil brine pollution affecting the fishes in the drainage. Price (1965) observed oil scum on the water surface, as well as on the shoreline vegetation, and debris in Galum Creek and the Middle Fork. Both of these sites contained poor fish diversity (8 and 13 species, respectively), and the fish assemblages were dominated by tolerant species (i.e., red shiner [*Cyprinella lutrensis*], redfin shiner [*Lythrurus umbratilis*], western mosquitofish [*Gambusia affinis*], bluegill [*Lepomis macrochirus*]).

Siltation, Stream Dredging, and Wetland Drainage

The cycle of poor soil conservation practices accelerating stream siltation, which in turn provides impetus for dredging, draining, and channelization projects, has plagued aquatic habitats in the basin for some time (Price 1965). The results include loss of adequate woody riparian corridors, loss of perennial and ephemeral riparian wetlands, a decrease in low flows (especially in tributaries), degradation of the floodplain, blockage of high flow channels, and homogenization of in-stream habitats. According to Smith (1971) excessive siltation ranks first in Illinois as the principal factor responsible for changes in fish populations. Its effects include loss of water clarity and subsequent disappearance of aquatic vegetation, and the deposition of silt over substrates that were once bedrock, rubble, gravel, and sand. Feeding and spawning sites have surely been reduced by siltation in the Big Muddy River drainage in this century. Likewise, the draining of floodplain wetlands has eliminated specialized spawning and nursery habitats for some fishes and reduced the primary habitat for others (see section on extirpated fishes). Smith (1971) ranked the drainage of wetlands as the second most important factor responsible for changes in fish populations in Illinois. At least 80 stream km of the Big Muddy River drainage have been channelized (Lopinot 1972), allegedly for flood control and to increase arable land. The effects of channelization include the straightening of natural stream meanders, denuding of the banks, and widening and deepening of the channel. The change in substrate and loss of instream cover and shade from channelization have resulted in stream fish communities represented by only the most tolerant species. Given the historical evidence that the mainstem generally carried a heavy silt load and often pooled up in the summer, we speculate that the effects of these factors on fishes were probably most severe in the river's tributaries.

Garbage

Various streams in the Big Muddy River drainage have been the dumping grounds for human garbage for many years (Walker 1952). While this irresponsible behavior results in an aesthetically unappealing and perhaps unhealthy environment, it is difficult to assess the long-term ecological effects of such abuse on the fish fauna.

Impoundments

The richness of the Big Muddy River fish fauna presumably is related directly to the number of different habitats available (Smith 1971). Flowing streams consist of alternating riffles and pools, each of which has many distinct microhabitats formed by various permutations of substrate type, depth, cover, and velocity. When the river and its tributaries were impounded, riffles and their respective microhabitats were eliminated and, in the shallow reservoirs of the Big Muddy River drainage (e.g., Rend Lake), the bottom was covered quickly with silt, resulting in only one basic fish habitat. Dams constructed to form impoundments also blocked natural migration and dispersal of fishes. Historically, the blue sucker (*Cycleptus elongatus*) was known to make spring spawning runs up the Big Muddy River; it has not been reported in the drainage since the 1950's (Lewis 1955). The paddlefish (*Polyodon spathula*) has been observed in the tailwaters of Crab Orchard and Rend lakes, but their dams prevent further upstream migration and spawning that may have occurred historically. Although preimpoundment

data generally are lacking and distributional information is scant (Smith 1979), we suspect that dam construction also impeded spring spawning runs of important sportfishes in the river, such as walleye (*Stizostedion vitreum*), white bass (*Morone chrysops*), and perhaps yellow bass (*Morone mississippiensis*), and hence diminished the potential of the river's fishery. As noted previously, there are numerous small, medium, and large reservoirs in the Big Muddy River drainage. Unfortunately, the construction of Cedar, Kincaid, Little Grassy, and Devil's Kitchen lakes destroyed some of the least affected and most aesthetically pleasing streams in the drainage.

Because of the basin's pollution history, some impoundments have exhibited elevated levels of trace metals in the fish populations, particularly mercury. In the past decade biomagnification of mercury in the flesh of various sportfishes was reported from Crab Orchard, Cedar, and Kincaid lakes (Call 1989). Call (1989) pointed out, however, that the sediments in these lakes ultimately may serve as a sink for trace metals, and thereby aid in mitigation of biological effects.

The Fish Fauna

General Faunal Composition

A total of 106 fish species, representing 25 families, has been recorded from the Big Muddy River drainage from 1892 to 1992 (Table 1). Of these, 97 species are considered native, and 9 occur in the drainage as a result of introductions of exotics or transplantations of species native to other parts of the continent. Just over half (51.9%) the total (187 species) native fish fauna known from Illinois (Burr 1991) occur in the Big Muddy River drainage. The native fish fauna of the drainage constitutes just over one-fourth of the 375 freshwater fishes found in the Mississippi River basin (Burr and Mayden 1992). The five dominant families are Cyprinidae (26 species), Catostomidae (13 species), Percidae (12 species), Centrarchidae (11 species), and Ictaluridae (8 species); in total they comprise 72% (70 species) of the native fauna. The families Petromyzontidae, Acipenseridae, Polyodontidae, Amiidae, Anguillidae, Hiodontidae, Umbridae, Percopsidae, Aphredoderidae, Amblyopsidae, Gadidae, Poeciliidae, and Sciaenidae are each represented by one extant native species.

The Kaskaskia River, the next major river drainage (15,022 km^2) to the north of the Big Muddy River, has at least 103 native species, and the Cache River, a major river drainage (2,717 km^2) to the south of the Big Muddy River, has at least 71 native species (Burr and Page 1986). Adjusting for catchment size (species per kilometer^2), the Big Muddy River drainage with about 0.02 species/km^2 has over twice the species density of the larger Kaskaskia River drainage (0.007) and slightly more than half that of the smaller Cache River drainage (0.03). Differences in catchment size, habitat diversity, and geological history are among the most important factors influencing native species diversity in the upper Mississippi River basin (Burr and Page 1986), and almost certainly account for the differences in native species diversity and density among the Big Muddy, Cache, and Kaskaskia rivers.

Unusual fishes known from the drainage that are apparently year-round residents with limited ranges in Illinois (Smith 1979) include the paddlefish, spotted gar (*Lepisosteus oculatus*), central mudminnow (*Umbra limi*), Mississippi silvery minnow (*Hybognathus nuchalis*), pugnose minnow (*Opsopoeodus emiliae*), lake chubsucker (*Erimyzon sucetta*), shorthead redhorse (*Moxostoma macrolepidotum*), freckled madtom (*Noturus nocturnus*), spring cavefish (*Forbesichthys agassizi*), mud darter (*Etheostoma asprigene*), and river darter (*Percina shumardi*). Exposed rock riffles during low flow on the mainstem near Murphysboro and at Rattlesnake Ferry often yield 25–30 species, including nearly all of the species listed above.

Unsubstantiated or Erroneous Fish Records

As with any major river system in North America, several fish species have been reported from the Big Muddy River drainage that remain unsubstantiated by voucher specimens or are considered erroneous. If recognized, they would constitute an extension of the range of a species, an enigmatic zoogeographic occurrence, or an improbable occurrence in a given habitat, or they could represent any of several similar species. Erroneous records are those misidentified as confirmed by examination of extant voucher specimens. Species reported from the drainage that remain unsubstantiated or erroneous include smallmouth bass (*Micropterus dolomieu*[= *M. salmoides*]), rock bass (*Ambloplites rupestris*, probably *L. gulosus*, no voucher; Forbes and Richardson 1908); highfin carpsucker (*Carpiodes velifer*, probably *C. cyprinus*, no voucher;

from Lewis 1955); steelcolor shiner (*Cyprinella whipplei* [= *C. lutrensis*] Lewis and Gunning 1959); mooneye (*Hiodon tergisus*, probably *H. alosoides*, no voucher), black redhorse (*Moxostoma duquesnei*, probably *M. erythrurum*, no voucher; Atwood 1988); river redhorse (*M. carinatum*, probably *M. macrolepidotum*, no voucher; Hite et al. 1991).

Rare and Extirpated Species

Over the last century at least 10 species are indicated as having been extirpated from the Big Muddy River drainage (Table 2), and several others are rare, uncommon, or distributionally problematic in the basin. Three of the 10 species considered as extirpated have received conservation status rankings from the state of Illinois (Illinois Endangered Species Protection Board 1990): alligator gar (*Atractosteus spatula*), cypress minnow (*Hybognathus hayi*), and pallid shiner (*Hybopsis amnis*). None of these species has been reported from the drainage in over 50 years (Table 2). Two other species, the blacktail shiner (*Cyprinella venusta*) and cypress darter (*Etheostoma proeliare*), are on the Illinois watch list (Burr 1991).

The alligator gar, a large-river and lowland species, was reported from the drainage by Forbes and Richardson (1908). The species rarely has been seen anywhere in Illinois since the 1960's (Smith 1979) and has declined precipitously throughout the upper Mississippi River valley (Burr and Page 1986). The cypress minnow was last collected in the drainage from three sites in the Little Muddy River and Beaucoup Creek in 1940 by A. Bauman (Warren and Burr 1989). He took large numbers (>30 specimens) at each site by seining, indicating the species was a relatively common, if somewhat localized (3 of 10 sites), component of the fish fauna. In an effort to rediscover the cypress minnow in the drainage, we resampled Bauman's localities, as well as others, without success, and we consider the species extirpated from the drainage (Warren and Burr 1989). Our sampling of a few remaining riparian wetland habitats (e.g., along Beaucoup Creek) that might potentially support cypress minnows generally yielded a depauperate and tolerant assemblage of fish (e.g., sunfishes, gizzard shad [*Dorosoma cepedianum*], western mosquitofish) and lacked native cyprinids, with the exception of the ubiquitous golden shiner (*Notemigonus crysoleucas*). We suggest that drainage of floodplain wetlands for agriculture was a prime factor in the disappearance of the cypress minnow. Wetlands adjacent to stream channels apparently were used by the species as spawning and nursery areas (Warren and Burr 1989). Agriculture and mining pollution (particularly in the case of Beaucoup Creek) also may be implicated in the extirpation of this once relatively common member of the fauna. The pallid shiner was taken in 1900 and 1940 at three sites, including the Big Muddy River mainstem, Crab Orchard Creek, and the Little Muddy River (Warren and Burr 1988). Despite specific searches for the species, extant populations have not been reported since 1940 (Warren and Burr 1988). The cypress minnow and pallid shiner persist elsewhere in Illinois and nearby states, albeit tenuously in much of the upper Mississippi valley. The alligator gar, however, is poorly represented throughout its range, and there is no evidence of

Table 2. Fish recorded from the Big Muddy River drainage, Illinois, in the period 1892–1992, and now considered extirpated.

Species	Years of collection or probable occurrence			
	1900	1920	1940	1960
Atractosteus spatula	0[a] _____	X[b]		
Hybopsis amnis	0 _____	_____	0	
Hybognathus hayi	X _____	_____	0	
Percopsis omiscomaycus	X _____	_____	0	
Luxilus chrysocephalus	X _____	_____	0	
Cyprinella venusta	X _____	_____	0	
Cycleptus elongatus	0 _____	_____	_____	X
Lota lota	0 _____	_____	_____	X
Anguilla rostrata	0 _____	_____	_____	X
Cyprinella whipplei	X _____	0 _____	_____	0

[a] 0 = occurrences documented by specimens in museums or recorded in the literature and considered valid.

[b] X = probable occurrence of a species at a given time, on the basis of collection or reliable reports in other parts of the drainage.

reproduction anywhere in the upper Mississippi valley.

During the course of status surveys conducted in 1992 (Burr et al. 1992), the blacktail shiner and cypress darter were not found in the Big Muddy River drainage. Both are on the northern edge of their range in Illinois (Smith 1979; Page and Burr 1991), were known from only one or two localities each in the drainage, and were taken originally in small numbers. The cypress darter's habitat now is impounded by Lake Kincaid, and the blacktail shiner probably occurred as a waif in the lower reaches of the mainstem from the Mississippi River. Both species survive elsewhere in southern Illinois and in suitable habitat to the south but can no longer be considered extant in the Big Muddy River drainage.

At least three of the extirpated species, including the American eel (*Anguilla rostrata*), burbot (*Lota lota*), and blue sucker (Table 2), are of some commercial value, and all were present before dam construction and excessive industrial, urban, and agricultural pollution. The striped shiner (*Luxilus chrysocephalus*) and steelcolor shiner (*Cyprinella whipplei*) were known from the lower mainstem. Both have suffered range compression in western Illinois, a pattern attributed to siltation, turbidity, and conversion of perennial to ephemeral streams (Smith 1979), certainly factors operating in the Big Muddy River drainage. Interestingly, Smith (1979) noted that in Illinois the steelcolor shiner was being replaced by the more ecologically tolerant spotfin shiner (*Cyprinella spiloptera*), a species recently recorded for the first time in the Big Muddy River drainage (Table 1).

The former occurrence of the trout-perch (*Percopsis omiscomaycus*) in the Big Muddy River drainage is near the southernmost edge of its range (Gilbert and Lee 1980; Burr et al. 1988). Two collections of the species were made in the 1940's in Kincaid Creek, where the species was apparently common (15 specimens at one site; Burr et al. 1988); now both Kincaid Creek sites are impounded by Lake Kincaid, and no subsequent collections have been made of this species in the drainage. The species is considered extirpated from the drainage.

Based on Table 1, several other species, although not considered extirpated, are rare or at least present problematic distributions in the basin. In 1978, the lake chubsucker was discovered in the basin in a large remnant wetland in the floodplain of the lower river (Burr et al. 1988). Although historical substantiation is lacking, we suggest its restricted distribution in the drainage is a product of the demise of the basin's wetlands. Four other species in the drainage have not been taken for at least 30 years (Table 1), including chestnut lamprey (*Ichthyomyzon castaneus*), silver chub (*Macrhybopsis storeriana*), river carpsucker (*Carpiodes carpio*), and blue catfish (*Ictalurus furcatus*). These species, all characteristic of the Mississippi River, are not rare, sensitive, or extirpated and probably continue to enter the Big Muddy River near the mouth.

On a smaller spatial scale, drainage alteration and watershed deforestation in the Galum Creek system before the 1960's probably contributed to the extirpation of three fishes from that system: Mississippi silvery minnow, emerald shiner (*Notropis atherinoides*), and pugnose minnow (Carney 1990). Five species historically known from Galum Creek were represented only in Little Galum Creek samples in 1989. Little Galum Creek is the only stream in the Galum Creek system that has not been diverted or modified for mining activities (Carney 1990).

Introduced Species

As with most impounded waters in the Midwest, exotic or transplanted sportfishes and forage species have been introduced into all of the moderate to large reservoirs in the drainage. The presence of introduced species raises questions as to their source, their ecological role in the drainage, and their importance to human welfare. The potential ecological effects of introduced and exotic fish on native aquatic communities include habitat alterations (e.g., removal of vegetation, degradation of water quality); introduction of parasites and diseases; trophic alterations (e.g., predation, competition for food); and hybridization, and spatial alterations (e.g., overcrowding; Taylor et al. 1984).

Of the nine introductions in the drainage, eight were apparently intentional, and one, the bighead carp (*Hypophthalmichthys nobilis*), is a recent invader from introductions made elsewhere in the Mississippi River basin. Three of the species are natives of Europe or Asia (grass carp, *Ctenopharyngodon idella*; common carp, *Cyprinus carpio*; bighead carp), one is from western North America (rainbow trout, *Oncorhynchus mykiss*), one originates from the Atlantic Slope (striped bass, *Morone saxatilis*), and the remainder are native to more northern or eastern waters. A plethora of tropical and subtropical aquarium fishes has

been released into the impoundments in the drainage only to perish in the ensuing winter. During the summer of 1992, anglers caught South American pacus (*Colossoma* spp.) from Little Grassy Lake and Southern Illinois University at Carbondale Campus Lake. Rainbow trout have been stocked into Devil's Kitchen and Crab Orchard lakes; they are not known to oversummer in Crab Orchard Lake. Two pikes, *Esox lucius* (northern pike) and *E. masquinongy* (muskellunge), have been transplanted into Kincaid Lake, where the northern pike reproduced the first 2 years. For ostensible vegetation control, the grass carp has been introduced into the Southern Illinois University at Carbondale Campus Lake and numerous farm ponds in the Big Muddy River catchment. On 4 August 1992 one of us (B. M. Burr) documented a single young-of-the-year (27 mm SL) grass carp from the lower mainstem of the river, the only record of natural reproduction of this species in Illinois waters. In the past 2 years, adult bighead carp were taken by anglers from the lowermost mainstem. We recently (4 August 1992), however, documented a single young-of-the-year (24 mm SL) bighead carp from the lower mainstem at Rattlesnake Ferry, again the first confirmation of natural reproduction of this species in the state. We are not certain that either of these species spawned in the Big Muddy River, but plan to conduct additional field work in 1993 in an effort to substantiate reproduction. The common carp was the first and only exotic found in the drainage during the Forbes and Richardson (1908) era, and it remains the most common exotic species. The striped bass has been introduced into Kincaid, Rend, and Crab Orchard lakes as a sportfish and has escaped over the spillways in all three lakes, although nothing is known regarding the survival of the escaped individuals. Humanmade ponds on the Crab Orchard National Wildlife Refuge have received introductions of the pumpkinseed (*Lepomis gibbosus*), and one adult male of unknown origin is documented from Beaucoup Creek. The yellow perch (*Perca flavescens*), transplanted to Crab Orchard and Devil's Kitchen lakes, has reproduced in the latter. The threadfin shad (*Dorosoma petenense*), native to the lower reaches of the drainage, and the inland silverside have been introduced in various impoundments as forage. The inland silverside is dispersing rapidly throughout the lower drainage.

Obviously, some of these introduced species are localized, uncommon, or small and apparently ecologically unimportant. In contrast, many others are voracious predators (e.g., northern pike) on or potential competitors (e.g., recently introduced carps) with native fishes. We do not have enough information to predict the long-term effect of these introductions, but we do note that the ratio of extant native to introduced fish has decreased from 97:1 in 1900 to 9.7:1 today. Given the model provided by the common carp, finding evidence of potential reproduction of bighead carp and grass carp in the drainage is disturbing. If we can confirm that these species are using the river as a spawning and nursery area, we speculate that the mainstem riverine fauna may be given over to these exotics, as it is to some extent now by the common carp.

Sport, Commercial, and Forage Fishes

In 1977, Illinois Department of Conservation fishery biologists, expending at least 60 min of effort per site, sampled five stations on the Big Muddy River with a boat-mounted electrofishing unit. From 1978 to 1986 annual sampling was continued at stations located near the mouth (Rattlesnake Ferry) and middle reaches of the river (near Benton). A comparison of total electrofishing catch at the five 1977 stations indicated greater fish population density near the river's mouth and near the Rend Lake tailwater than elsewhere (Atwood 1988). Over all years (1978–86) sampled, the most abundant fishes listed in decreasing order were common carp, gizzard shad, bigmouth buffalo (*Ictiobus cyprinellus*), bluegill, longear sunfish (*Lepomis megalotis*), largemouth bass (*Micropterus salmoides*), smallmouth buffalo (*Ictiobus bubalus*), freshwater drum (*Aplodinotus grunniens*), channel catfish (*Ictalurus punctatus*), black crappie (*Pomoxis nigromaculatus*), and bowfin (*Amia calva*).

The Quality Sport Fisheries Index (QSFI) also was calculated for the Illinois Department of Conservation samples. The QSFI is derived from sample abundances of a given sportfish weighted by a measure of angler preference (Atwood 1988). According to recent angler preference in southern Illinois, the five most popular sportfishes are catfish, crappie, largemouth bass, white/yellow bass, and sunfish (Atwood 1988). All of the 1977 Big Muddy River stations had either fair or poor QSFI ratings. Over the 10-year monitoring period, the site at Rattlesnake Ferry (near the mouth) had the highest QSFI ratings. Ratings were correlated (Pearson product-moment correlations [r]), in part,

with discharge at the time of sampling (r = .773) and mean annual discharge (r = .741). Low catch rates at some stations probably resulted from high stream temperature, low stream flow, and low dissolved oxygen. Low dissolved oxygen levels could have resulted because of high nutrient loading from substandard sewage treatment facilities at West Frankfort and Herrin (Hite et al. 1991), and also from high organic content of the silt/mud sediments. These factors also may account for the high densities of common carp at some stations.

Composition and relative abundance of species taken during the Illinois Department of Conservation surveys of 1977–86 are similar to those reported by Lewis (1955). He emphasized that most fishing in the river at that time was of a commercial nature. In 1951, only one full-time and 10 part-time commercial fishermen operated on the river. Catches were dominated by common carp and buffalofish (Starrett and Parr 1951). Few commercial operations still exist on the Big Muddy River in large part because of the resultant low standard of living (i.e., low price per kilogram). Today, most commercial fishermen harvest buffalofish (*Ictiobus* spp.), carpsuckers (*Carpiodes* spp.), common carp, and catfishes (channel catfish and flathead catfish, *Pylodictis olivaris*).

Lewis (1955) suggested that the sportfish populations were controlled by extreme fluctuations in water level, lack of spawning sites, and mine-waste pollution. To produce better recreational stream fishing, he urged the elimination of chemical pollution and that more impoundments be built to completely control water-level fluctuations. Ironically, except for Rend Lake, most of the large dams since constructed in the basin have no means of controlling the amount or timing of tailwater release. Garver (1974) described fishing opportunities as abundant in the Big Muddy River, with many desirable species of large size being present, but indicated that fishing pressure was light. Allen and Wayne (1974) described the fishing pressure as heavy at the Rend Lake tailwater, light to moderate in middle downstream sections, and becoming progressively heavier in the lowermost reaches near the river's confluence with the Mississippi. In a survey of stream access, Davin and Sheehan (1991) noted that about one-fourth of all fishing trips in Illinois are made to streams. Weekday pressure accounted for 70% of total fishing pressure (a total of 25,342 h) on the Big Muddy River. At the most commonly used access site on the Big Muddy River (near the mouth), only 15% of the use was for angling purposes during 1989–90. Compared with the nearby Ohio and Kaskaskia rivers, fishing pressure on the Big Muddy River is low. Of the 6,664 h of angling effort recorded by creel clerks during a 20-month period in 1989–90, 52% of that effort was directed to the Ohio River, 34% to the Kaskaskia River, and only 2% to the Big Muddy River (Davin and Sheehan 1991). Poor access to fishing sites is a primary limiting factor. The top four species harvested in southern Illinois during this same period were crappies (combined), bluegill, channel catfish, and largemouth bass.

Index of Biotic Integrity

Hite et al. (1991) sampled seven sites in the drainage with a boat-mounted electrofishing unit in an effort to assess community structure and to evaluate the fish fauna with the Alternate Index of Biotic Integrity (AIBI; Karr et al. 1986). Categories used for the AIBI included (1) species richness and composition, (2) trophic composition, and (3) fish abundance and condition. Hite et al. (1991) collected 947 fish representing 33 species at seven mainstem sites on 15–18 August 1988 (Table 3). Seven species, including shortnose gar (*Lepisosteus platostomus*), gizzard shad, common carp, smallmouth buffalo, channel catfish, bluegill, and freshwater drum, were present at all sites. The common carp was the most abundant species, followed by freshwater drum and bluegill. Centrarchids dominated the 1988 samples, accounting for 31% of all fish collected (mostly bluegill), followed by cyprinids (22.9%), sciaenids (13.6%), clupeids (11.9%), catostomids (8.7%), ictalurids (6.6%), and lepisosteids (3.4%).

Biotic integrity of mainstem fish communities was rated fair based on AIBI values ranging from 31.6 at a station on the lower river (Turkey Bayou) to 38.2 at a station near the mouth (Rattlesnake Ferry) and a more centrally located station (Route 14 West of Benton) out of a total possible AIBI of 51–60. The closest point source pollution to the Turkey Bayou site is 26.4 km upstream at the Murphysboro wastewater treatment plant. This may account, in part, for the low AIBI scores at that site. The AIBI values were generally higher in the upper section (downstream from Rend Lake, southeast of DeSoto, at Blairsville) of the mainstem even though this area has been affected historically by point source pollution.

In the Galum Creek system, Carney (1990) found mean AIBI values to vary from 34.9 to 42.0. Little Galum Creek yielded the highest biotic integrity

Table 3. Summary of 1988 fish community characteristics as used in the Alternate Index of Biotic Integrity (AIBI) at seven sites on the mainstem of the Big Muddy River (Hite et al. 1991). Sampling stations are as follows: N-06 (Rt. 14 W Benton); N-11 (1.1 km W Plumfield); N-17 (Cambria Rd. @ Blairsville); N-16 (3.2 km SE DeSoto); N-12 (Rt. 127 S Murphysboro); N-23 (4.8 km E Johns Spur); N-99 (Rattlesnake Ferry). ND = not determined.

Community categories, metrics, and ratings	Site							
	N-06	N-11	N-17	N-16	N-12	N-23	N-99	Totals
Species richness/composition								
Total species	18	15	20	16	21	16	21	33
Sucker species	2	4	2	4	4	3	4	6
Sunfish species	5	4	7	4	4	2	5	7
Darter species	0	0	0	0	0	0	0	0
Intolerant species	2	3	1	2	2	1	2	4
Trophic composition (%)								
Green sunfish	0	0	1.5	0	0	0	0	0.2
Omnivores	30.5	42.2	39.7	48.1	43.8	36.8	18.7	33.9
Insectivorous cyprinids	6.0	0	2.3	2.8	0	1.1	0.4	2.1
Carnivores	13.0	15.7	10.7	12.3	21.0	24.1	14.5	15.1
Fish abundance/condition								
Proportion of hybrids	0	0	0	0	0	0	0	0
Proportion diseased	ND	ND	ND	ND	ND	ND	ND	ND
Total no. individuals	200	83	131	106	105	87	235	947
Index of Biotic Integrity (AIBI)	38.2	38.2	36.0	36.0	33.8	31.6	38.2	
Stream quality assessment	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Stream classification (BSC)	C	C	C	C	C	C	C	

scores among nine sites sampled in the system in 1989. Except for Little Galum Creek, the other major streams in the Galum Creek system have been diverted and modified as a result of mining activities. The higher AIBI values in the undiverted Little Galum Creek were because of the presence of more native species, particularly darters and suckers.

Fish Contaminants

In 1988, Hite et al. (1991) removed 48 fish representing six species (29 common carp, 1 bigmouth buffalo, 1 flathead catfish, 15 channel catfish, 1 spotted bass (*Micropterus punctulatus*), 1 walleye) from four mainstem sites on the Big Muddy River for contaminant analysis (Table 4). Chlordane, DDT, and PCB's occurred at low levels but attest to the persistence and probably widespread historical use of these compounds in the watershed. Total mercury concentrations were higher in some common carp fillets from river samples than in those from Crab Orchard Lake but did not warrant issuance of a consumption advisory (Hite et al. 1991). The sources of mercury in the drainage are probably from sewage and industrial effluents.

Changes in Fish Assemblages

The 12 collections (Table 1) made in the drainage between 1892 and 1900 contained 45 native species and 1 exotic (Forbes and Richardson 1908). A. C. Bauman made 10 collections in 1939–40 totaling 58 native species and 1 exotic. The surveys of W. M. Lewis from 1950 to 1959 included at least 30 collections containing 64 native species and 1 exotic. P. W. Smith and his colleagues made 65 collections in the drainage from 1963 to 1978 and found 67 native species and 2 introductions. From 1980 to 1992, we made 55 collections in the drainage and recorded 71 native species and 9 introductions. Species richness during each of these periods plotted against the respective number of collections indicates that richness primarily is a function of effort (Fig. 4). Considering sampling techniques, sampling period, effort, and locations sampled, the overall native species composition from several decades of record has changed only moderately in the Big Muddy River drainage (Table 1). Except for some large-river fishes known only from near the mouth of the river, presumed extirpated species, and the more recent fish introductions, Bauman's

Table 4. Concentrations of organochlorine compounds, mercury, and lipids in whole fish samples at selected sites in the Big Muddy River mainstem, 1988 (Hite et al. 1991). Results are as μg/g (parts per million) except as otherwise noted.

Station[a]	Species	Sample type	No. of fish	Length (mm)	Weight (g)	Lipid (%)	Total mercury	Total chlordane	Alpha + gamma chlordane	Dieldrin	Total DDT	Total PCB's	Heptachlor epoxide
N-06	Spotted bass	whole	1	272	300	2.0	0.15	0.09	0.03	0.01[b]	0.04	0.14	0.01[b]
	Flathead catfish	whole	1	458	1090	1.2	0.30	0.07	0.03	0.01[b]	0.02	0.12	0.01[b]
	Bigmouth buffalo	whole	1	437	1180	0.4	0.17	0.02[b]	0.02	0.01[b]	0.03	0.19	0.01[b]
	Common carp	whole	1	465	1340	2.9	0.36	0.07	0.04	0.01[b]	0.02	0.13	0.01[b]
N-11	Common carp	whole	1	487	1420	4.4	0.37	0.33	0.14	0.01	0.09	0.46	0.01[b]
	Common carp	whole	1	455	1150	7.5	0.23	0.53	0.26	0.01[b]	0.12	0.53	0.01
N-12	Walleye	whole	1	467	870	3.1	0.83	0.26	0.11	0.01[b]	0.18	0.89	0.01[b]
	Channel catfish	whole	1	443	710	4.8	0.13	0.17	0.07	0.01	0.15	0.61	0.01[b]
	Common carp	whole	1	411	910	6.3	0.32	0.26	0.11	0.02	0.34	0.78	0.01[b]
N-06	Common carp	fillet	5	398[c]	744[c]	2.5	0.33	0.07	0.05	0.01[b]	0.03	0.29	0.01[b]
N-11	Channel catfish	fillet	4	365[c]	423[c]	0.8	0.45	0.03	0.02[b]	0.01[b]	0.11	0.10[b]	0.01[b]
	Common carp	fillet	5	389[c]	689[c]	1.0	1.05	0.04	0.02[b]	0.01[b]	0.02	0.10[b]	0.01[b]
	Common carp	fillet	5	381[c]	705[c]	3.8	0.89	0.21	0.11	0.01	0.05	0.22	0.01[b]
N-12	Channel catfish	fillet	5	396[c]	554[c]	1.7	0.36	0.03	0.02[b]	0.01[b]	0.03	0.10	0.01[b]
	Common carp	fillet	5	455[c]	1327[c]	1.8	0.80	0.11	0.05	0.01[b]	0.07	0.13	0.01[b]
N-99	Channel catfish	fillet	5	374[c]	499[c]	1.6	0.45	0.05	0.03	0.01[b]	0.04	0.10	0.01[b]
	Common carp	fillet	5	400[c]	822[c]	1.6	0.85	0.02	0.02[b]	0.01[b]	0.03	0.10[b]	0.01[b]

[a] Sample sites are identified in Table 3.
[b] Less than detection limit.
[c] Average length and weight of multiple fish.

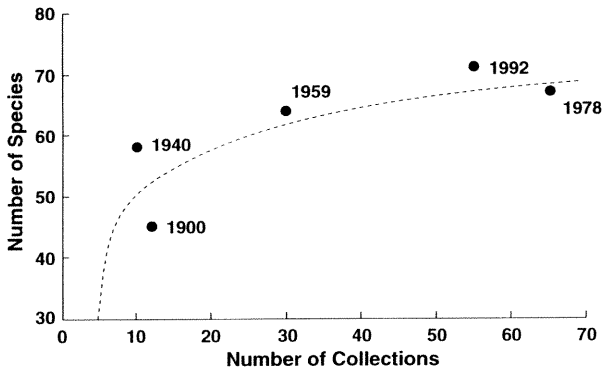

Fig. 4. Relation between fish species diversity and sampling effort (number of collections) over time in the Big Muddy River drainage. Years correspond to the five eras as discussed in the text: 1900 (Forbes and Richardson); 1940 (A. C. Bauman); 1959 (W. M. Lewis, Sr.); 1978 (P. W. Smith); and 1992 (B. M. Burr). The line was fitted by visual inspection.

samples from 1939–40 seem to be representative of the present known native fish fauna. This interpretation of the data, however, may be misleading and may overlook some important subtleties. For instance, could Bauman's results of 58 species in 10 collections be repeated today? We suspect not.

Changes in the fauna are not as readily apparent in species richness as in assemblage structure. Examination of Bauman's collection records from tributaries and comparison with other collections from the same localities made at later dates (Table 5) demonstrate rather striking changes in cyprinid fish assemblages over time. For example, one site on the Little Muddy River near Tamaroa has been sampled for maximum species diversity and abundance on four different occasions (Table 5). Three species (cypress minnow, pallid shiner, pugnose minnow) taken in Bauman's samples have not been collected at this site in over 50 years. Interestingly, Bauman did not collect any of the tolerant cyprinids that are now common at this site and elsewhere in the drainage. Even in 1963, the now abundant red shiner was not present at this site. The original cyprinid assemblage at the Little Muddy River site and elsewhere in the basin appears to have been replaced by aggressive minnows (e.g., red shiner, common carp) that are either tolerant of a wide range of chemical and physical parameters (i.e., dissolved oxygen, temperature, turbidity, siltation) or spawn readily in disturbed habitats (e.g., ribbon shiner [*Lythrurus fumeus*], redfin shiner). Considering the dramatic physical and chemical alterations that have occurred in the drainage for over 100 years, the permanence of the bulk of the fauna is a testament to the ability of fish communities to respond and persist under a variety of stochastic processes.

Discussion

As a matter of historical record, we have emphasized the many changes that have taken place in a century of use by humans living, working, and recreating in the Big Muddy River drainage. From written history, the river always has displayed lowland characteristics, and because of its muddy banks, predominantly silt substrate, and sluggish flow has never been particularly popular with anglers, boaters, and other potential users. The drainage also has been as abused environmentally as any in the Midwest; conversely, portions of the drainage are as scenic (e.g., Little Grand Canyon, Giant City State Park) and heavily used for a variety of purposes as any in Illinois. Except for the heavy angling use on reservoirs, the fishery resources have been underused historically in the river. Several small upland streams in the basin contain significant populations of spotted bass, and the mainstem maintains large populations of important commercial and sport fishes and smaller populations of desirable sport fishes, all of which have received little fishing pressure, as judged from surrounding areas.

Illinois is a model state in view of its excellent database documenting changes in fish distributions over time. Although we have learned a great deal about the effects of human activities on the aquatic environment in the Big Muddy River, we must continue to conduct basic survey work on its fish populations and to document long-term changes in the fauna. Because fishes are sensitive indicators of environmental quality, continued collection of data will aid in monitoring a variety of stream-quality parameters and assist public agencies in identifying quality habitats in need of protection. Many of the smaller streams in the Big Muddy watershed have never been sampled adequately for fishes or had their environments assessed in any modern sense.

Because of the number of species extirpated or endangered in the Big Muddy River drainage, we need to establish a monitoring program and status surveys of species on the watch list. The most effective course of action might be to allocate funds and efforts on species that may be realistically

Table 5. Changes in the minnow (*Cyprinidae*) fauna over time as recorded from Little Muddy River, 8 km east Tamaroa, Jefferson County, Illinois. Data are number of specimens collected.

Species	Bauman 1940	Smith et al. 1963	Burr & Mayden 1979	Burr & Warren 1988
Hybognathus hayi	37			
Hybopsis amnis	2			
Opsopoeodus emiliae	3			
Notemigonus crysoleucas	62	4		
Semotilus atromaculatus	1	2		
Lythrurus fumeus		10	5	10
L. umbratilis		6	35	2
Pimephales notatus		11	6	41
Cyprinella lutrensis			17	57
Cyprinus carpio				4

recoverable, rather than expending efforts on species already nearing extirpation in the basin.

Over the past several years, we have come to recognize that single-species fish management, developed largely to placate the perceived needs of predominant users (i.e., anglers), often results in overly expensive programs emphasizing simplified ecological principles and low biological diversity. Future management practices should strongly consider a fish-community approach that encompasses an entire basin and its fauna, not just the artificial milieu of reservoirs. In view of this, more funding is needed for studies on basic fish biology, especially nonsport fishes, emphasizing reproductive biology, trophic ecology, predator-prey interactions, and parasites and diseases.

Game and sportfishes have been stocked in Big Muddy River reservoirs for years. Observations by several biologists have confirmed that many of these species disperse over the dams, and their presence has been confirmed in the tributaries and mainstem. The ecological effects on stream fishes never subjected to such major predators as striped bass and muskellunge are unknown but are probably detrimental. In addition, the long-term ecological and economic effects of the recently introduced Eurasian carps (i.e., grass and bighead carps), both of which are documented here for the first time to be either reproducing in the river or using it as a nursery area, are again unknown. We strongly recommend discontinuance of stocking of nonnative sportfishes and nonnative forage species until their effects on the river fauna can be monitored and assessed.

An education program for potential users of the Big Muddy River could be developed to convince anglers to seek out fish in the drainage because its "muddy" condition is natural. In addition, resource managers could control harvest of sportfishes to create a trophy fishery for catfishes. This might attract anglers and thus build a base of concerned users.

While environmental problems of nearly every conceivable kind have plagued many of the tributaries and parts of the mainstem for decades, recent changes in legislation and regulation regarding wastewater treatment, strip-mine reclamation, and water quality standards have greatly improved the condition of the river and presumably the fish populations. Much of the previous pollution that continued unabated for years has now been either halted, or plans for improvement are being implemented. These improvements probably will not allow recovery of already extirpated species but may allow rare species to survive in the habitat available.

The drainage of wetlands adjacent to the river has historically eliminated spawning and nursery areas for some species and year-round habitat for others. We recommend that wetland drainage be halted on any scale until an ecological plan for the entire drainage can be formulated. Moreover, we advocate recovery of lost riparian wetlands and the development of a land acquisition program to achieve more wetlands in the watershed. Likewise, reservoir construction and stream channelization also should be discontinued because of the destructive effects these practices have on large expanses of stream habitat.

Some practical and economically feasible suggestions (Davin and Sheehan 1992) to increase use of the Big Muddy River include (1) improving stream access sites (e.g., clean-up silt loads at boat ramps), (2) providing more support facilities near

access sites, and (3) adding additional access sites to provide opportunity for additional use of the resources. In addition, we recommend establishment of permanent mainstem and tributary sampling stations where annual or biannual standard (i.e., CPUE) monitoring can be conducted.

There is still a need to identify stream segments of exceptional quality in the Big Muddy River drainage that warrant special consideration for protection. Continued vigorous reclamation of abandoned mine lands and treatment of acid mine drainage is imperative. Finally, we must focus greater emphasis on the importance of valuable stream resources and an awareness of where these resources exist.

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