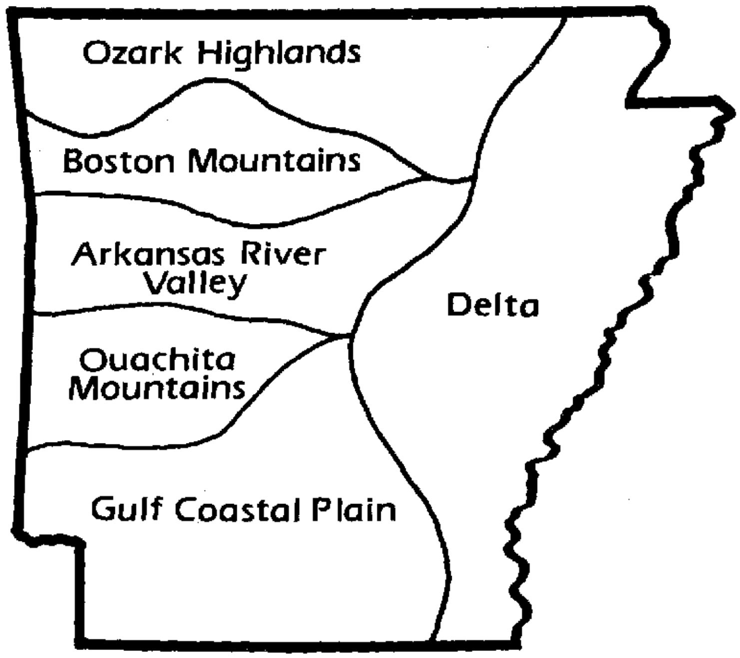
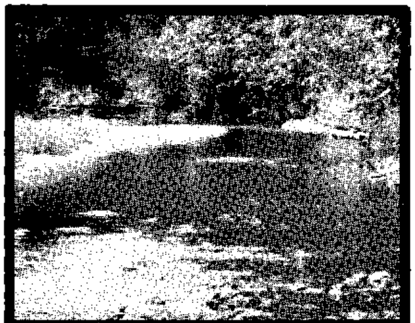
Physical, Chemical, and Biological Characteristics of Least-Disturbed Reference Streams in Arkansas' Ecoregions





Yocum Creek
Ozark Highlands

Archey Creek
Boston Mountains

Dutch Creek
Arkansas River Valley

Little Missouri River
Ouachita Mountains

Moro Creek
Gulf Coastal Plain

Bayou DeView
Delta

Volume II: Data Analysis
1987

State of Arkansas
Department of Pollution Control and Ecology

PHYSICAL, CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF LEAST-DISTURBED REFERENCE STREAMS IN ARKANSAS' ECOREGIONS

Volume II - Data Analysis

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PHYSICAL, CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF LEAST-DISTURBED REFERENCE STREAMS IN ARKANSAS' ECOREGIONS

Volume II - Data Analysis

Introduction

The following discussion is an analysis of the salient data presented in the document "Physical, Chemical and Biological Characteristics of Least-Disturbed Reference Streams In Arkansas' Ecoregions, Volume I: Data Compilation." The data was obtained from intensive field investigations of 37 reference streams during both the low-flow, high-temperature season and the higher flows and cooler temperatures of spring. Among the immediately apparent and currently needed uses of this data are: (1) providing baseline data from waterbodies with the least amount of point source and nonpoint source disturbance; (2) a characterization of the streams within each ecoregion; (3) classification of streams based on their instream uses; (4) a reference gauge to evaluate monitoring data, abatement activities and perturbations; and (5) a sound basis for developing realistic water quality standards and beneficial uses within ecoregions.

Methodology

The delineation of ecoregions within Arkansas is based on the principles described by J.M. Omernik, M.A. Shirazi and R.M. Hughes in a "Synoptic Approach for Regionalizing Aquatic Ecosystems" (1981). The ecoregions were established as the areas of greatest homogeneity of land surface forms, potential natural vegetation, soil types and land uses. Areas within each ecoregion which contain similar characteristics of all four of the above-named features are established as the most typical area of the ecoregion. All other areas which are similar within three of the four features of the ecoregion are designated as generally typical.

Reference streams and sample sites were selected on the basis of the following criteria: (1) no (or very few) point source discharges and no substantial areas of nonpoint source disturbances; (2) the greatest possible amount of the drainage area within the most typical area of the ecoregion; and (3) a wide range of drainage areas above the sample sites.

Sampling activities at each site included measurements of numerous physical features of the stream. Some of these were flow, channel and stream width, substrate types, instream cover, composition of riparian area and amount of stream canopy. Approximately 20 water quality parameters were measured during both the spring and summer sampling and 48- to 72-hour continuous recordings of water temperature and dissolved oxygen were made. Macroinvertebrate populations were intensively sampled during both periods and a comprehensive fish population sample was taken during the summer period. Detailed descriptions of sampling and data collection methodology are given in the Data Compilation report.

Reference Streams and Sample Sites

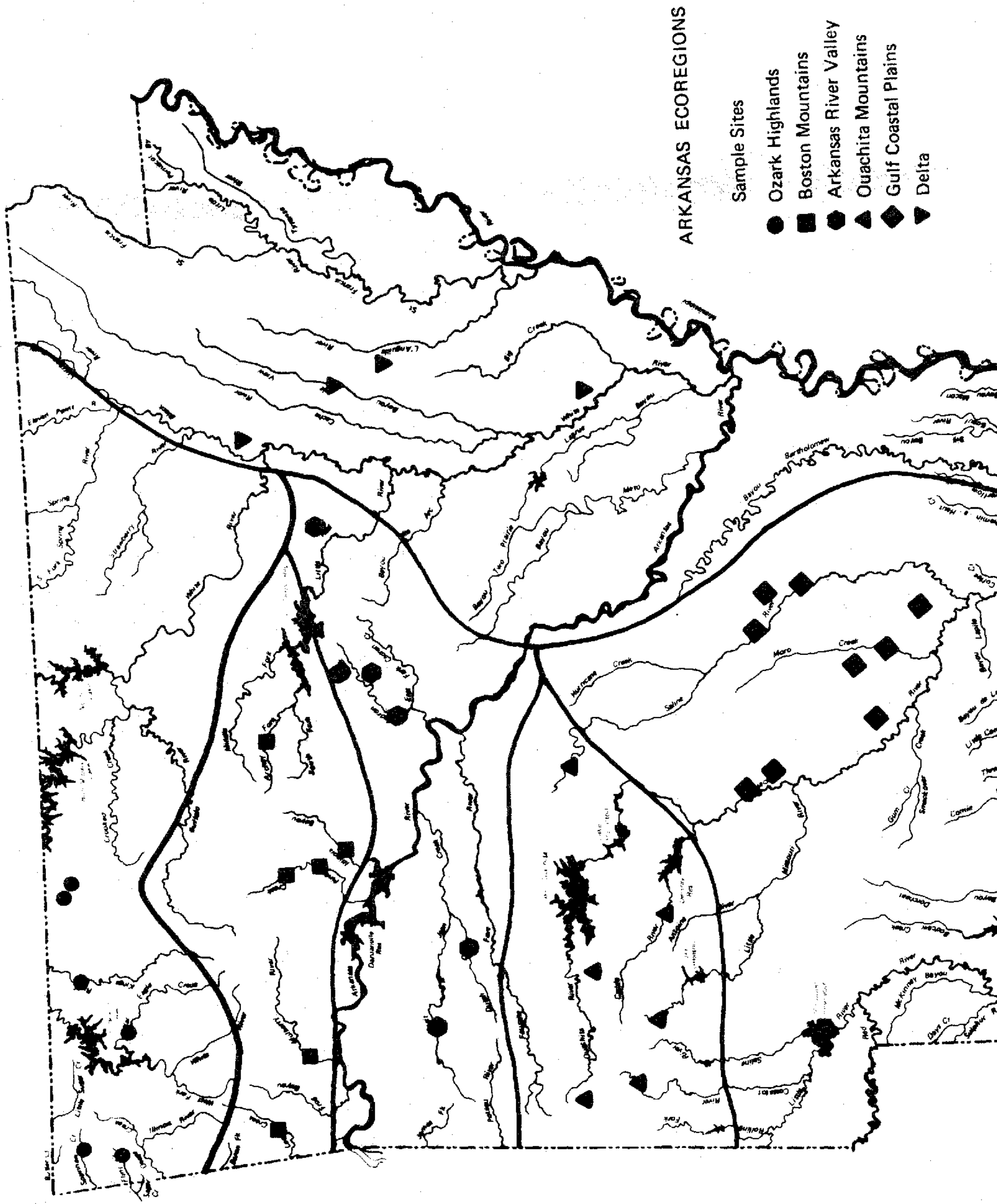
The following map shows the distribution of sample sites among the ecoregions; the corresponding table on page 4 lists all reference streams with their watershed size, stream gradient and seasonal flows at the sample site.

All reference streams chosen in the Ozark Highlands Ecoregion are located in the western half of the region. This is where the majority of the most typical areas of the ecoregion are located. All but the two smallest reference stream watersheds are located almost entirely within the most typical area of the ecoregion.

In the Boston Mountains Ecoregion, all sites except Lee Creek drained predominantly most typical areas of the ecoregion. The Archey Creek site was not in the most typical area, but much of the watershed above the site drained most typical areas.

Four of the sites within the Arkansas River Valley Ecoregion are located within the most typical area of this ecoregion. The Dutch Creek and Petit Jean River watersheds are located in a zone of disputed classification between the Ouachita Mountains and the Arkansas River Valley. According to Hughes and Omernik, both of these watersheds are within the Ouachita Mountains Ecoregion; however, Foti (1974) places this section of the state with the Arkansas River Valley subdivision. Physical, chemical and biological data collected at the Dutch Creek and Petit Jean River sample sites are more characteristic of the Arkansas River Valley and share very few similarities to Ouachita Mountains; therefore, these sites are included as part of the Arkansas River Valley Ecoregion.

Almost all of the reference stream sample sites in the Ouachita Mountains Ecoregion are located within the most typical areas. Only the Caddo River site has less than one-half of its watershed within the most typical area of the region. The South Fork Ouachita River site has one of the smaller watershed sizes selected for the region, but the stream gradient is only 7 ft/mi, which is relatively low for a small Ouachita Mountains stream. Conversely, the Cossatot River site has a watershed of 120 mi^2 and the steepest stream gradient of any sample site. These features substantially affected the biotic and abiotic features at both sites. Summertime flows encountered in the Ouachita Mountains streams are significant even in the smaller streams.


ARKANSAS ECOREGIONS
Sample Sites
Ozark Highlands
Boston Mountains
Arkansas River Valley
Ouachita Mountains
Gulf Coastal Plains
Delta

Watershed Size, Stream Gradient and Seasonal Flows of Ecoregion Reference Streams

Stream	Watershed Size (mi²)	Gradient (ft/mi)	Summer Flow (cfs)	Spring Flow (cfs)
Delta Ecoregion				
Boat Gunwale Slash	23	0.7	2.9	230.0
Second Creek	60	0.8	7.5	165.0
Village Creek	194	0.5	133.5	35.0
Bayou DeView	460	0.6	191.0	500*
Gulf Coastal Ecoregion				
E. Fork Tulip Cr.	46	3.5	5.2	56.0
Cypress Creek	73	4.2	10.8	150.0
Whitewater Creek	23	2.8	0.0	2.3
Big Creek	59	2.7	0.0	0.5
Derrieusseaux Cr.	148	3.4	0.0	200*
Bayou Freeo	156	3.0	0.0	16.1
Hudgin Creek	187	1.4	0.0	300*
L'Aigle Creek	232	2.6	0.0	188.7
Moro Creek	451	1.6	0.0	350.0
Arkansas River Valley Ecoregion				
Mill Creek	17	13.5	0	10
North Cadron Creek	21	10.0	0.1	10
Ten Mile Creek	49	8.1	0.2	105
Dutch Creek	110	3.8	0.5	70
Petit Jean River	241	3.9	0.3	300*
Cadron Creek	308	0.6	15.0	500*
Ouachita Mountains Ecoregion				
Board Camp Creek	19	27.8	2.7	19.7
Little Missouri R.	30	29.0	3.9	25.8
So. Fork Ouachita R.	46	7.0	6.7	33.7
Cossatot River	120	40.0	17.4	97.4
Caddo River	291	13.3	134.0	500*
Saline River	361	4.1	53.0	400*
Ozark Highlands Ecoregion				
South Fork Spavinaw Creek	18	25.5	1.4	17
Flint Creek	19	19.6	4.5	27
Yocum Creek	55	18.0	5.3	162
Long Creek	184	7.0	9.5	183
War Eagle Creek	263	4.0	25.1	102
Kings River	526	4.6	48.8	252
Boston Mountains Ecoregion				
Indian Creek	47	32	0.1	19
Hurricane Creek	50	33	0.1	30
Archey Creek	107	14	0.6	122
Illinois Bayou	125	12.5	1.0	147
Lee Creek	168	15.3	3.5	300*
Mulberry River	373	13.7	6.4	300*

*Estimated

Nine reference streams were ultimately selected within the Gulf Coastal Ecoregion. This larger number of reference streams resulted from the discovery of two major categories of streams within the ecoregion. Two streams with substantial springwater discharges, East Fork of Tulip Creek and Cypress Creek, were found to have significantly different physical, chemical and biological characteristics from the other seven typical Gulf Coastal Ecoregion streams. The most typical areas of this ecoregion are very scattered and small except for a large area located in the oil production section of southern Arkansas. Much of this area has substantial water quality impairment associated with the oil industry. As a result, only 30% to 50% of the watershed of most of the reference streams were within the most typical areas. None of the watersheds of Whitewater Creek and Freeo Bayou were within the most typical areas. Seventy (70) to 90% of the watersheds of Cypress and East Fork of Tulip Creek were in the most typical area, but these streams were considered atypical because of their springwater influence.

Only four reference streams were located in the highly agricultural Delta Ecoregion. Village Creek and Boat Gunwale Slash sites had drainage areas which were 80% to 100% within the most typical areas of the ecoregion. Bayou DeView and Second Creek drained only 20% to 30% of most typical areas. Although summertime flows in the Delta may be substantially influenced by withdrawals and discharges from irrigation activities, it is strongly suspected that the flows recorded at Village Creek and Bayou DeView during the summer period were atypically high from a previous summertime rain storm. Conversely, the spring flow recorded for Village Creek was atypically low due to the lack of springtime rainfall.

Physical Characteristics of Reference Streams

The geophysical components of each of the six physiographic regions in Arkansas are the major determinants of the overall water quantity and quality of each region. They are also generative forces in the composition of the aquatic community within the specific regions. Differing geologic formations influence various water quality conditions, e.g., the limestone geology of the Ozark Highlands increases the conductivity and hardness of its waters, while the turbid condition of some Arkansas River Valley waters result from the geology and soil types of this region. The soil types of the regions also determine the vegetation types. Water color in the Gulf Coastal Region is influenced by vegetation and soil types in the watershed. The geology of a region will determine the general characteristics of the groundwater and its relationship to surface water. Groundwater contribution to the base flow, therefore, will vary in quantity and duration within each region. The stream gradient influences water quality and also the composition of the aquatic community. Higher gradients generally produce higher stream velocities, which in turn affect the substrate by scouring, cutting channels and changing the features of the physical habitat. High stream velocities affect the benthic and fish community structure to the degree that only certain species adapt and thrive in this type of stream habitat. As gradient and stream velocities decline the aquatic community composition tends to reflect these changes. Instream dissolved oxygen is also influenced by stream velocity and turbulence which is a function of gradient and flow.

Although major physical features such as geologic formations serve to establish the different ecoregions, many other physical characteristics are unique to the streams within each ecoregion. These characteristics and their influence on the aquatic communities will be evaluated on a regional basis.

Delta Ecoregion

There are several physical features that are unique to Delta streams (Table P-1). The most obvious feature is the very low gradient. The average slope of all the streams surveyed was only 0.65 feet per mile drop in elevation. Many reaches of these streams have ill-defined streams channels, as evidenced by measured channel widths of almost one quarter mile wide. The substrates of these streams are composed predominantly of mud and silt, yet aquatic habitat is present in the form of brush, logs, debris and inundated vegetation. The land use in this ecoregion is 77% agricultural activities with the primary type being grain and fiber crop production. Irrigation practices in this type of agriculture have a definite impact on the stream flow in the late summer period. The smallest stream studied - Boat Gunwale Slash - with a watershed size of 23 mi^2 had almost a 3 cfs flow on August 2, 1983. The stream with the largest watershed - Bayou DeView - had a flow of 191 cfs on July 30, 1985. Both streams according to U.S.G.S. flow data, have a Q_{7-10} flow of 0 cfs. The influence of irrigation drainage is readily apparent in these and the other Delta streams surveyed. In the Delta streams influenced by these agricultural practices, the critical flow period and the critical temperature period do not generally coincide. The low flow months usually occur in the fall of the year after crop irrigation has ceased. By this time, the stream temperatures have usually declined by a few degrees. Despite the dominance of agricultural activities in the Delta, the stream canopy in the reference streams averaged 75%, which is the second highest value recorded in the ecoregion surveys. This is an atypically high value because least-disturbed streams were surveyed. Most of the drainage in the Delta has very limited wooded areas adjacent to the streams.

Gulf Coastal Ecoregion

The major streams in this region originate in the Ouachita Mountains Ecoregion. Another significant feature of this ecoregion is that some areas have perennially flowing streams of various watershed sizes while in other areas, streams with the largest watersheds have only intermittent flow during the summer and early fall months of the year. Table P-2 provides a summary of the physical characteristics evaluated during the

Table P-1

DELTA ECOREGION

PHYSICAL ATTRIBUTES

Stream Name	Watershed Size mi^2	Watershed Land Use	Stream Grad. ft/mi	Channel Width ft.	Stream Width ft.	Stream Vel. fps	Stream Flow cfs	Substrate Type percent	Instream Cover percent	Stream Canopy
Boat Gunwale Slash	23	72% agri. 28% forest	0.7	182	122	0.17	2.9	mud/silt	27% brush, logs, debris; 13% inundated veg.	94%
Second Creek	60	70% agri. 30% forest	0.75	62.5	42.2	0.28	7.5	mud/silt	35% brush, logs, debris; 6.4% overhanging veg; 1% inundated veg	55%
Village Creek	194	92% agri. 5% forest 3% urban	0.5	923	609	N/A	133.5	mud/silt	87% brush, logs, debris; 22% inundated veg.	85%
Bayou DeView	460	72% agri. 28% forest	0.6	1575	509	N/A	191	mud/silt	22% brush, logs, debris; 2% inundated veg.	60%

Physiographic Region Average

Delta Ecoregion Averages	183.25	77% agri. 23% forest	0.65	685	321	0.23	83.7	mud/silt	43% brush, logs, debris; 10% inundated veg; 2% overhanging veg.	73.5%

Table P-2
GULF COASTAL ECOREGION

PHYSICAL ATTRIBUTES

Stream Name	Watershed Size mi^2	Watershed Land Use	Stream Grad. ft/mi	Channel Width ft.	Stream Width ft.	Stream Vel. fps	Stream Flow cfs	Substrate Type percent	Instream Cover percent	Stream Canopy
Whitewater Creek	23	91% forest 7% agri.	2.8	29	15	0	0	100% sand	32% brush, logs, debris; 1% overhanging veg.	96%
Big Creek	59	88% forest 12% agri.	2.7	40	6.4	0	0	100% sand	16% brush, logs, debris; 13% undercut bank	100%
Derrieusseaux Creek	148	93% forest 7% agri.	3.4	50	12	0	0	74% sand 22% mud/ silt; 4% gravel	41% brush, logs, debris; 2% undercut bank	88%
Bayou Freeo	156	91% forest 7% agri.	3	47	26	0	0	64% sand 36% gravel	74% brush, logs, debris	100%
Hudgin Creek	187	74% forest 26% agri.	1.4	69	32	0	0	100% mud/ silt	55% brush, logs, debris; 3% inundated veg; 1% overhanging veg.	68%
L'Aigle Creek	232	91% forest 7% agri.	2.6	89	34	0	0	66% mud 31% gravel	20% brush, logs, debris	47%
Moro Creek	423	91% forest 7% agri.	1.6	96	35	0	0	58% sand 26% gravel 16% mud/ silt	61% brush, logs, debris	71%
*East Fork Tulip Creek	46	96% forest 4% agri.	3.5	41.4	25.8	0.26	5.2	100% sand	51% brush, logs, debris; 5% overhanging veg. 1% undercut bank	95%
*Cypress Creek	73	73% forest 27% agri.	4.2	44.8	32	0.36	10.8	61% sand 28% mud/ silt 8% gravel	13% brush, logs, debris; 2% overhanging veg.	90%

*All physical parameters included in ecoregion averages except stream flows.

Physiographic Region Average:

Gulf Coastal Ecoregion Averages	150	88% forest 12% agri.	2.8	60	23	0	0	62% sand 26% mud/ silt 12% gravel	40% brush, logs, debris; 2% undercut bank; 1% overhanging vegetation	84%

stream surveys of this ecoregion.

Two of the reference streams in the Gulf Coastal Ecoregion, East Fork Tulip Creek and Cypress Creek, represent a unique group of streams in that they have a continuous year-round flow. Numerous springs in the headwaters of these streams produced flows of 5.2 and 10.8 cfs, respectively, during the summer surveys. This is a substantial flow for the 46 mi^2 watershed of East Fork Tulip and the 73 mi^2 watershed of Cypress Creek. The more typical Gulf Coastal Ecoregion streams are represented by the other seven reference streams. Of these streams, which range in watershed size from 23 to 451 mi^2, the dominant characteristic is the absence of flow during the summer and early fall months. Another unique feature of this region is the low stream gradients in an area containing rolling hills. These streams meander back and forth through the broad sandy flats between these hills, with the stream channels being established by the high flows of winter and spring.

Land use in this region is dominated by forestry activities. Approximately 88% forestry cover existed in the watersheds of the streams surveyed while 12% was used for agricultural purposes - primarily pastureland. The forestry cover contributes to the high stream canopy which averaged 84% in the streams surveyed. The generally forested watersheds also contribute to instream cover by deposition of logs, brush and debris into the stream through the natural growth and death processes and through streambank erosion and the subsequent falling of trees. The 40% composition of brush, logs, and debris as instream cover was one of the highest values encountered during the survey. Another unique feature of the Gulf Coastal region is the predominance of sand in the stream substrates. Three of the nine streams surveyed had substrates of 100% sand while the average sand content of all reference streams substrates was 62%. The permeability and porosity of the soils in this ecoregion may be a pertinent factor in the lack of summer flow in the more typical streams.

The high stream canopy plays an important role in regulation of water temperatures. In only one stream did the stream temperature reach 30°C during the surveys of this region. That stream had the least canopy cover of all streams survey. Most of the streams showed little or no diurnal variation in water temperature because of the large amount of stream canopy.

Arkansas River Valley

The Arkansas River Valley Ecoregion contains streams with characteristics similar to those of the Boston Mountains to the north and the Ouachita Mountains to the south. The general topography of this ecoregion reflects its transitional nature by being relatively flat in some areas while showing some of the greatest elevations in the state in other areas. Table P-3 summarizes the physical characteristics of the streams surveyed.

Table P-3

ARKANSAS RIVER VALLEY ECOREGION

PHYSICAL ATTRIBUTES

Stream Name	Watershed Size mi^2	Watershed Land Use	Stream Grad. ft/mi	Channel Width ft.	Stream Width ft.	Stream Vel. fps	Stream Flow cfs	Substrate Type percent	Instream Cover percent	Stream Canopy
Mill Creek	17	57% agri. 43% forest	13.5	39.2	32	0	0	76% bedrock 24% mud/silt	1% undercut bank 2% brush, logs, debris	56%
North Fork Cadron	21	61% agri. 39% forest	10	42.3	20.3	0.05	0.07	57% bedrock 25% rubble 6% gravel	1% undercut bank 3% brush, logs, debris; 3% inundated veg.	33%
Ten Mile Creek	49	43% agri. 55% forest	8.1	61.3	41.5	0.1	0.2	49% boulder 26% rubble 19% gravel	17% inundated vegetation	88%
Dutch Creek	110	35% agri. 65% forest	3.8	62.2	37.3	0.05	0.5	43% gravel 43% mud/silt 13% rubble	44% brush, logs, debris; 2% undercut bank	98%
Petit Jean River	241	45% agri. 52% forest	3.9	65	48	0.03	0.3	29% boulder 33% rubble 23% gravel	3% brush, logs, debris; 1% undercut bank; 5% inundated veg.	64%
Cadron Creek	308	62% agri. 38% forest	0.6	115	93	0	0	100% mud/silt	6% brush, logs, debris	22%

Physiographic Region Average

Stream Name	Watershed Size mi^2	Watershed Land Use	Stream Grad. ft/mi	Channel Width ft.	Stream Width ft.	Stream Vel. fps	Stream Flow cfs	Substrate Type percent	Instream Cover percent	Stream Canopy
Arkansas River Valley Ecoregion Averages	124	51% agri. 49% forest	6.7	64.2	45.4	0.04	0.18	22% bedrock 16% rubble 15% gravel 15% boulder 31% mud/silt	1% undercut bank 10% brush, logs, debris; 4% inundated veg.	55%

The Arkansas River Valley streams with small watersheds that were studied are similar to some of the larger Boston Mountains streams in regard to stream gradient and substrate type. These small streams' substrates are dominated by bedrock, which is also the case for Lee Creek and the Mulberry River, located in the southern portion of the Boston Mountains Ecoregion. The stream gradients of Mill Creek and North Fork Cadron are the highest of all the Arkansas River Valley streams surveyed and are similar to the largest watershed Boston Mountains streams studied.

The land use patterns in this ecoregion consist of about 31% agriculture and 49% forestry. Generally, the agricultural uses are dominated by the production of beef cattle, dairy cattle and poultry. These agricultural activities in the Arkansas River Valley result in high water usage during the hot, dry period.

Flow in the Arkansas River Valley streams is generally very low or nonexistent during the summer and early fall months. Many of the streams studied were pooled, while the remainder had only a trickle of flow between pooled areas. Some of the larger Arkansas River Valley streams are similar to Delta streams in terms of gradient and substrate type. Cadron Creek has a 308 mi^2 watershed at the study site. The stream gradient at this site is only 0.6 feet per mile and the substrate consists of mud and silt. This stream had no measurable flow during the late August survey. Streams of a similar size surveyed in the Delta had flows of 133 and 191 cubic feet per second.

Instream cover in the Arkansas River Valley streams is generally dominated by brush, logs and debris; however, there is considerable variation among these streams and many have only limited amounts of this type of instream cover. Only Dutch Creek, which had the greatest canopy cover at 98%, had substantial brush, logs and debris instream cover (44%). Ten Mile Creek, with a watershed size of 49 mi^2 and an 88% canopy cover, had instream cover consisting solely of 17% inundated vegetation. The substrate types in these streams contribute substantially to the habitat of many species of aquatic inhabitants. Although not specifically designated as instream cover in this study, boulders and rubble serve as attachment sites for many macroinvertebrate species and as refuge areas for fish species. A combination of boulders and rubble dominated the substrates in Ten Mile Creek and Petit Jean River.

Ouachita Mountains Ecoregion

The steep topography of the Ouachita Mountains Ecoregion influences the physical characteristics of the streams in this region and the recreational uses of these waterways. The steep slopes promote rapid stormwater runoff, which generates high velocity streams with many rapids and chutes. These streams attract "white water" boating enthusiasts from Arkansas and several adjacent states during the high flow periods. The physical characteristics of the six least-disturbed streams studied in this ecoregion are summarized in Table P-4.

The Ouachita Mountains streams surveyed had the second highest average summer flow of all the ecoregions studied. The geology of the Ouachita Mountains Ecoregion generates perennial stream flow in many very small watersheds. Board Camp Creek had the smallest watershed size of the reference streams in this ecoregion, yet a summer flow of 2.9 cfs was measured. Springs and seeps in this ecoregion not only serve to provide stream flow, but also aid in keeping the water temperatures cool. This is important because the Ouachita Mountains streams, although having watersheds dominated by forests, generally have a low percentage of stream canopy. This lack of canopy exposes more of the stream surface to the sun, resulting in warmer stream temperatures. An example of this is the Cossatot River, which had no canopy in the reach studied. This stream had the highest temperature of any of the Ouachita Mountains streams surveyed. The paucity of canopy in this ecoregion is due in part to the very rocky stream banks which do not promote tree growth and also a result of the erosive action of spring flooding.

A high stream gradient exists in many of the headwater streams in this ecoregion, which creates very high stream velocities of stormwater runoff. Streams in the Ouachita Mountains have been known to rise several feet in only a few hours during a storm event. The scouring action of this water as it flows downstream cuts a stream channel much wider than the normal stream width and in the process removes streamside vegetation. In most instances the channel width is more than twice the stream width in the Ouachita Mountains streams surveyed. Stream gradients ranged from a high of 40 ft/mi for the Cossatot River to a low of 4.1 ft/mi for the Saline River.

In some instances, the gradient affects the presence of instream cover. The high velocities of flood events tend to scour the higher gradient streams of any accumulated debris, brush and logs, while the lower stream gradients tend to have a greater percentage of this kind of instream cover. The Saline River appears to be an exception. It has a slope of 4.1 ft/mi and only 2% of the stream channel contained brush, logs and debris at the sample site. The large volume of water that accumulates in the 361 mi^2 watershed during storm events may be sufficient to effectively scour this stream as well. The South Fork of the Ouachita River has a much smaller watershed but a similar stream gradient. However, due to the larger stream width in relation to channel width in the South Fork Ouachita compared to the Saline River, a greater percentage of canopy and brush, logs and debris exist in South Fork.

The substrate components of the Ouachita Mountains streams are comprised of gravel (36%), rubble (31%), boulders (14%) and bedrock (13%). The remainder consists of mud/silt, sand and detritus. In many streams in this ecoregion, boulders and

Table P-4

OUACHITA MOUNTAINS ECOREGION

PHYSICAL ATTRIBUTES

Stream Name	Watershed Size mi^2	Watershed Land Use	Stream Grad. ft/mi	Channel Width ft.	Stream Width ft.	Stream Vel. fps	Stream Flow cfs	Substrate Type percent	Instream Cover percent	Stream Canopy
Board Camp Creek	19	90% forest 10% agri.	27.8	61.3	28.5	0.36	2.7	62% gravel 18% rubble 15% bedrock	12% inundated veg; 6% overhanging veg.	72%
Little Missouri River	30	90% forest 10% agri.	29.4	47.1	31	0.44	3.9	50% rubble 19% gravel 24% boulder	2% inundated veg; 4% overhanging veg.	24%
South Fork Ouachita River	46	90% forest 10% agri.	7.3	47.3	37	0.35	6.7	91% gravel 9% mud/silt	16% brush, logs, debris; 3% under cut bank; 1% overhanging veg.	48%
Cossatot River	120	85% forest* 15% agri.	40	187	74.1	0.47	17.2	37% bedrock 42% boulder 18% rubble	<1% inundated vegetation	0%
Caddo River	291	60% forest 40% agri.	13.3	315	127	N/A	133.8	63% rubble 16% boulder 12% gravel	7% inundated veg 4% brush, logs, debris; 3% overhanging veg.	26%
Alum Fork Saline River	361	95% forest 5% agri.	4.1	126	64	N/A	33.4	34% rubble 29% gravel 26% bedrock	2% brush, logs, debris; 3% inundated veg.	11%

*Estimate based on visual observation of watershed.

Physiographic Region Average

Ouachita Mountains Ecoregion Averages	144.5	85% forest 15% agri.	20.2	130.7	60.3	0.41	33	36% gravel 31% rubble 14% boulder 13% bedrock	4% inundated veg 2% overhanging veg; 4% brush, logs, debris	30%

rubble provide sanctuary to numerous aquatic species and thus serve as a source of instream cover.

Land use in the Ouachita Mountains is dominated by forestry activities. Most of the land is owned by private timber companies and the Ouachita National Forest. Timber cutting activities in many areas disturb the soil and increase erosion. This can subsequently alter the substrate composition of the streams.

Ozark Highlands Ecoregion

Probably the single most important factor affecting the water quality of the streams in the Ozark Highlands Ecoregion is the land use patterns that exist in the watersheds of these streams. There are many streams and lakes in this ecoregion that serve large numbers of recreation seekers each year. The popularity of the Buffalo River is an excellent example of the recreational potential that exists. The streams selected for study are presently being affected by the land uses in the watershed. These effects are more evident in the chemical analyses than in the physical analyses. The physical characteristics of the six streams selected in this ecoregion are summarized in Table P-5.

The Ozark Highlands Ecoregion is unique because of its rugged mountains with steep ridges and many "plateau" areas which have been developed for agricultural activities. There are numerous grape vineyards, apple orchards and other types of fruit crop production in this region. Much of the area is also used for beef cattle and dairy cattle farming. The agricultural activities that appear to have the greatest impact on the streams of this ecoregion are the increasing numbers of poultry and hog farming operations. The waste products from these operations are commonly used as fertilizer on the pasturelands. The average watershed land use for the six streams surveyed indicates that 62% of the watersheds are being used for agricultural activities. The majority of this consists of pasturelands. Although there are areas of natural prairie in the Ozark Highlands, many other areas have been cleared of forestry cover in order to develop the land for agricultural purposes. A reduction in stream canopy is one result of this land clearing activity. The low percent of stream canopy in the Ozark Highlands allows a greater length of time for sunlight to reach the streams, which promotes both increasing stream temperatures and growth of aquatic vegetation.

The geology of the Ozark Highlands Ecoregion is dominated by large amounts of of limestone, dolomite and chert. The presence of limestone as surface rocks influences both water quality and quantity. The solubility of these surface rocks and the many subsurface fractures produce springs and seeps that feed the streams in this ecoregion. The nature of the geology not only produces stream flow but also can eliminate stream flow due to the presence of solution channels. The "losing stream" phenomenon is present in this ecoregion

Table F-5

OZARK HIGHLANDS ECOREGION

PHYSICAL ATTRIBUTES

Stream Name	Watershed Size mi^2	Watershed Land Use	Stream Grad. ft/mi	Channel Width ft.	Stream Width ft.	Stream Vel. fps	Stream Flow cfs	Substrate Type percent	Instream Cover percent	Stream Canopy
South Fork Spavanaw Creek	18	70% agri. 30% forest	25.5	78.5	27.6	0.55	1.4	87% gravel 13% rubble	5% brush, logs, debris; 5% over-hanging veg; 23% inundated veg.	19%
Flint Creek	19	82% agri. 18% forest	19.6	34.8	28.9	0.71	4.5	66% gravel 28% rubble	2% brush, logs, debris; 11% over hanging veg; 15% inundated veg.	11%
Yocum Creek	55	70% agri. 30% forest	18.2	72.2	26.2	1	5.3	69% gravel 27% rubble 5% bedrock	3% brush, logs, debris; 2% over-hanging veg.	21%
Long Creek	**184**	70% agri. 30% **forest**	**6.8**	**54.8**	**39.8**	**0.57**	**9.5**	51% gravel **25% sand** 12% bedrock 5% rubble	3% brush, logs, **debris; 2% under** cut bank; 4% overhanging veg; 3% inundated veg	**36%**
War Eagle Creek	263	47% agri. 52% forest	4	109	57	0.77	25	54% gravel 35% rubble 7% sand	3% brush, logs, debris; 2% over-hanging veg; 3% inundated veg.	37%
Kings River	526	35% agri. 63% forest	4.6	146	112	N/A	48.8	52% gravel 23% bedrock 7% rubble 7% sand	1% undercut bank 1% inundated veg	29%

Physiographic Region Average

Stream Name	Watershed Size mi^2	Watershed Land Use	Stream Grad. ft/mi	Channel Width ft.	Stream Width ft.	Stream Vel. fps	Stream Flow cfs	Substrate Type percent	Instream Cover percent	Stream Canopy
Ozark Higlands Ecoregion Averages	178	62% agri. 37% forest	13.1	82.6	48.6	0.72	15.8	63% gravel 19% rubble 7% bedrock 7% sand	3% brush, logs, debris; 4% over-hanging veg; 8% inundated veg; 1% undercut bank	26%

largely due to the limestone geologic formations. South Fork Spavinaw Creek and Flint Creek, with 18 and 19 mi^2 watersheds, respectively, are influenced by springs and seeps and had flows of 1.4 and 4.5 cfs during the summer sample. Summer flow measurements ranged from the 1.4 cfs in South Fork Spavinaw Creek to 48.8 cfs in the 526 mi^2 watershed of the Kings River. The average flow for the reference streams was 15.8 cfs with an average watershed size of 178 mi^2. Only the Delta and the Ouachita Mountains had greater average flows. Land use patterns may reduce the water volume in the Ozark Highlands due to consumption by livestock and use for irrigation of some types of crops.

The substrates of the streams in this ecoregion are dominated by gravel. The average gravel content of the six streams surveyed was 63%. Nineteen percent of the substrate consisted of rubble while sand and bedrock totalled 7% each. The majority of the instream cover consisted of inundated vegetation. This is not surprising considering the impact of nutrient contributions from the watershed and the low percentage of canopy cover. These two factors also contribute to periphyton and algae production. Other instream cover included 4% overhanging vegetation and 1% undercut bank.

Stream gradients ranged from 25.5 ft/mi to 4 ft/mi in reference streams of this ecoregion. Although the gradient average was substantially lower than that of the Ouachita Mountains and the Boston Mountains, the average stream velocity was much higher in the Ozark Highlands. The velocity difference appears to be a result of the geologic formations of the ecoregions. The Ouachita Mountains, while having greater slopes, have streams consisting of varying lengths of relatively flat areas interspersed with sharp drop or fall areas. The surface geology consists of novaculite, shales and sandstones which are relatively impermeable to the eroding action of high stream flows. Although having a lower gradient, the Ozark Highlands streams flow over a surface geology consisting primarily of limestone deposits. The porous nature of this substrate allows a more linear decline in stream gradient due to the "cutting" action into the substrate by high stream flows. As a result a more steady, uniform stream flow is achieved, resulting in faster stream velocities.

Boston Mountains Ecoregion

The Boston Mountains Ecoregion is the most rugged of the ecoregions, containing the highest reliefs. Its rugged nature produces streams with very high gradients. The stream slopes of the larger Boston Mountains streams which drain southward are similar to the smaller Arkansas River Valley streams located along the northern edge of the Arkansas River Valley Ecoregion. The high stream gradients promote rapid runoff during storm events which not only widens the stream channels but also removes accumulated debris by scouring the stream substrate. The majority of the Boston Mountains Ecoregion is within the Ozark National Forest and has a high recreational value. The physical characteristics of the six least-disturbed streams surveyed in this ecoregion are summarized in Table P-6.

One interesting relationship is the amount of the forestry cover as compared to stream canopy. This ecoregion has the highest average percentage of forestry cover of any ecoregion surveyed, and it has the lowest percentage of stream canopy. A very similar situation was evident in the Ouachita Mountains Ecoregion. In both ecoregions, the stream gradients and the ratio of stream widths to channel widths were similar and both had low total instream cover. There appears to be a definite inverse relationship between high stream gradients and low instream cover and canopy. The scouring action of floodwaters in high gradient streams removes the brush, logs and debris type of instream cover and reduces riparian canopy which protects the waters from prolonged exposure to the sun. In streams having substrates dominated by rock, these exposed rocks are heated by the sun and this heat is transferred to the water. The high stream temperatures of the Boston Mountains reference streams resulted from these conditions. The water temperature in Hurricane Creek was the coolest recorded from reference streams of the ecoregion and it also had the largest percentage of canopy.

Summer stream flows in the Boston Mountains Ecoregion are very low. The average summer flow of all reference streams with watersheds from 47 to 373 mi^2 was 1.9 cfs. These flow patterns are similar to the streams in the Arkansas River Valley. The substrate components of the Boston Mountains streams consist of 34% bedrock, 30% rubble, 13% boulders, 11% gravel and 9% sand. As was previously noted, the instream cover in these streams is minimal. Inundated vegetation averaged 5%. The remaining instream cover consisted of 1% brush, logs and debris, 1% undercut banks and 1% overhanging vegetation. However, many species of aquatic inhabitants utilize the abundant substrate components such as rubble and boulders.

Water Quality Data from Ecoregion Reference Streams

Both biochemical and chemical water quality parameters were measured at each reference stream sample site during the summer and spring sample period. Triplicate samples were taken for all parameters except fecal coliform. For discussion purposes, the 18 parameters measured are grouped as either biochemical, mineral or nutrient constituents. Biochemical constituents include BOD_5, BOD_{20}, chlorophyll a and fecal coliform. Mineral constituents are hardness, conductivity, alkalinity, total dissolved solids, total suspended solids, turbidity, pH, chlorides, sulfates and total iron. Nutrients include: ammonia nitrogen, nitrite-nitrate nitrogen, ortho-phosphorus and total phosphorus.

Table P-6

BOSTON MOUNTAINS ECOREGION

PHYSICAL ATTRIBUTES

Stream Name	Watershed Size mi²	Watershed Land Use	Stream Grad. ft/mi	Channel Width ft.	Stream Width ft.	Stream Vel. fps	Stream Flow cfs	Substrate Type percent	Instream Cover percent	Stream Canopy
Indian Creek	47	95% forest 5% agri.	32	53	40	0	0	43% bedrock 21% rubble 21% sand 11% gravel	No instream cover observed	5%
Hurricane Creek	50	95% forest 5% agri.	33	62	60	0	0	35% rubble 31% sand 23% gravel 6% mud/silt	2% undercut bank 1% brush, logs, debris	59%
Archey Fork Creek	107	85% forest 15% agri.	14	84.2	51.1	0.11	0.6	44% rubble 35% boulder 11% bedrock 8% gravel	13% inundated veg; 5% over-hanging veg; 1% undercut bank	7%
Illinois Bayou	125	82% forest 18% agri.	12.5	83.5	42.5	0.1	1	41% bedrock 25% rubble 15% boulder 14% gravel	3% inundated veg 2% overhanging veg; 2% brush, logs, debris	8%
Lee Creek	168	83% forest 17% agri.	15.3	132	63	0.11	3.5	54% bedrock 34% rubble 12% boulder	15% inundated vegetation	0%
Mulberry River	389	90% forest 10% agri.	13.7	259	141	N/A	6.4	56% bedrock 19% rubble 18% boulder 7% gravel	2% brush, logs, debris; 1% under cut bank	15%

Physiographic Region Average

Boston Mountains Ecoregion Averages	145	88% forest 12% agri.	20.1	112.3	66.3	0.1	1.9	34% bedrock 30% rubble 13% boulder 11% gravel 9% sand	5% inundated veg 1% overhanging veg; 1% under-cut bank; 1% brush, logs, debris	16%

Data from each ecoregion is discussed separately and a comparison among the ecoregions is in the concluding segment. Appendix A contains all water quality data collected.

Delta Ecoregion

Almost all mineral constituents, particularly those which can be associated with agricultural activities in the watershed, show notably higher values in the Delta Ecoregion. Specifically, these include turbidity, total dissolved solids, total suspended solids, sulfates and total iron (Figures C-1, C-2). Values for these parameters are also considerably elevated during the springtime, high flow season. Boat Gunwale Slash, which has the smallest watershed of the Delta reference streams and the largest proportion of undisturbed riparian area, has the lowest values for the agriculturally related mineral constituents. Second Creek has relatively elevated values for chlorides, conductivity, hardness and alkalinity during the summer period (Figures C-2, C-3). Initially this was believed to be caused by irrigation water from wells being drained from crops; however, there are areas within the Delta where isolated segments of saline soils occur.

The biochemical constituents are also noticeably higher in the Delta Ecoregion, particularly BOD_{20} and chlorophyll $\underline{a}$ (Figures C-4, C-5). These values seem to be directly related to size of watershed and/or flows. Fecal coliform values are very high but also appear related to nonpoint watershed contributions.

Both total and ortho-phosphorus values are highest in this region. A distinct, direct relationship of higher values to the larger watershed sizes and the higher flow season exists. However, Boat Gunwale Slash (the smallest watershed) appeared to have slightly higher than anticipated spring phosphorus values and notably higher total and ortho-phosphorus values during the summer period. Therefore, in this stream, the phosphorus values seem to be associated with instream activities rather than watershed runoff. The ammonia nitrogen values in Boat Gunwale Slash exhibit a pattern similar to that of phosphorus; however, the nitrite-nitrate value was very similar to the other reference streams of the region (Figures C-4, C-5).

It is apparent that the Delta Ecoregion reference streams show increasing impairment from agricultural activity as watershed size increases. This feature was magnified by the atypically high summertime flows in the larger reference streams.

Gulf Coastal Ecoregion

The reference streams of the Gulf Coastal Ecoregion fall into two distinguishable groups. They are the typical streams and the streams with substantial springwater inflow (East Fork Tulip and Cypress Creeks). The most obvious difference in these two groups is the summer flow (Figure C-6). Typical

Figure C-1. Water Quality Data for Delta Ecoregion Reference Streams

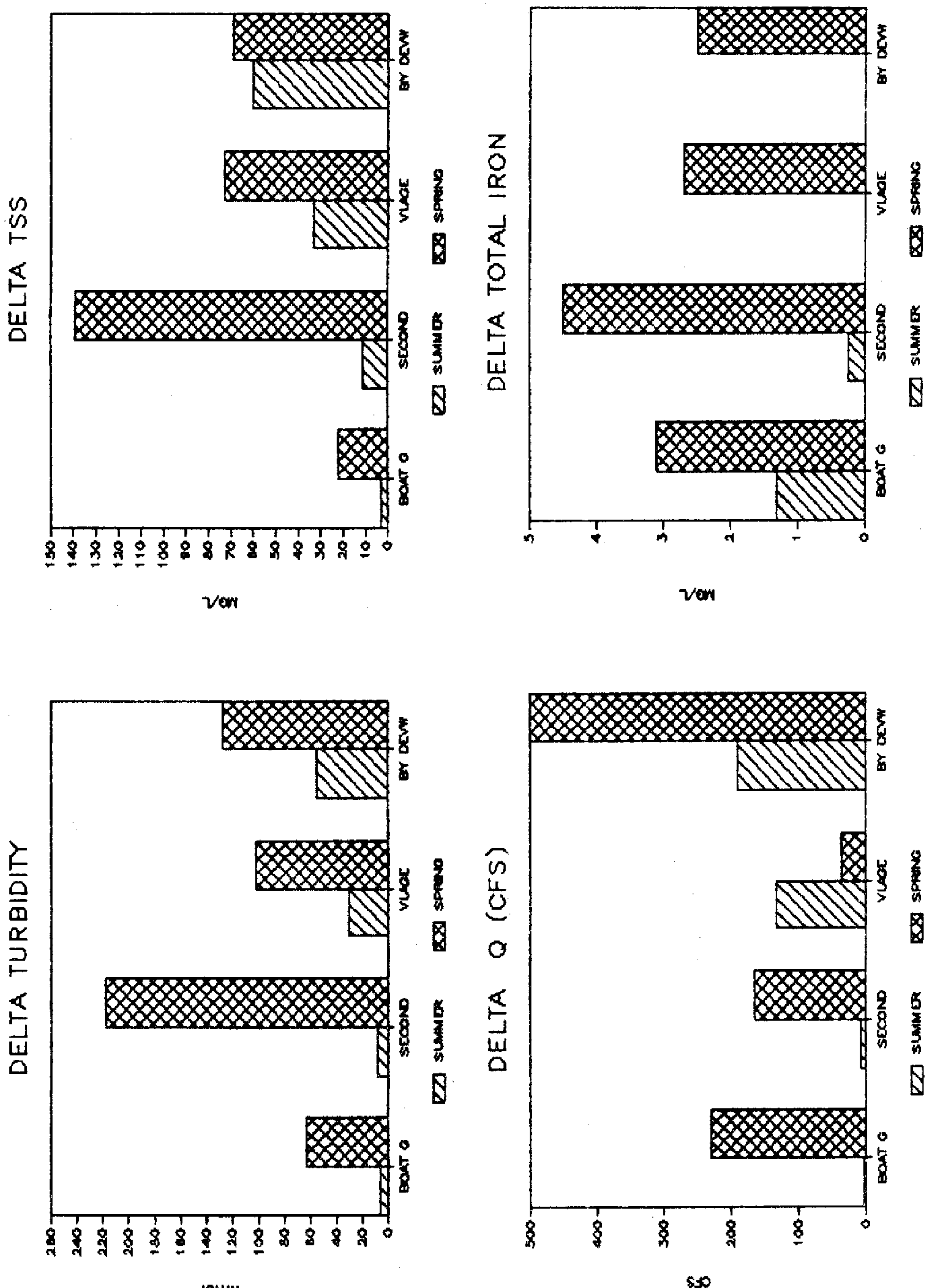
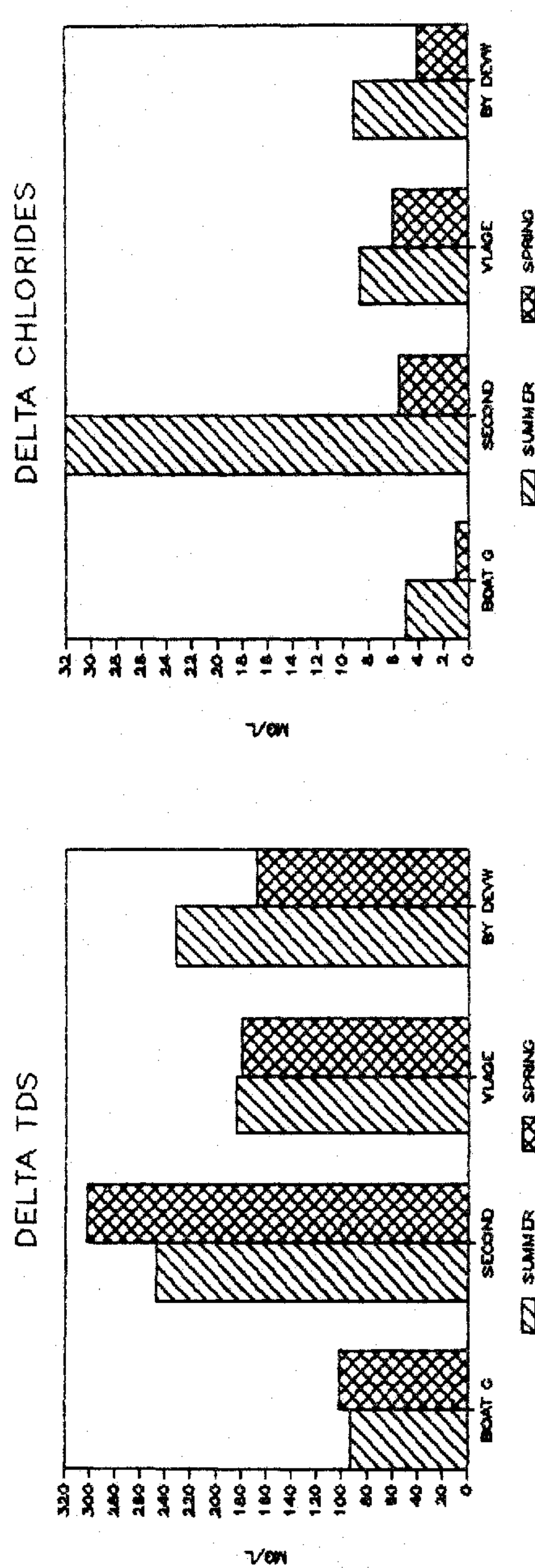


Figure C-2. Water Quality Data for
Delta Ecoregion Reference Streams



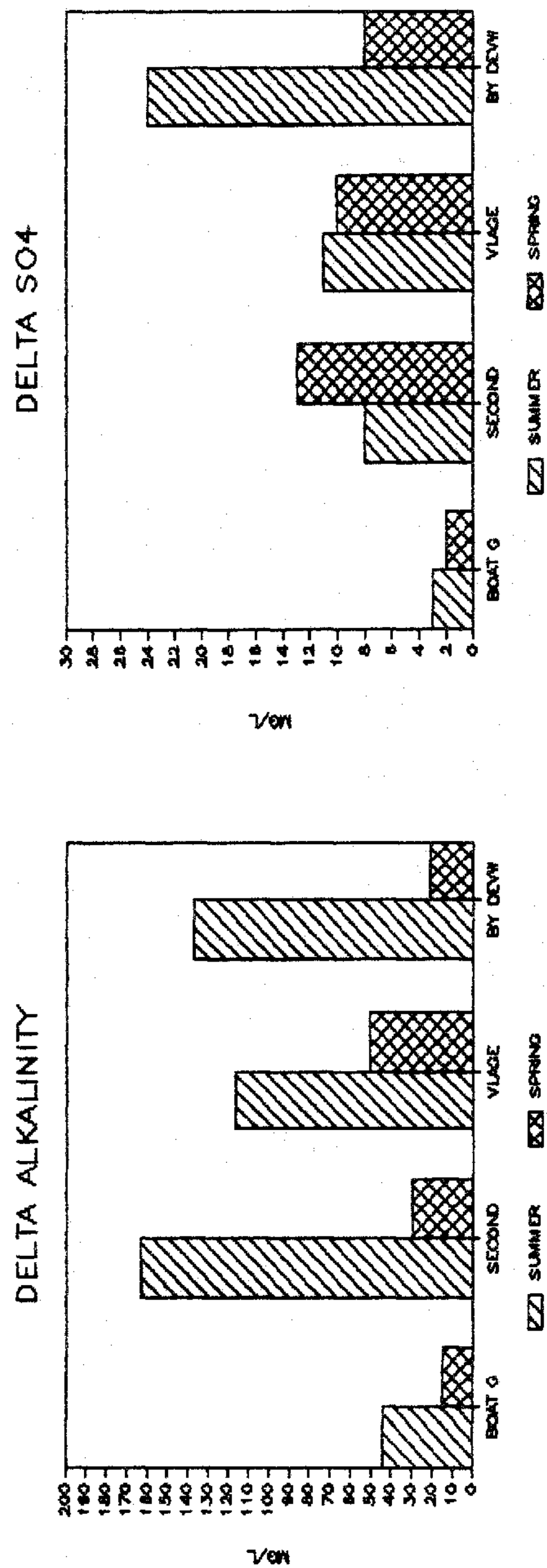
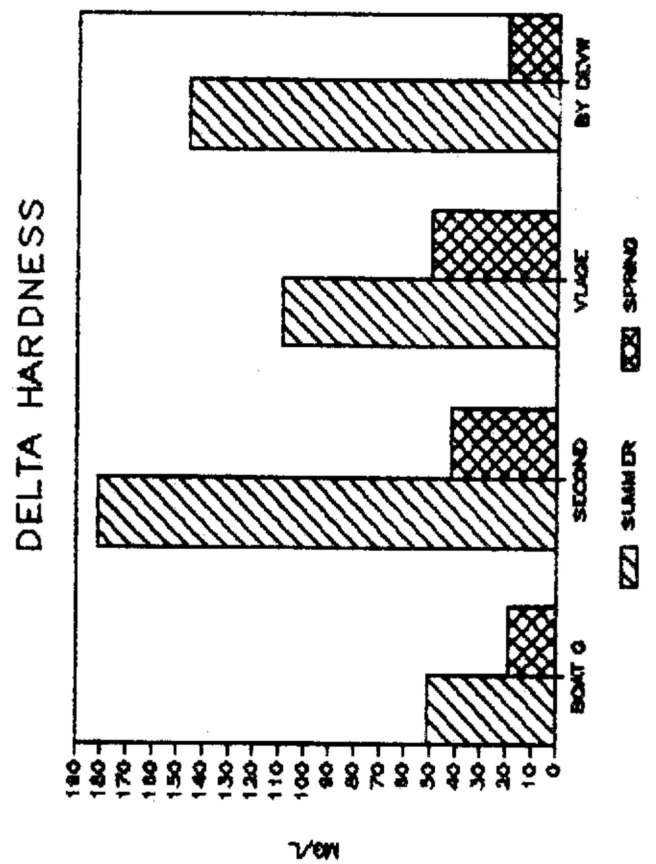
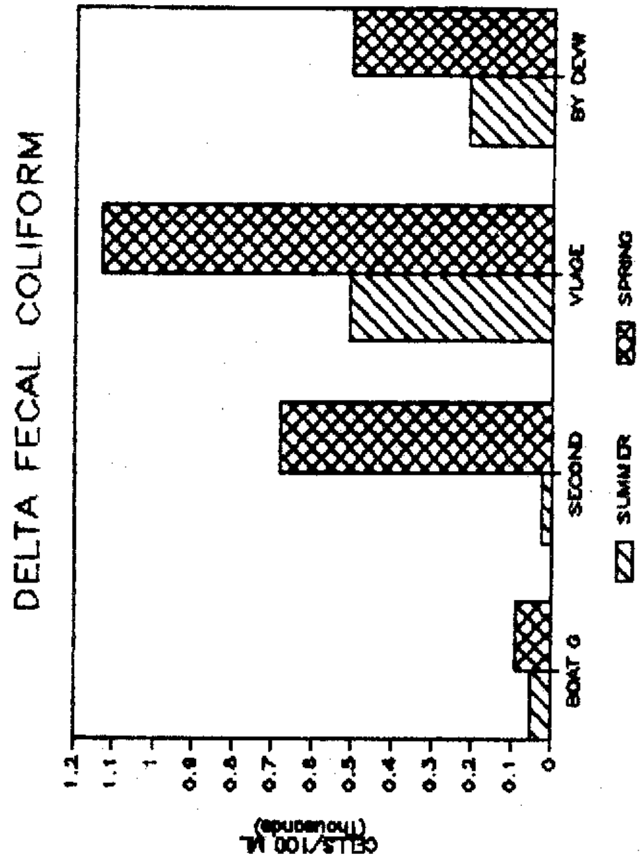


Figure C-3. Water Quality Data for
Delta Ecoregion Reference Streams





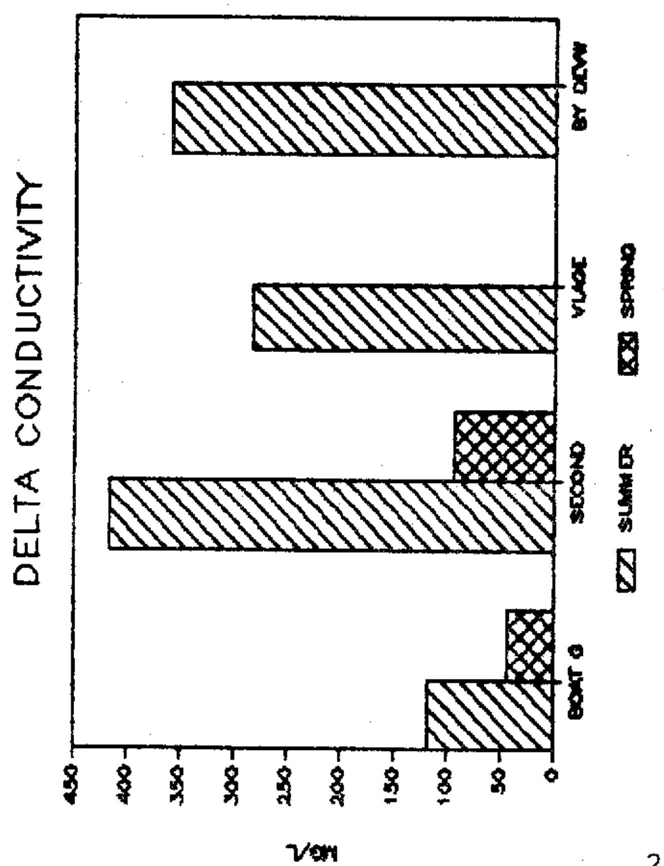


Figure C-4. Water Quality Data for Delta Ecoregion Reference Streams

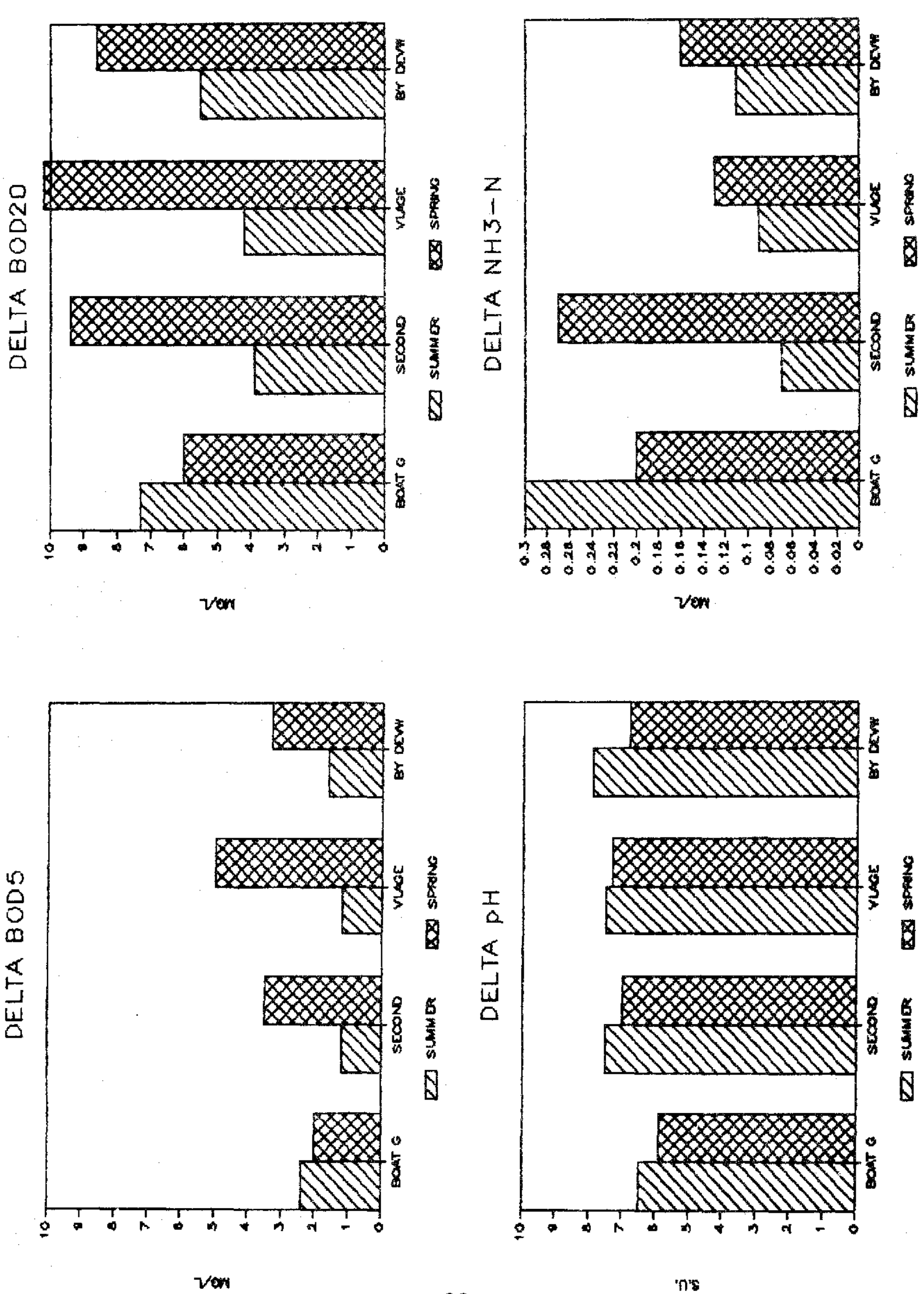


Figure C-5. Water Quality Data for Delta Ecoregion Reference Streams

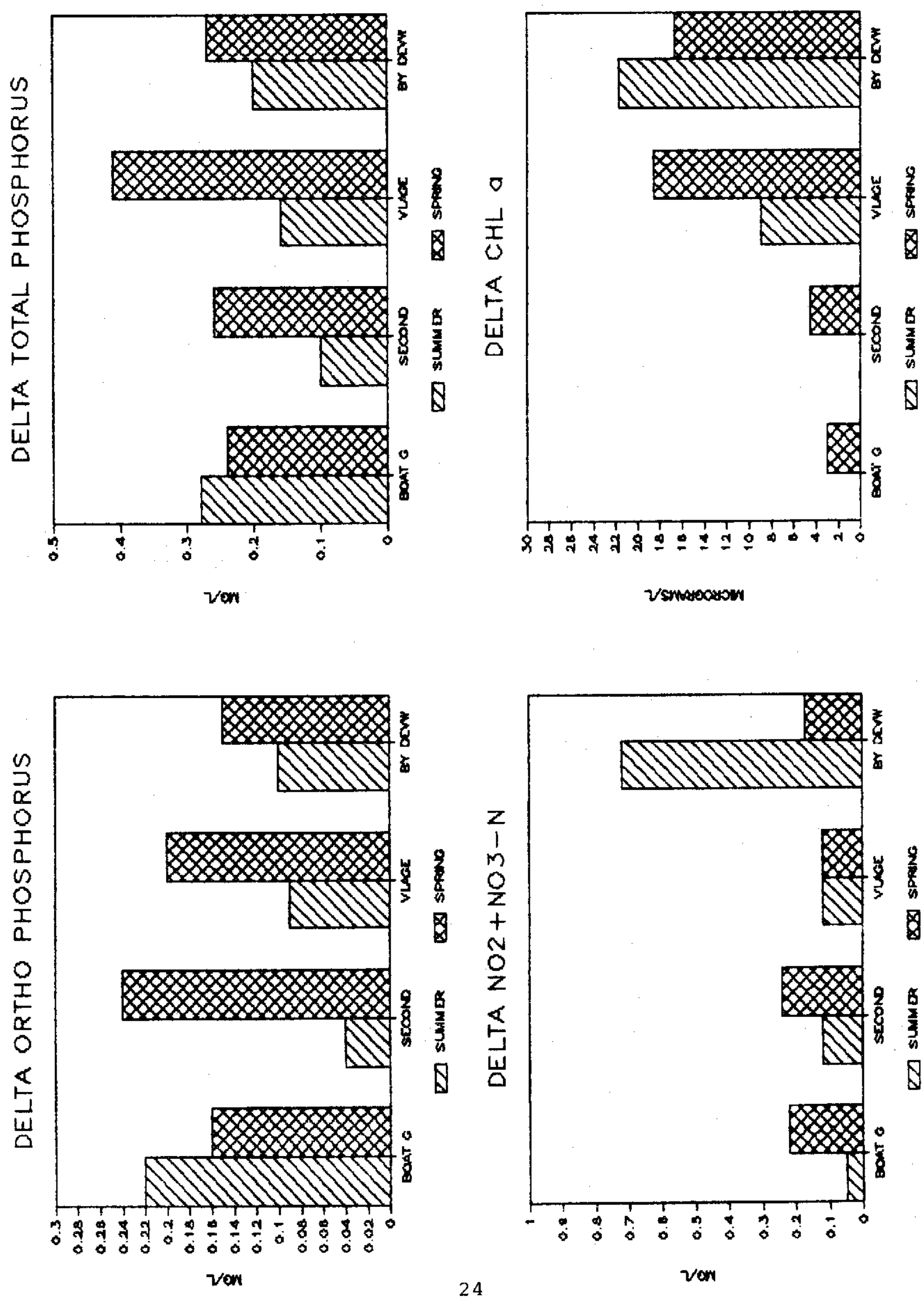
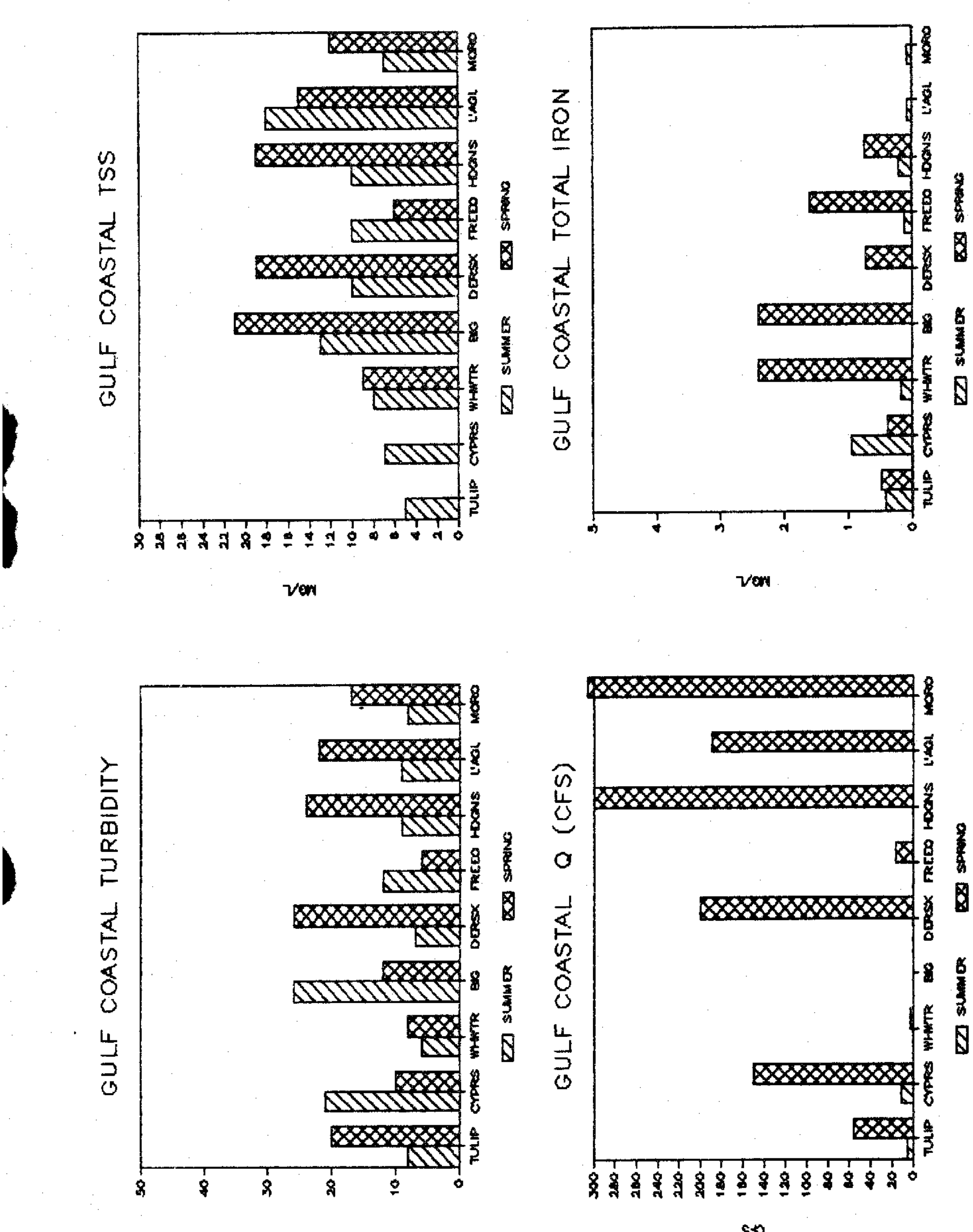


Figure C-6. Water Quality Data for
Gulf Coastal Ecoregion Reference Streams



Gulf Coastal streams with watershed sizes up to nearly 500 mi^2 cease to flow during the critical summer period. However, most of these streams maintain enduring pools of water of sufficient size to support a diverse fish population. The springwater-influenced streams maintain substantial flows during the critical summer period. Notable differences in the water quality also exist between these two types of Gulf Coastal streams.

Total dissolved solids, total suspended solids, alkalinity, hardness and conductivity are notably lower in the spingwater-influenced streams and fairly consistent in all of the typical streams (Figures C-6, C-7 and C-8). Summertime values of total iron are higher in the springwater streams although springtime values in some of the typical streams are elevated (Figure C-6). Very little difference is noted in the turbidity values of all Gulf Coastal reference streams. All values are low and generally show modest increases during increased spring flows (Figure C-6). Summer chloride values are very low in all streams but show slight elevations in the typical streams during the spring season. In contrast, spring chloride values decline in the springwater influenced streams (Figure C-7). Sulfates are notably lower in the springwater streams and unusually high in Big Creek and Hudgin Creek. These streams have adjacent watersheds and may share the same source of sulfates (Figure C-7). The pH values in all streams remained below 7.0 and the springwater-influenced streams generally remain below 6.0 (Figure C-9).

BOD patterns within the Gulf Coastal reference streams are interesting. Both BOD_5 and BOD_{20} are noticeably lower in the springwater-influenced streams during the summer. The spring values increase over the summer values in these two streams, but in the typical streams, the summer values are higher than the spring values (Figure C-9). All of the typical reference streams were restricted to enduring pools with no measurable flow during the summer sample period. This allows the biochemical reactions to take place in a confined area with little if any dilution. Chlorophyll $\bar{a}$ values were generally very low in all reference streams although notably high values of chlorophyll $\bar{a}$ and fecal coliform bacteria occurred in Big Creek (Figure C-8, C-10). With the exception of the spring value in Big Creek, all streams met the fecal coliform standard for primary contact use.

Nutrient parameters associated with nitrogen and phosphorus were very low in all reference streams, although summertime nitrite-nitrate nitrogen values were noticeably higher in the springwater-influenced streams (Figure C-10).

The water quality of the least-disturbed reference streams of the Gulf Coastal Ecoregion can generally be described as mildly acidic and low in mineral and nutrient quantities. However, in most of these streams, the intermittent summertime flows and pooled conditions allow the maximum extent of biochemical, oxygen-demanding activities to occur. In the absence of dilution and reaeration flows, dissolved oxygen

Figure C-7. Water Quality Data for
Gulf Coastal Ecoregion Reference Streams

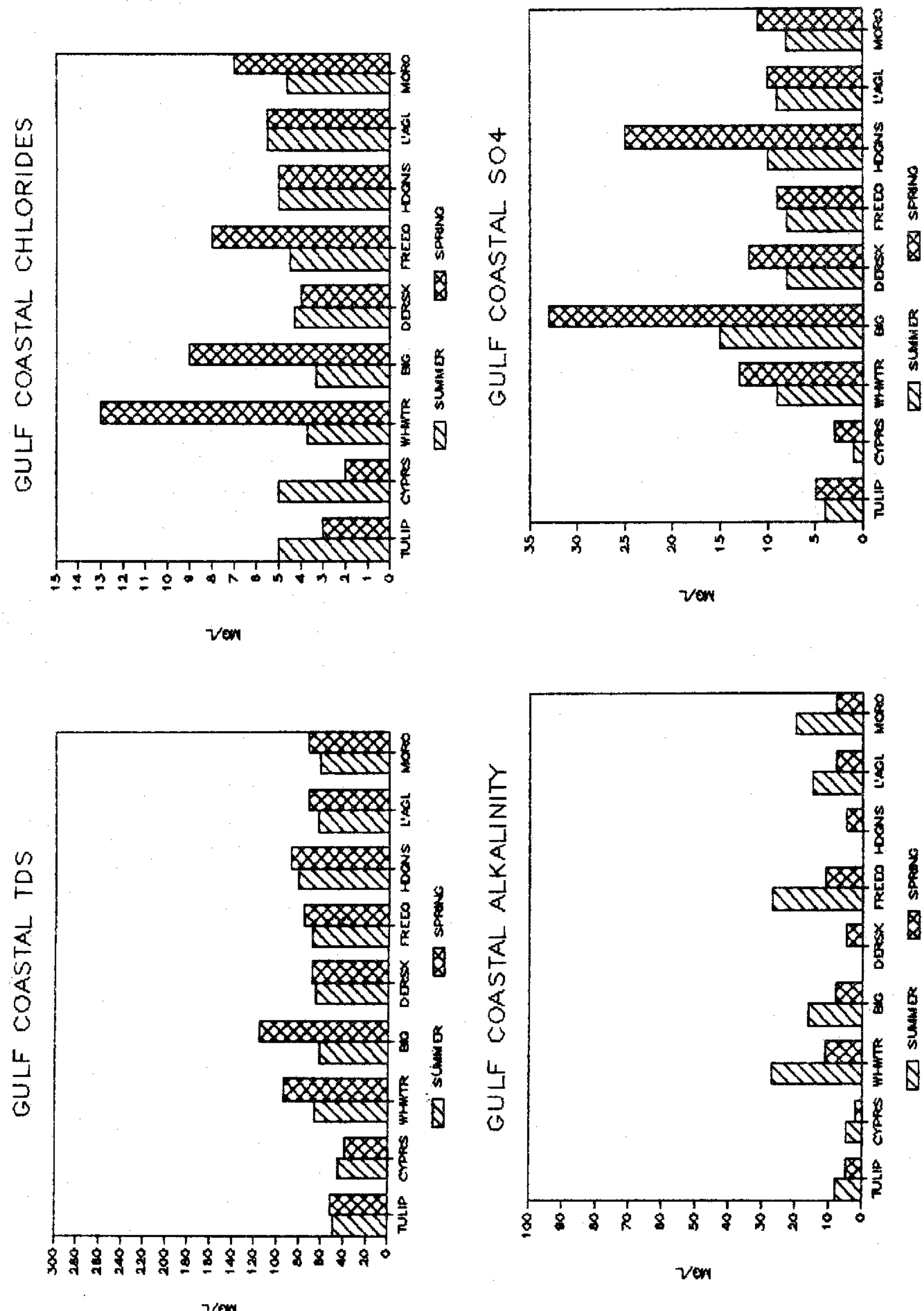
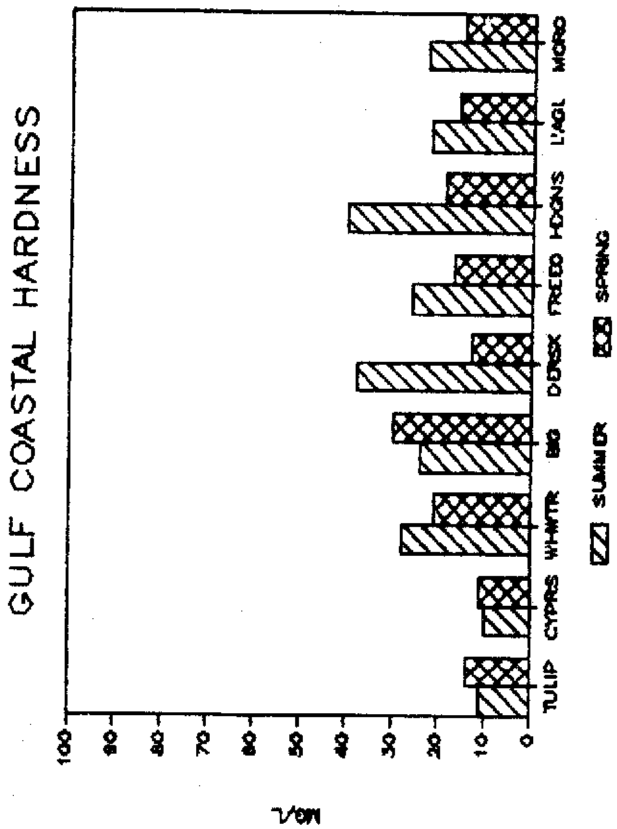
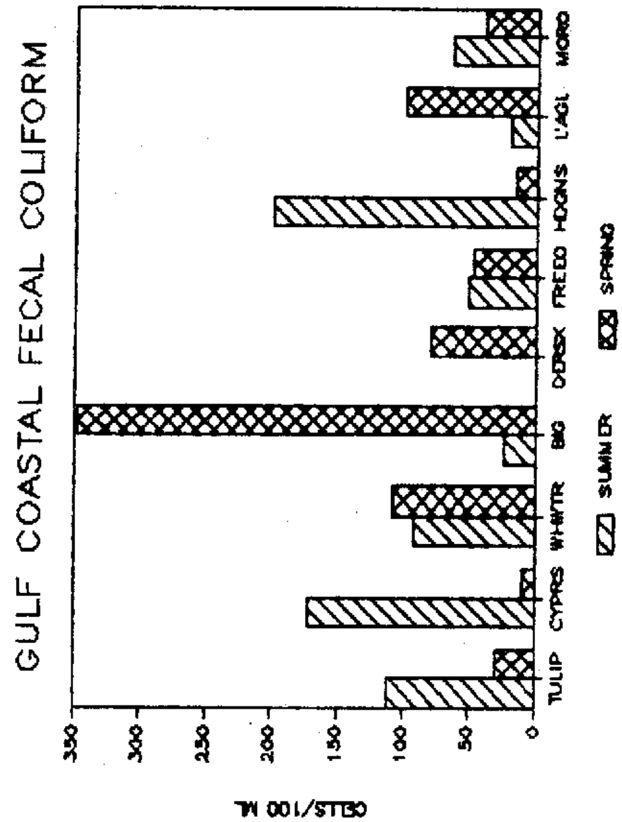


Figure C-8. Water Quality Data for
Gulf Coastal Ecoregion Reference Streams





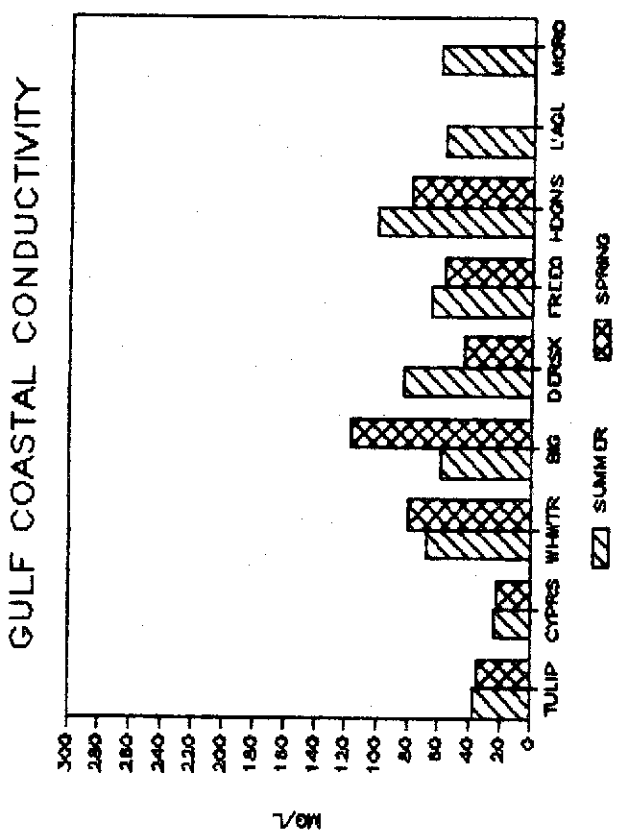


Figure C-9. Water Quality Data for
Gulf Coastal Ecoregion Reference Streams

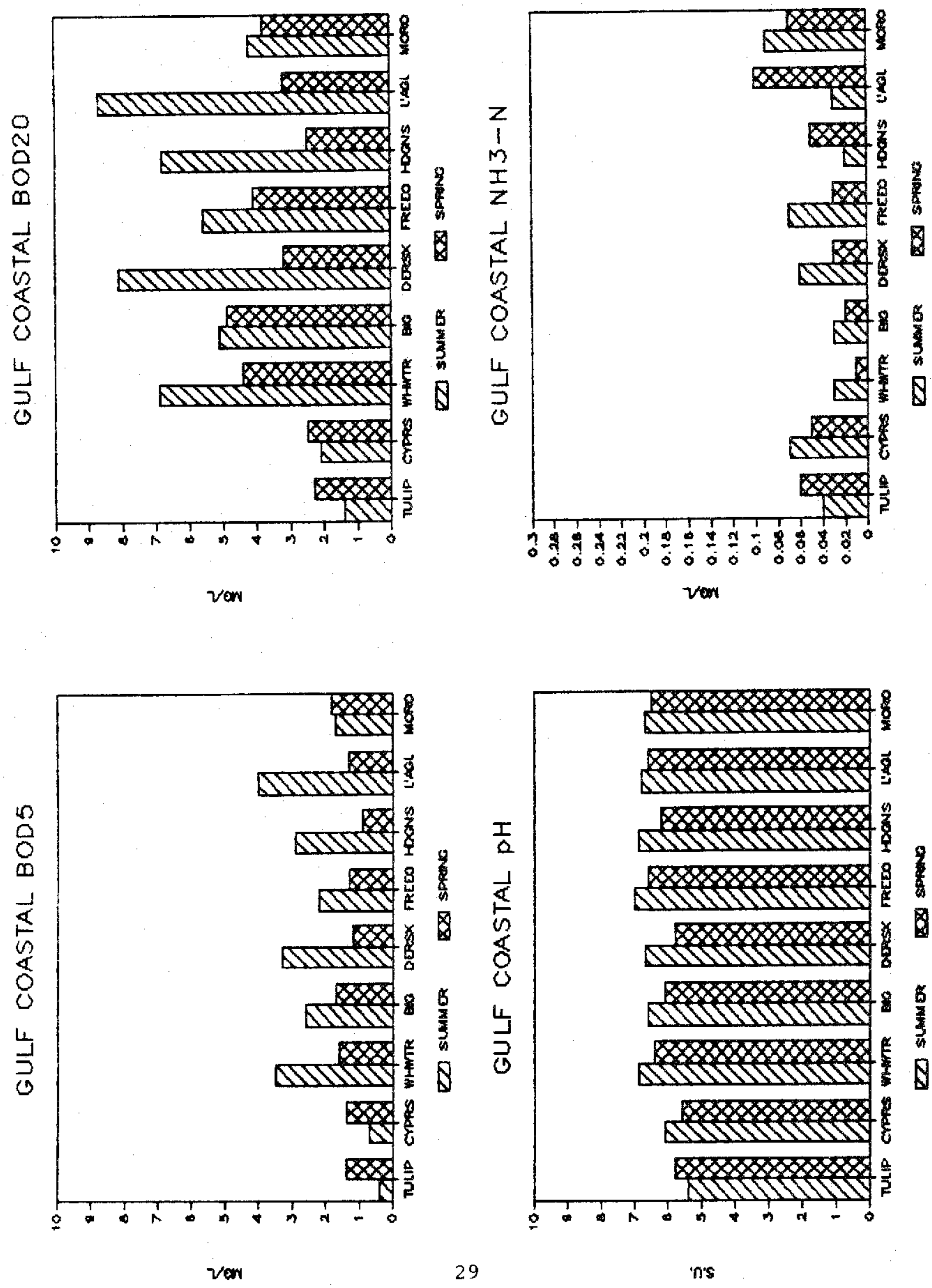
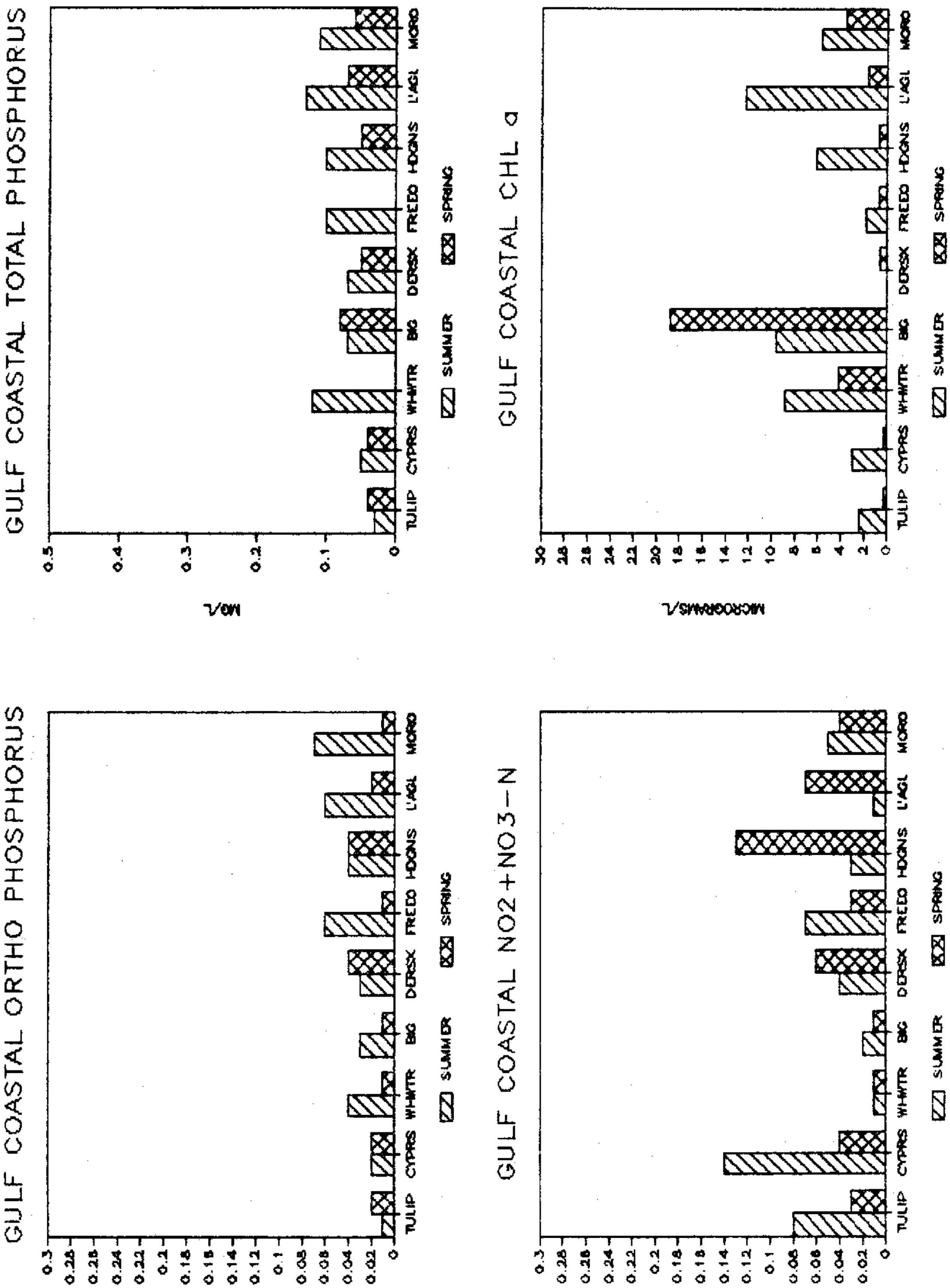


Figure C-10. Water Quality Data for
Gulf Coastal Ecoregion Reference Streams



becomes the critical water quality component. In a few of the Gulf Coastal streams which maintain summer flows through springwater inflow, these conditions do not occur and dissolved oxygen values remain high. Both types of streams have very little buffering capacity, either chemically or flow related, and their water quality characteristics are therefore rather sensitive and potentially unstable.

Arkansas River Valley Ecoregion

Most of the mineral constituents in the waters of the Arkansas River Valley Ecoregion reference streams are present in relatively low amounts. Values for total dissolved solids, total suspended solids, sulfates, turbidity, alkalinity and hardness indicate a possible positive correlation to stream watershed size (Figure C-11, C-12, C-13). In most cases, the seasonal variation of these parameters is distinctive. However, chlorides seem to be very uniform among all of the reference streams during both the spring and summer season (Figure C-12). During the summer period, these and other water quality parameters were not flow-related since the summer flows were near zero at all sites (Figure C-11). The high summer flow in Cadron Creek was estimated at the fish sample site, which was over a mile upstream of the water quality collection site. Upstream, a very slight water movement was noticed, and the wide, deep, continuous pool at this site produced an estimated flow of about 15 cfs. Almost no water movement, or even possibly backflow, was noted at the water sampling site. This condition was caused by the nearness of this site to the Arkansas River and its navigation pools, which retard flows from the tributaries to the river.

Consistency of the values of the biochemical parameters among the reference streams is apparent. Noticeable exceptions are the higher summer BOD and chlorophyll $\bar{a}$ values in Mill Creek and Cadron Creek (Figure C-14, C-15). These values are caused by the isolated pool conditions of Mill Creek and the large, deep pool in Cadron Creek, creating an almost lentic situation. Also, the stream is exposed to nearly total sunlight due to the limited stream canopy. Summer fecal coliform values exceed the primary contact use standard in Mill Creek, North Fork Cadron Creek and Ten Mile Creek. The extremely high value in North Fork Cadron Creek was probably caused by the high density of cattle grazing in pastures adjacent to the sample site and the use of the stream for cattle watering (Figure C-13).

Phosphorus and ammonia nitrogen values are generally low in the reference streams of the ecoregion. However, Ten Mile Creek has unexplained higher values for total phosphorus with almost all of it in the available (ortho-phosphorus) form. Also, nitrate-nitrate nitrogen values are notably elevated in most of the reference streams during the spring-flow season (Figure C-15). This is probably a reflection of cattle grazing as a major watershed use in much of the Arkansas River Valley.

Figure C-11. Water Quality Data for
Arkansas River Valley Ecoregion Reference Streams

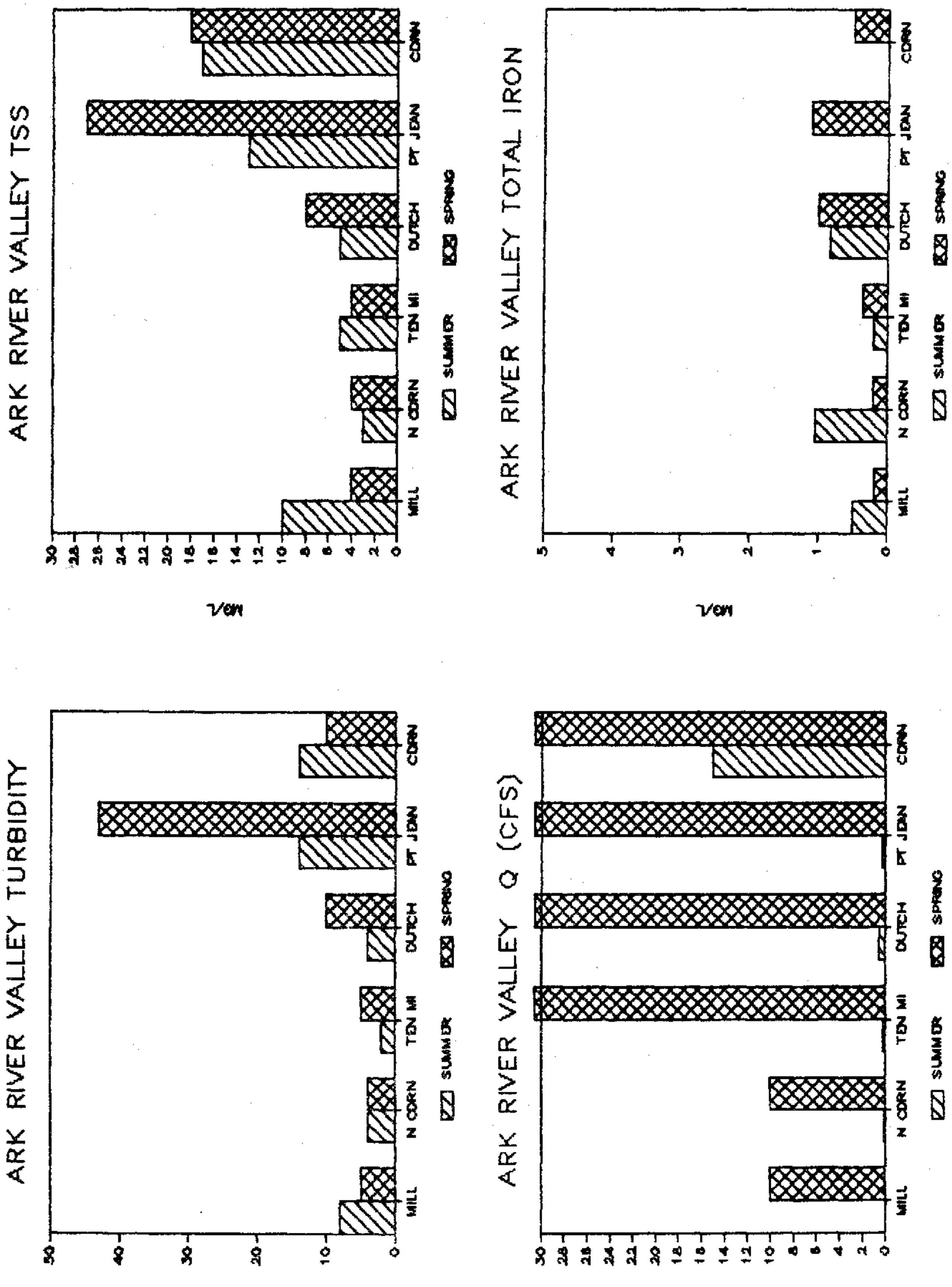


Figure C-12. Water Quality Data for
Arkansas River Valley Ecoregion Reference Streams

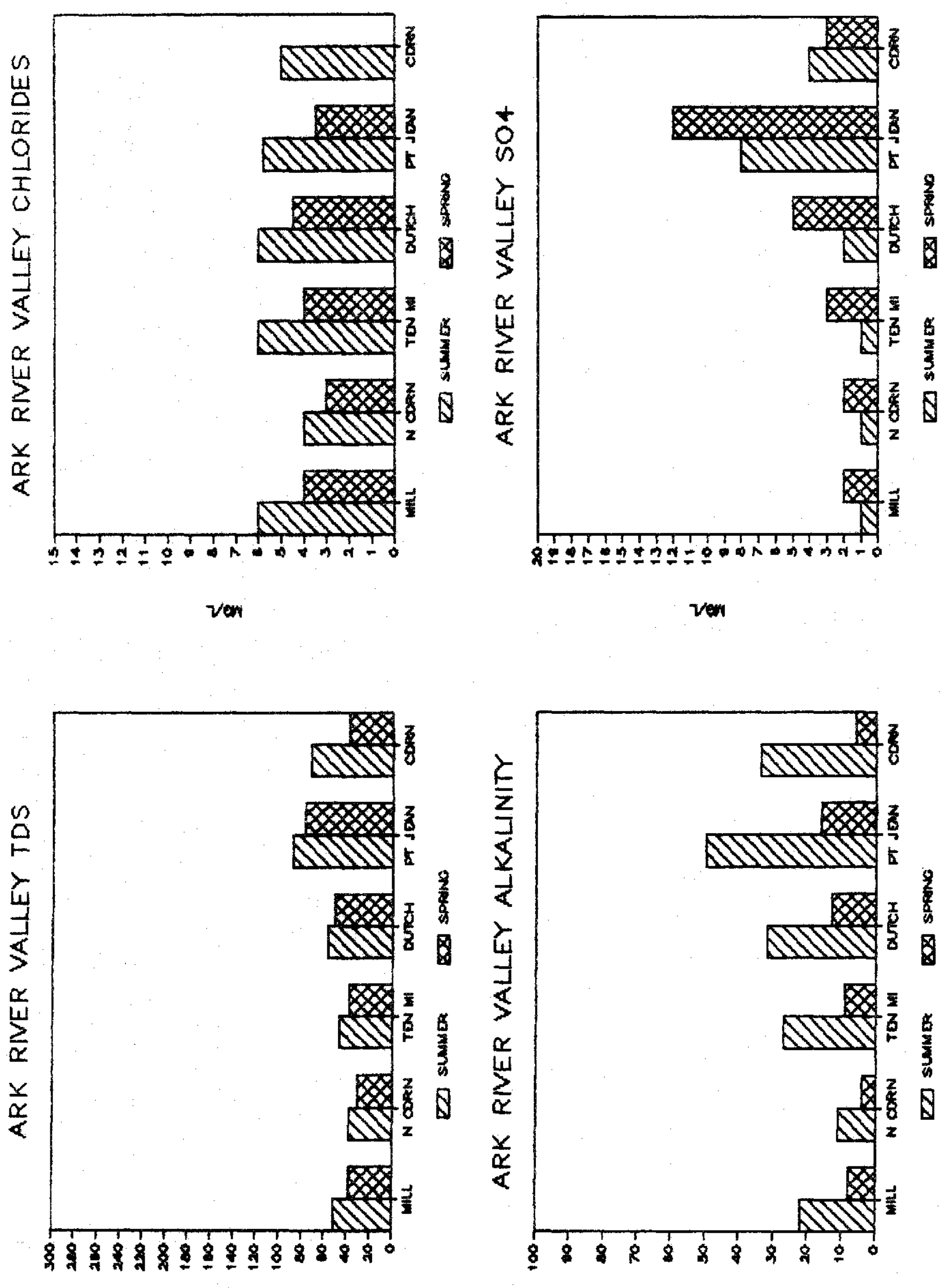
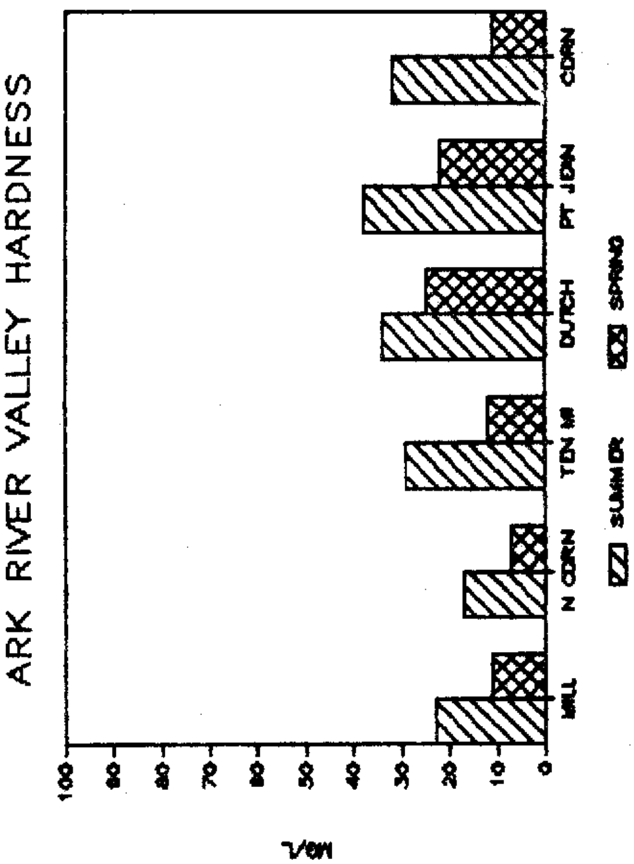
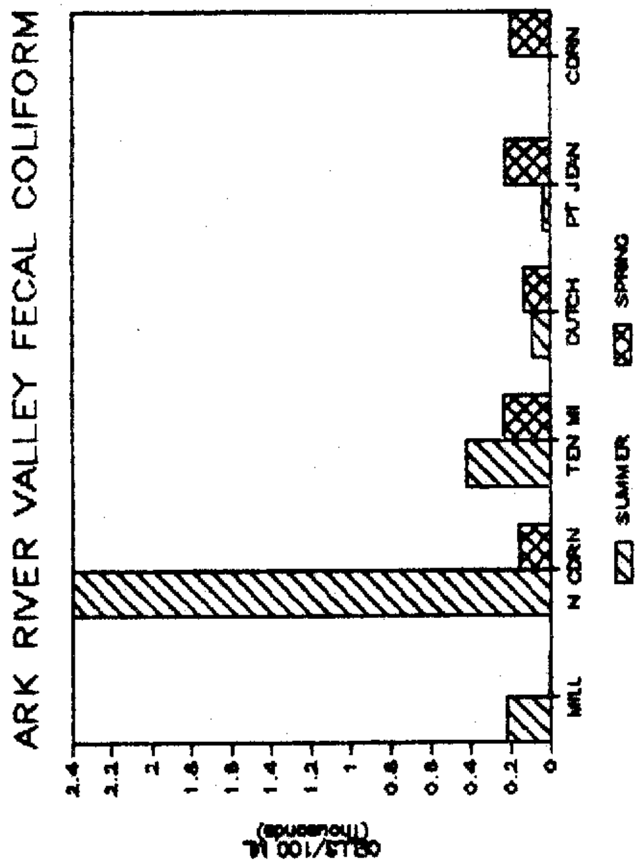


Figure C-13. Water Quality Data for
Arkansas River Valley Ecoregion Reference Streams





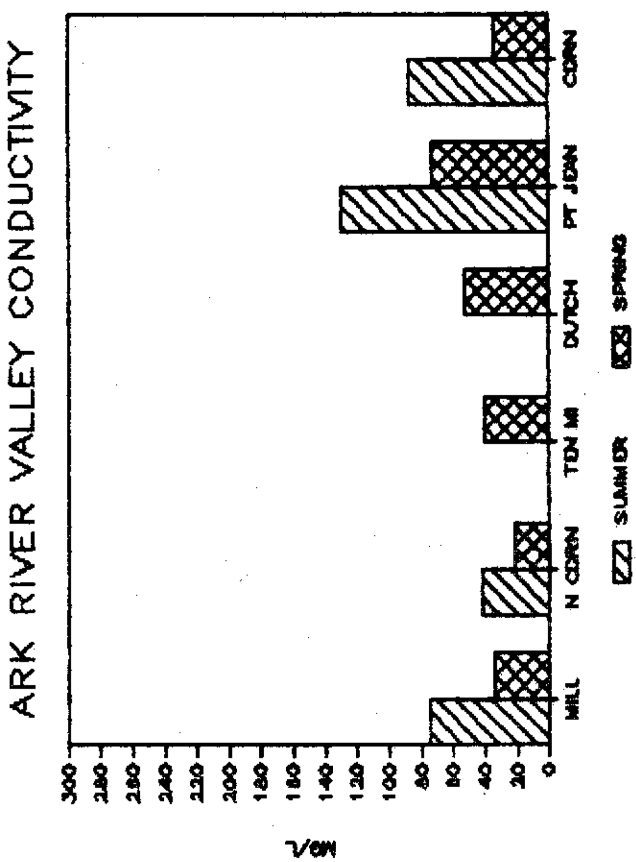
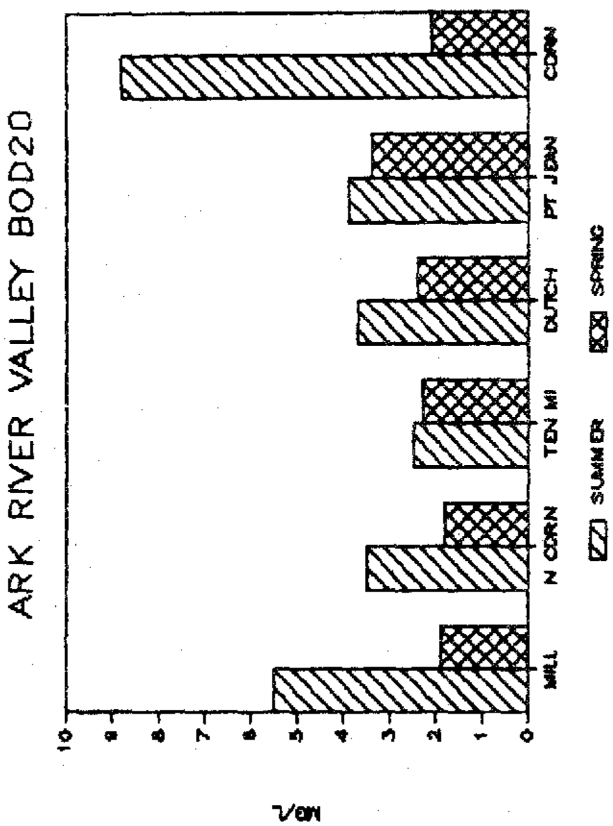
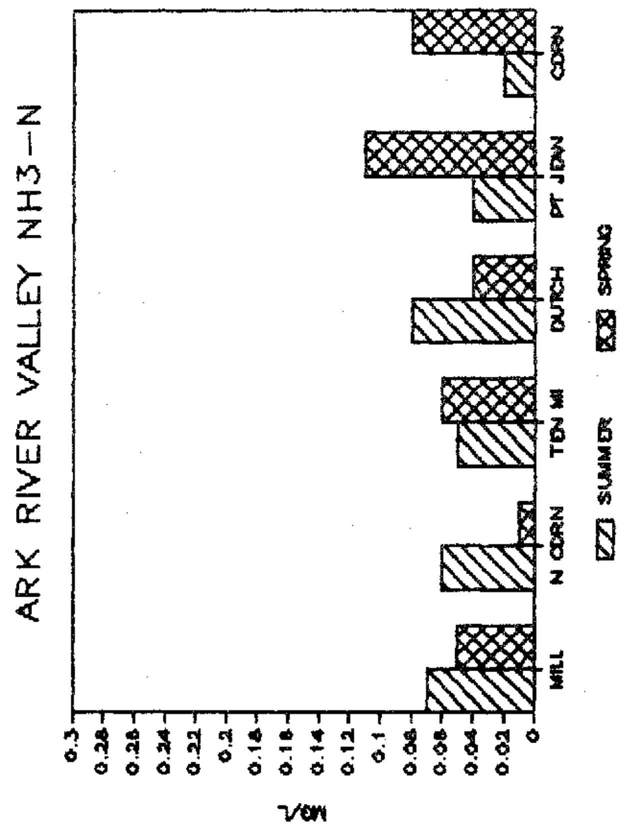
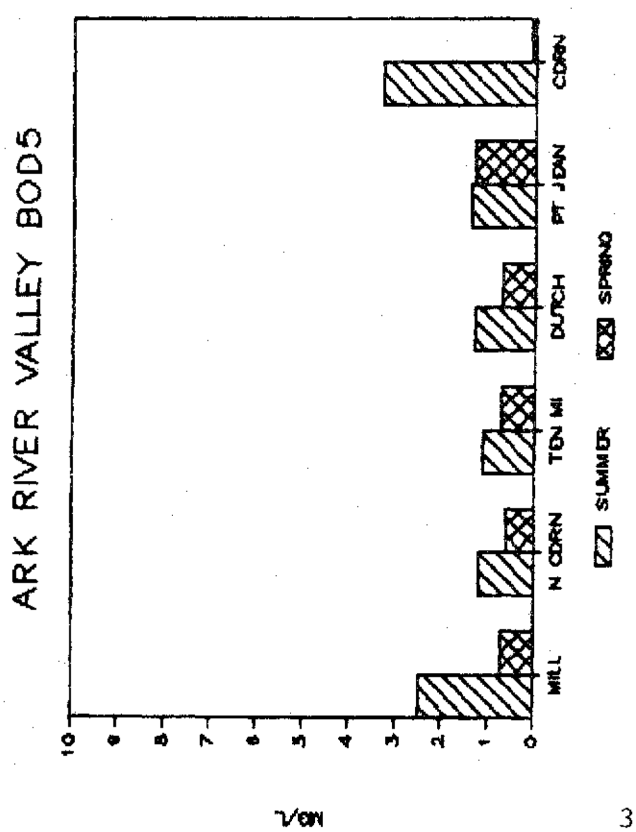


Figure C-14. Water Quality Data for
Arkansas River Valley Ecoregion Reference Streams







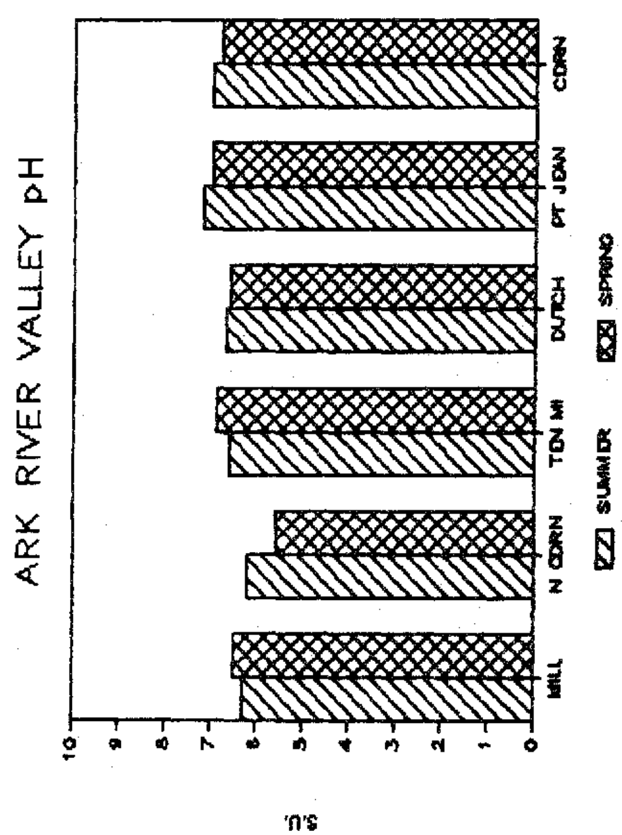
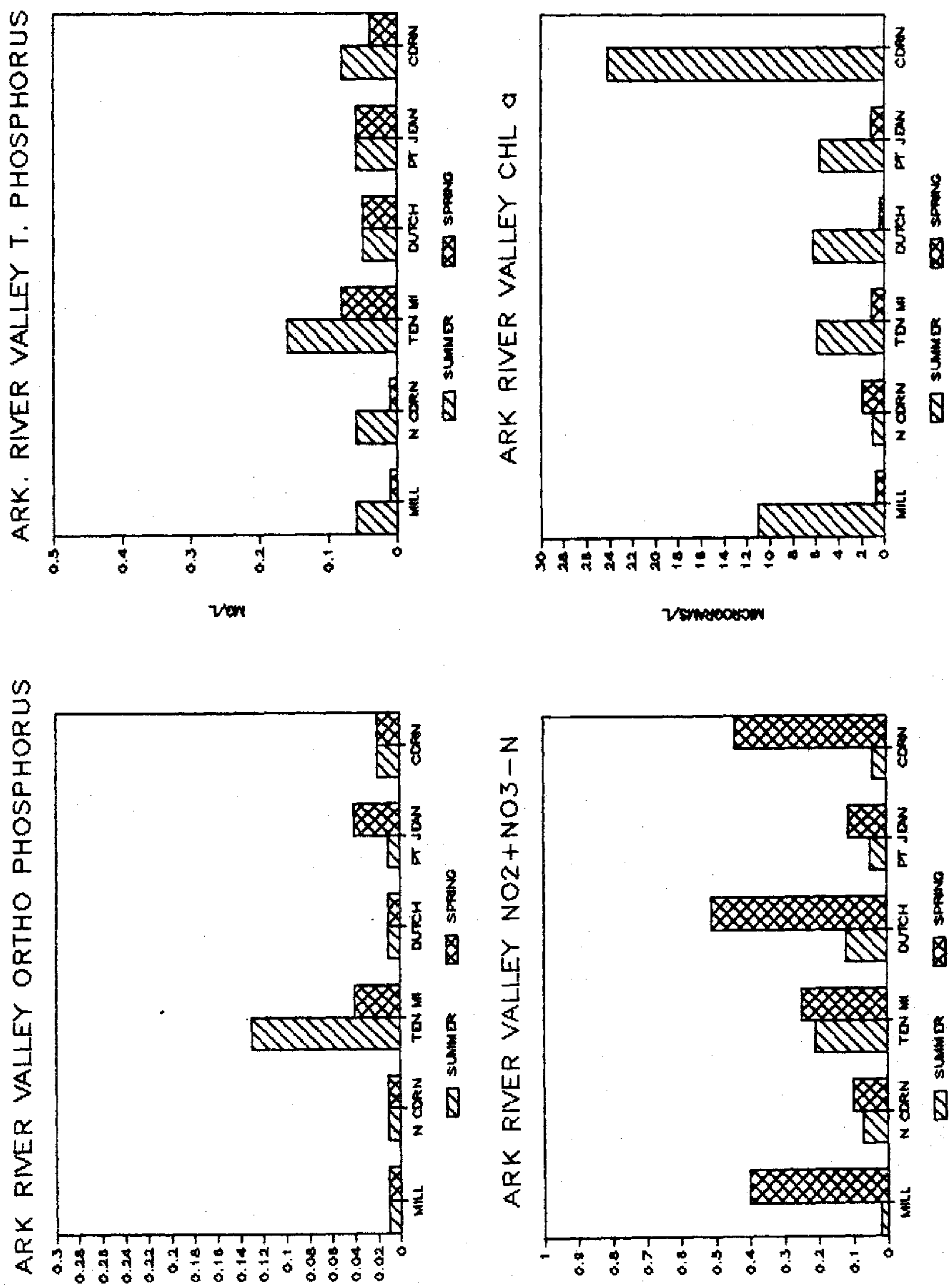


Figure C-15. Water Quality Data for
Arkansas River Valley Ecoregion Reference Streams



In general, the reference streams in this ecoregion have good water quality although perturbations in the watershed are distinctly reflected in the waters. The easily erodible soils found in much of this ecoregion increase the impact of land uses in the watershed in determining the quality of water in Arkansas River Valley streams.

Ouachita Mountain Ecoregion

In the Ouachita Mountains Ecoregion, almost all mineral, biochemical and nutrient water quality parameters measured are consistently low which indicates very high quality water. The mineral water quality values show the only substantial variation. This occurs at the site on the South Fork of the Ouachita River and reflects isolated limestone outcropping in the watershed. Alkalinity, hardness, conductivity and total dissolved solids are noticeably higher at this site (Figure C-16). Also, there is a general increase in the values for these parameters from the two reference streams with the largest watersheds, while the two smallest streams have the lowest values. Although representing a relatively low value, total iron is present in a substantially higher concentration in the spring sample on the Saline River (Figure C-18). This sampling followed a major rise and fall of the water level in this stream from heavy rains. In-wash from the watershed was probably the cause of this elevated iron concentration. Turbidity values in all reference streams during both seasons were very low even though substantial flows existed at all sites and spring flows were very high in the larger watersheds (Figure C-18).

Of the biochemical parameters, the BOD values are consistently very low in all reference streams, indicating very little water column demand on the dissolved oxygen in these waters (Figure C-19). The summer fecal coliform value in South Fork Ouachita River is high and probably reflects cattle grazing activities in small pastures along the streambed (Figure C-17). Also, slightly higher chlorophyll $\bar{a}$ values are noted in the Caddo River samples (Figure C-20). This sample site is in a very large, deep pool which slows water velocity and allows a slight increase in plankton production. The nutrient parameters associated with nitrogen and phosphorus are similarly very low in these reference streams and they are limiting factors in biotic production (Figure C-20).

Reference streams of the Ouachita Mountains Ecoregion demonstrate that waters of this region are naturally low in mineral quantities, except in areas of limestone outcroppings, and low in nutrient quantities. This results in a very low biotic production potential.

Ozark Highland Ecoregion

The water quality in the Ozark Highlands is substantially different from that of the other ecoregions. The differences are caused by natural geologic conditions and by man-induced conditions related to land uses. Minerals, some nutrients and

Figure C-16. Water Quality Data for
Ouachita Mountains Ecoregion Reference Streams

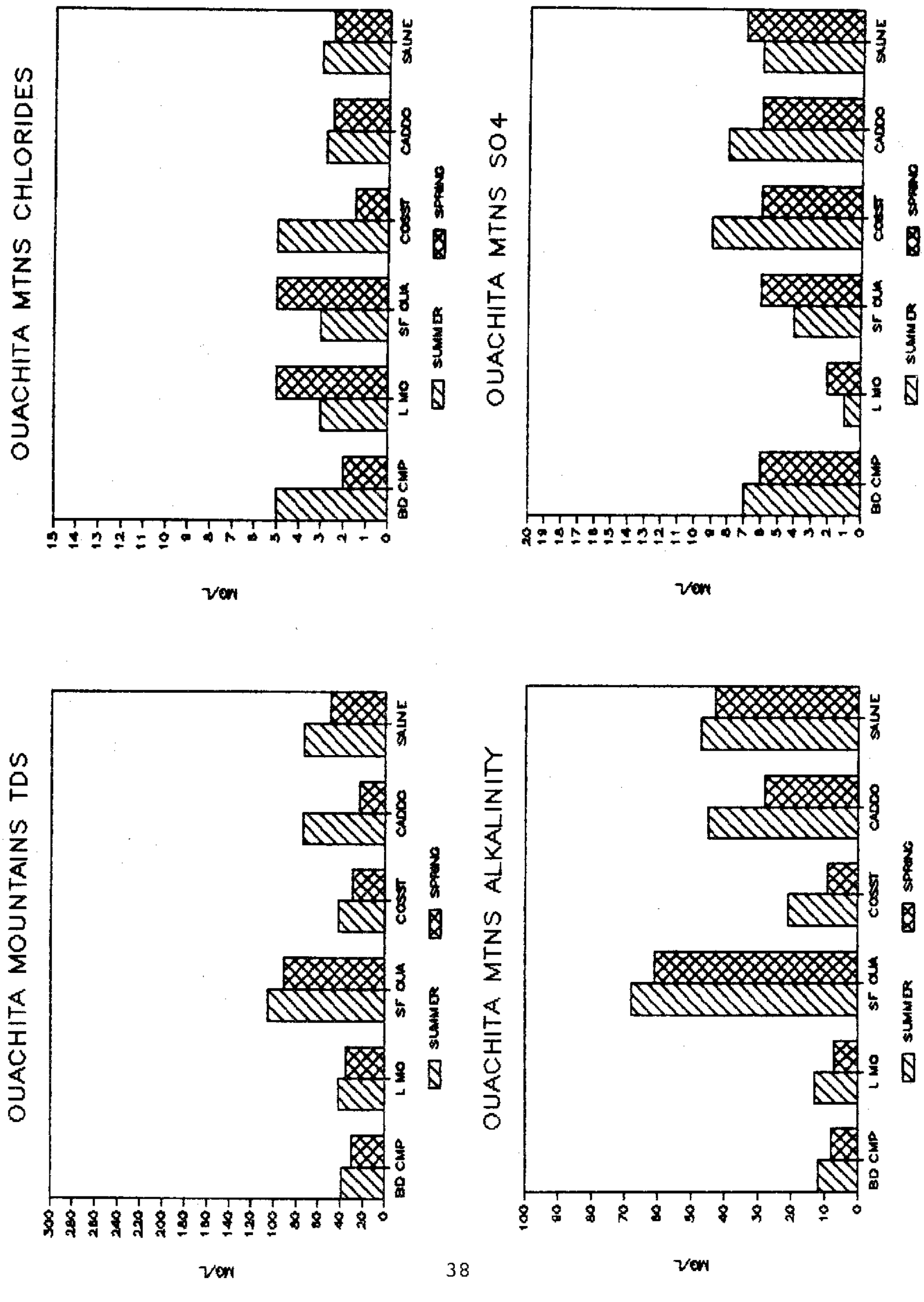
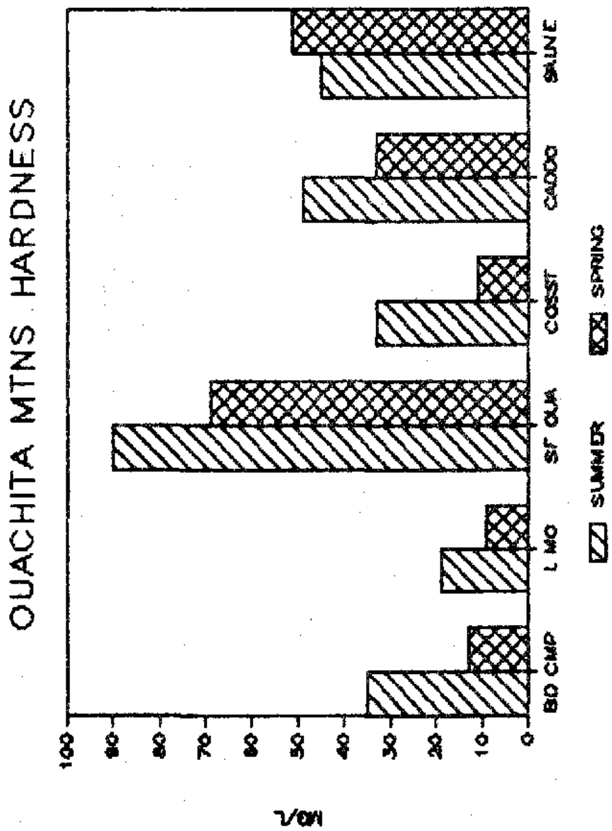
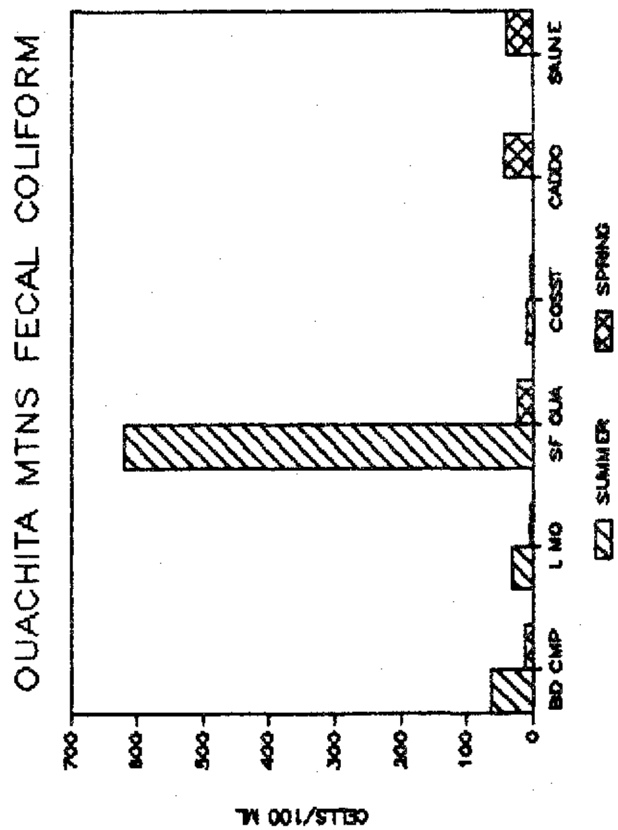


Figure C-17. Water Quality Data for
Ouachita Mountains Ecoregion Reference Streams





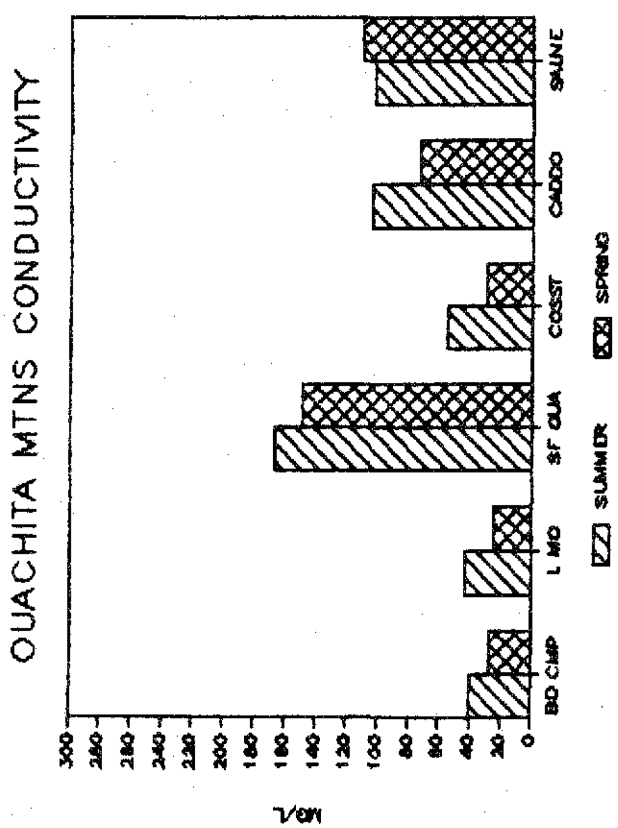


Figure C-18. Water Quality Data for
Ouachita Mountains Ecoregion Reference Streams

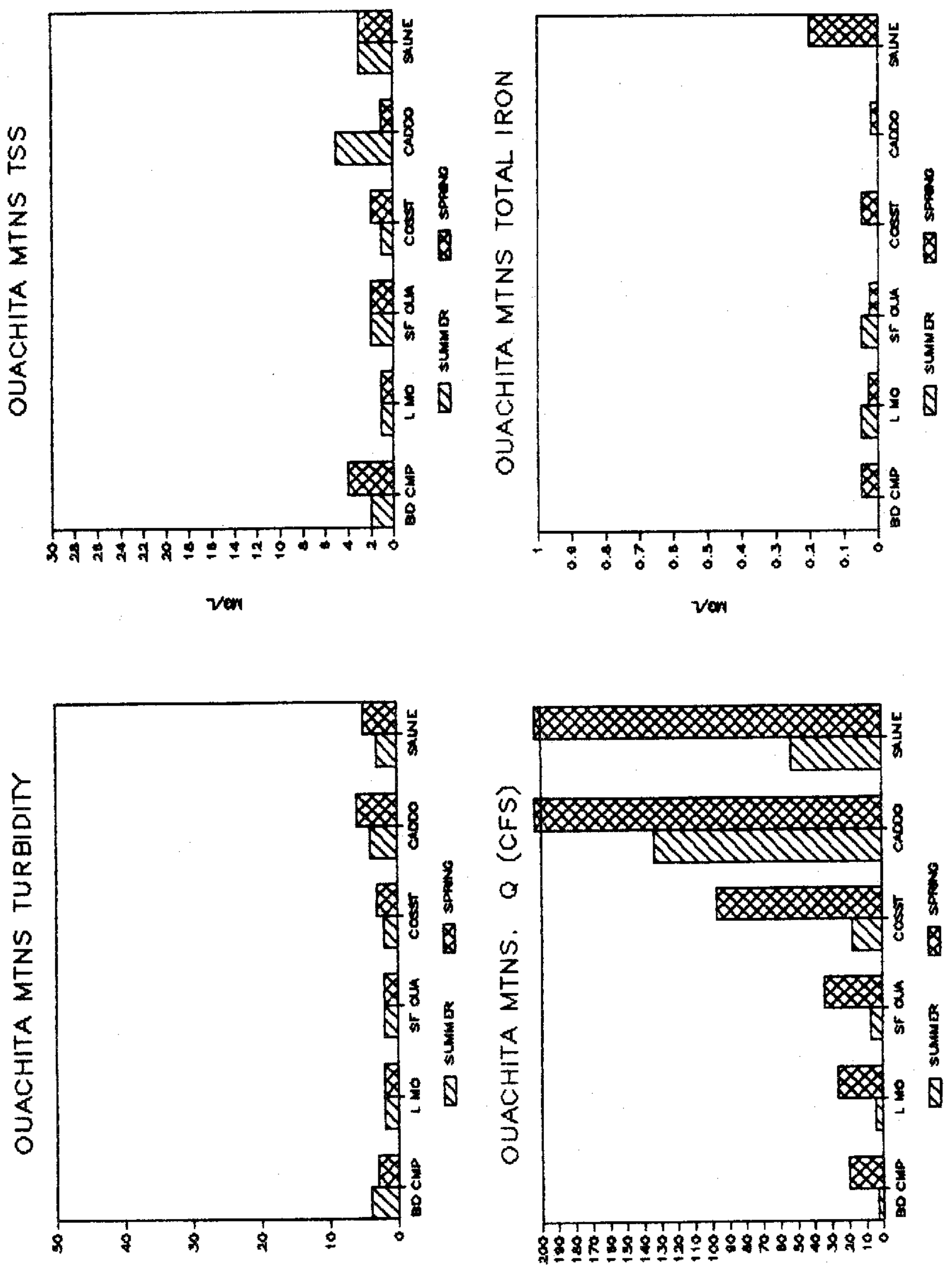


Figure C-19. Water Quality Data for
Ouachita Mountains Ecoregion Reference Streams

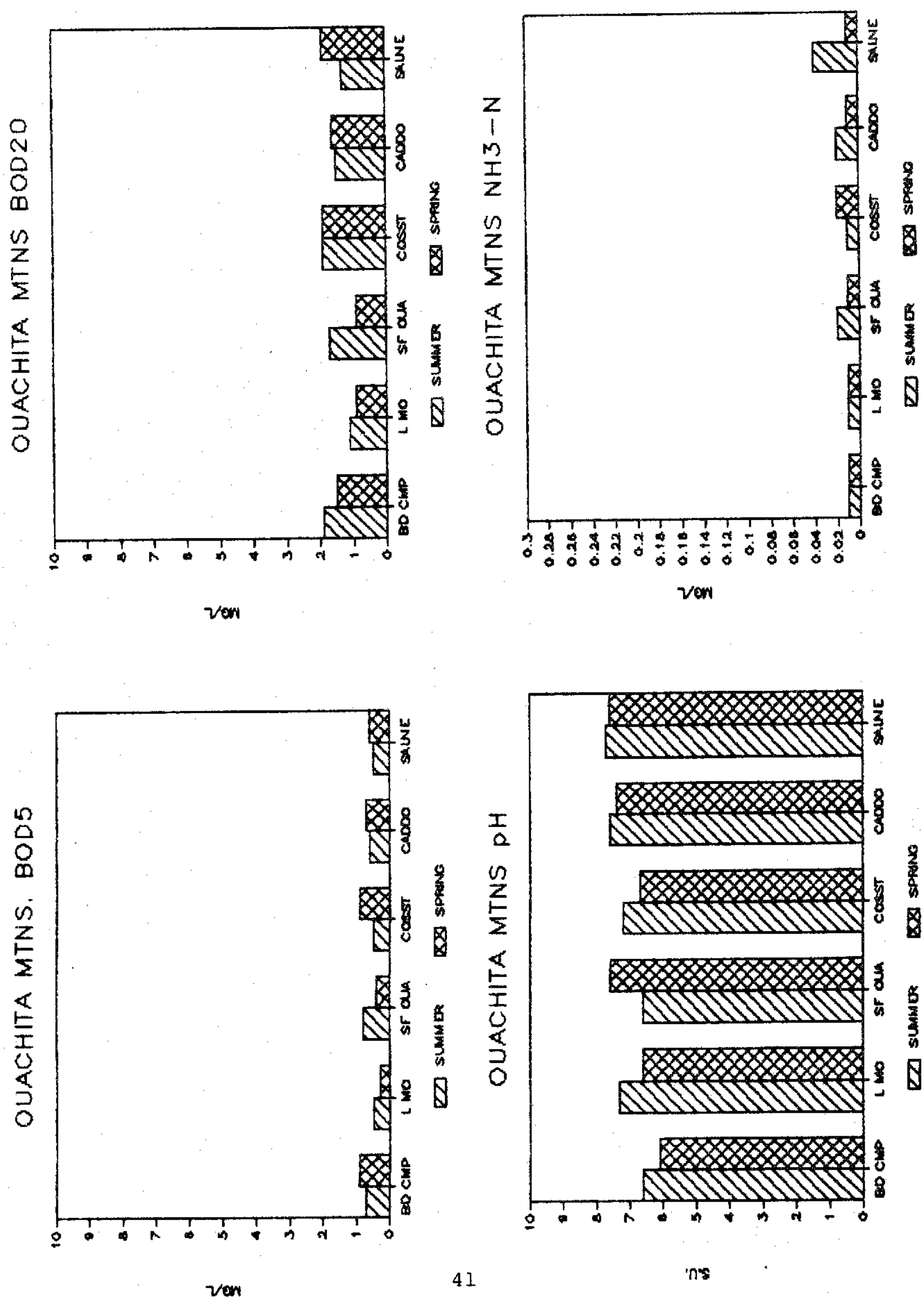
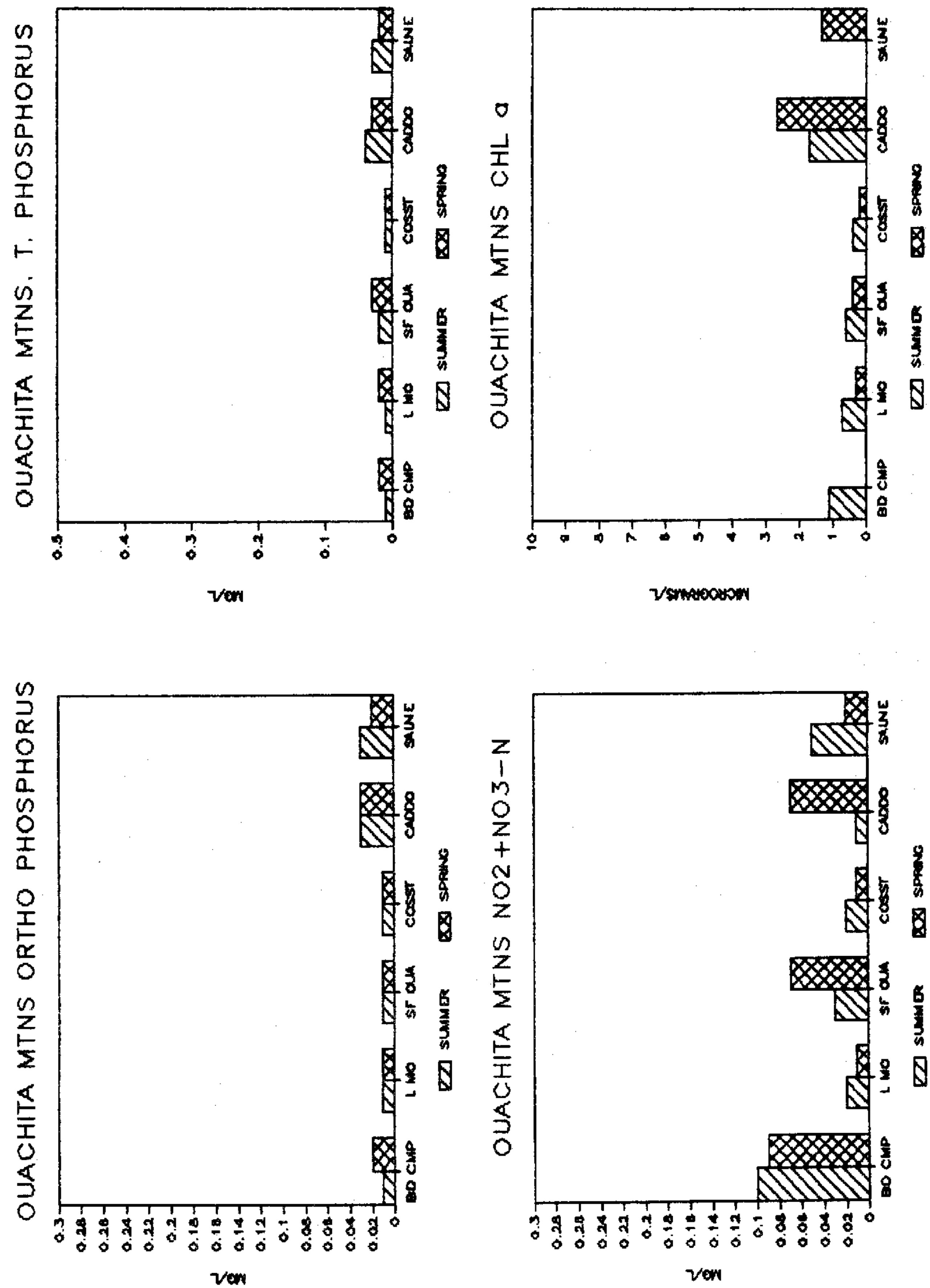


Figure C-20. Water Quality Data for
Ouachita Mountains Ecoregion Reference Streams



most biochemical parameters are notably high in this ecoregion when compared to other regions.

Stream flows within the region are normally present the entire year, even in relatively small watersheds. Flows include frequent groundwater contributions and sections of under-gravel flow within the streambed. Base flows as well as runoff flows are generally related to watershed size (Figure C-21). Although flows are substantial at times, water turbidity normally remains below 10 NTU (Figure C-21). Surface rocks in this ecoregion contain large amounts of limestone and dolomite and therefore produce high alkalinity, total hardness, conductivity and total dissolved solids in the surface waters (Figure C-22 and C-23). These values are consistently high in all reference streams and the variation that occurs is most likely related to the amount of limestone in the watershed. Sulfate values are similar to those in other ecoregions and appear to be directly related to watershed size (Figure C-22).

The biochemical water quality constituents appear to be similar to the other regions. However, there are definite indications in these waters of the practice of land application of waste from confined animal production facilities such as poultry and hogs. Also, many areas of improved pasture with intensive cattle grazing exist in this region. Exceptionally high fecal coliform values (2300 to 8800 cells per 100 ml) were found during spring sampling in South Fork Spavinaw, Flint and Yocum Creeks (Figure C-23). Since there are no major point source discharges in these streams and because these values are associated with springtime surface runoff, it is apparent that the source is from animal waste in the watershed. Although there is apparent heavy organic loading to the watershed of many of these streams, BOD values are not considered to be high (Figure C-24). Stream flows, substrate types and high stream gradients apparently result in reaeration rates which satisfy the oxygen demand from much of the watershed. Chlorophyll *a* values are similarly lower than might be expected with the known nonpoint source contribution to these streams (Figure C-25). However, stream flow velocities prevent excessive phytoplankton development. Periphyton production was not measured but general observations indicate that the primary production in these streams is periphyton.

Nutrient water quality values, particularly nitrite-nitrate nitrogen, also indicate substantial contributions from land uses. These values are much higher in the Ozark Highlands than any other region, and the highest values are found in the three reference streams which contained the highest fecal coliform values. These are also the streams with the smallest watersheds (Figure C-25). The two reference streams with the largest watersheds have relatively low nitrate-nitrite values. These were lower during the spring period than during the summer. This indicates watershed-specific problems related to location and magnitude of activity rather than size of watershed and magnitude of surface runoff. All phosphorus

Figure C-21. Water Quality Data for
Ozark Highlands Ecoregion Reference Streams

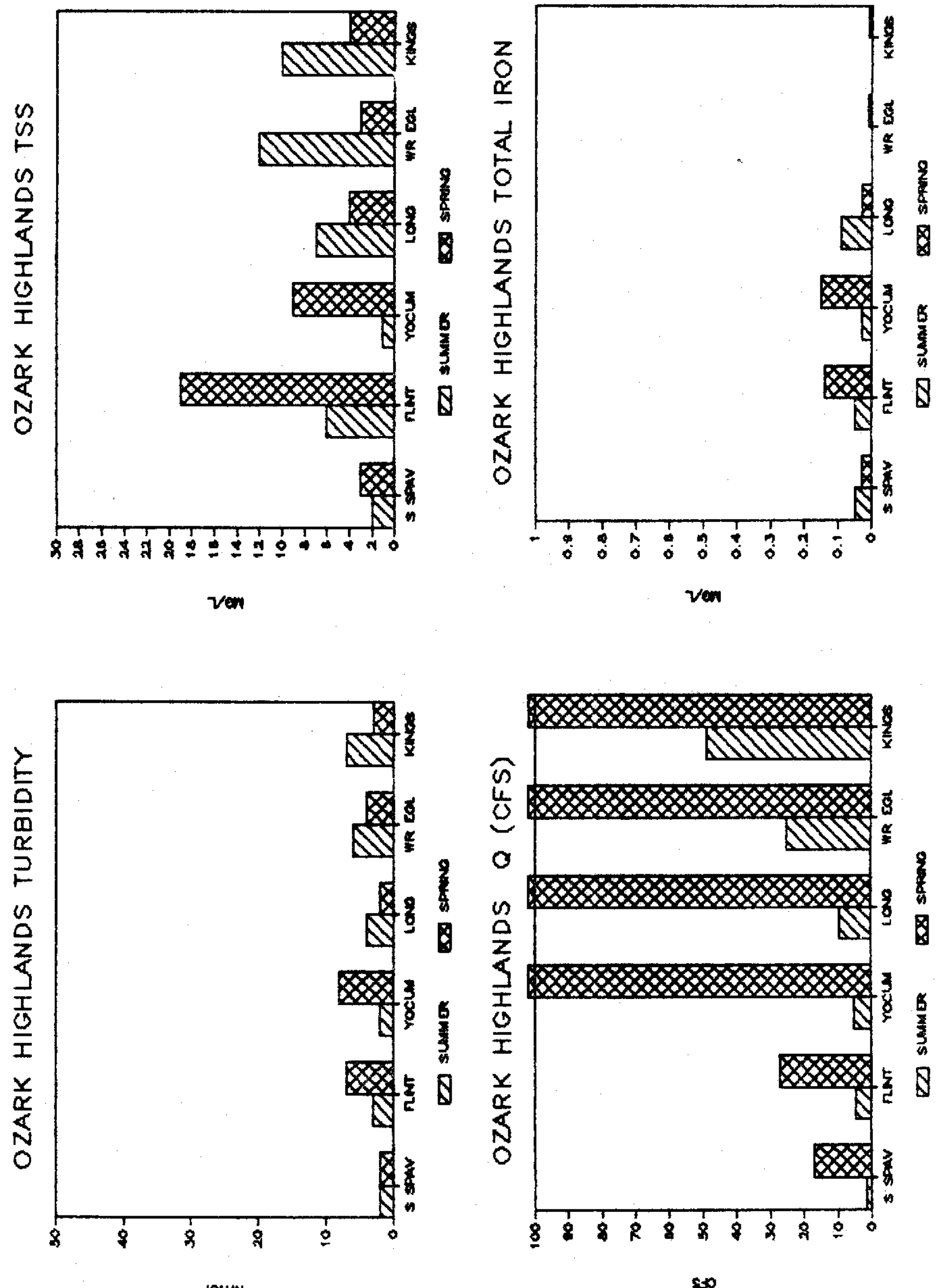


Figure C-22. Water Quality Data for
Ozark Highlands Ecoregion Reference Streams

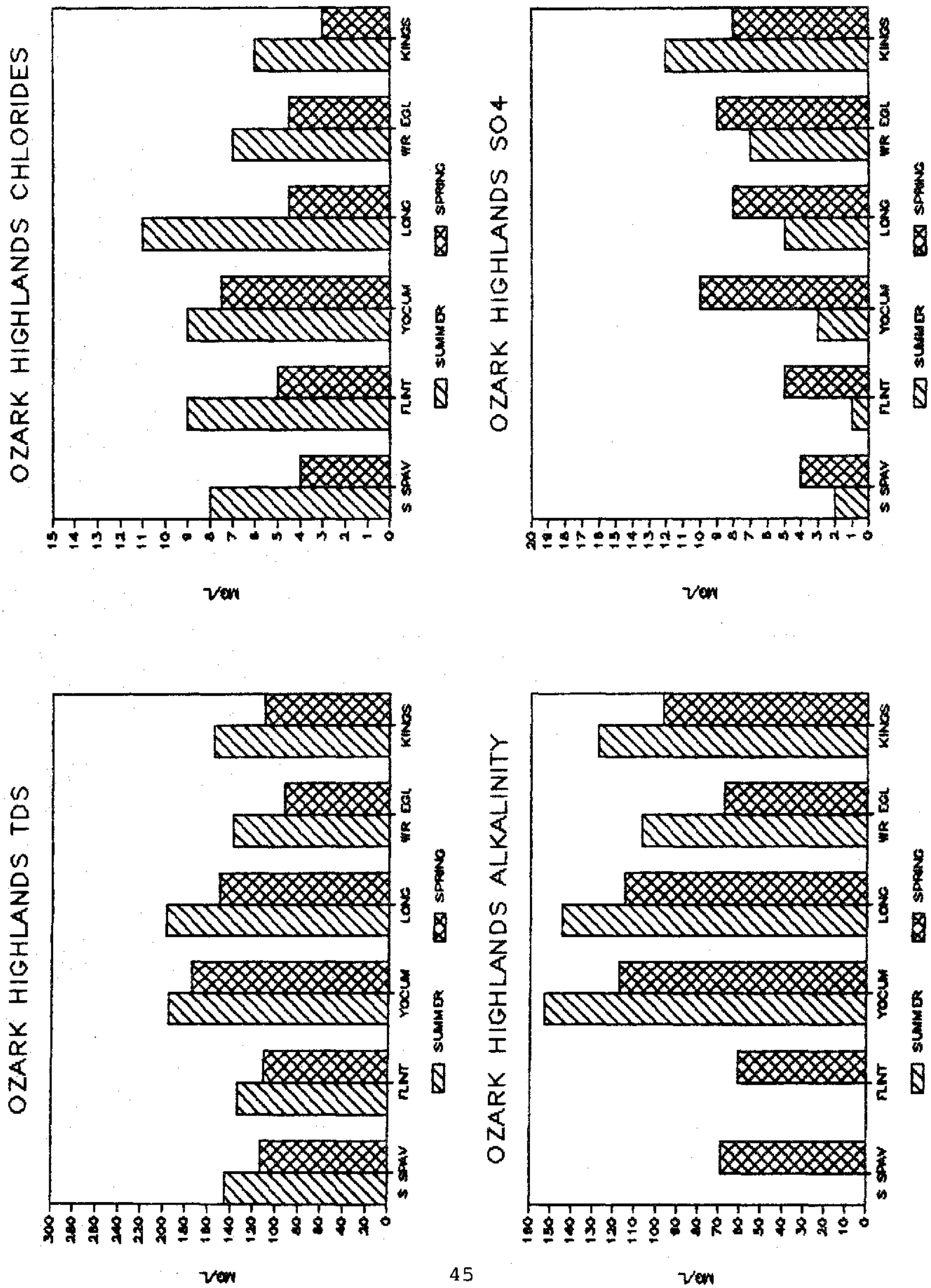
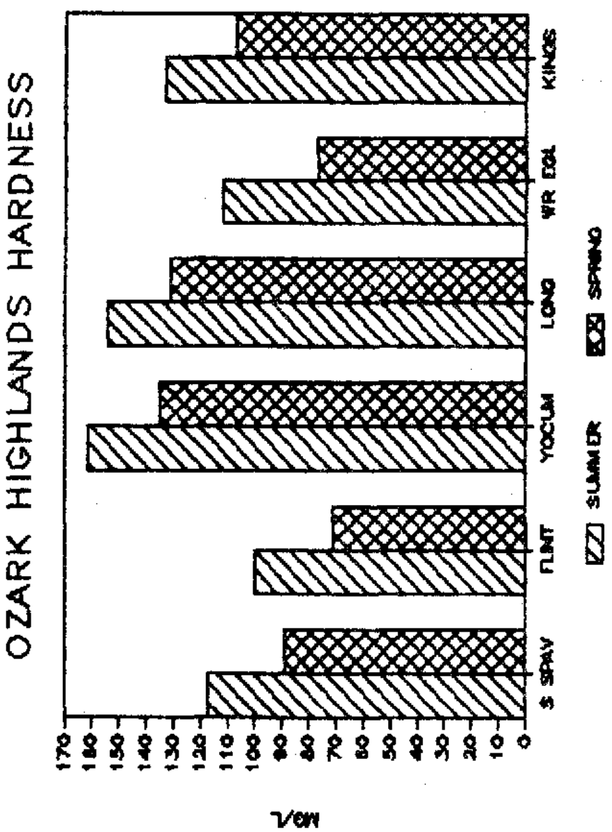
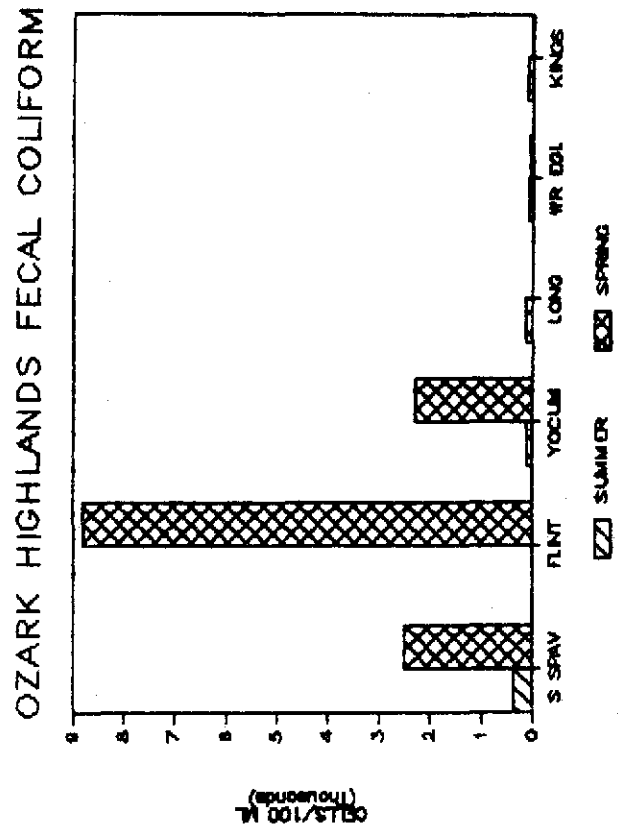


Figure C-23. Water Quality Data for
Ozark Highlands Ecoregion Reference Streams





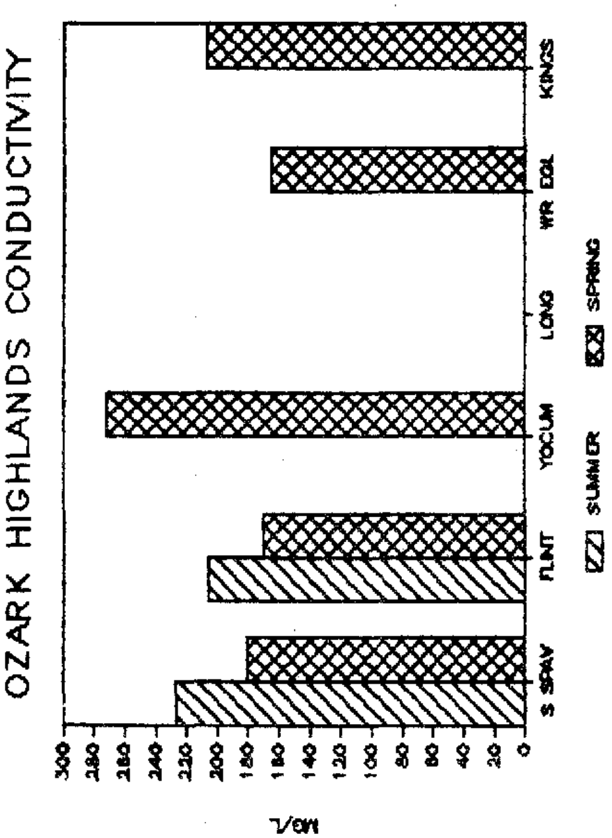


Figure C-24. Water Quality Data for
Ozark Highlands Ecoregion Reference Streams

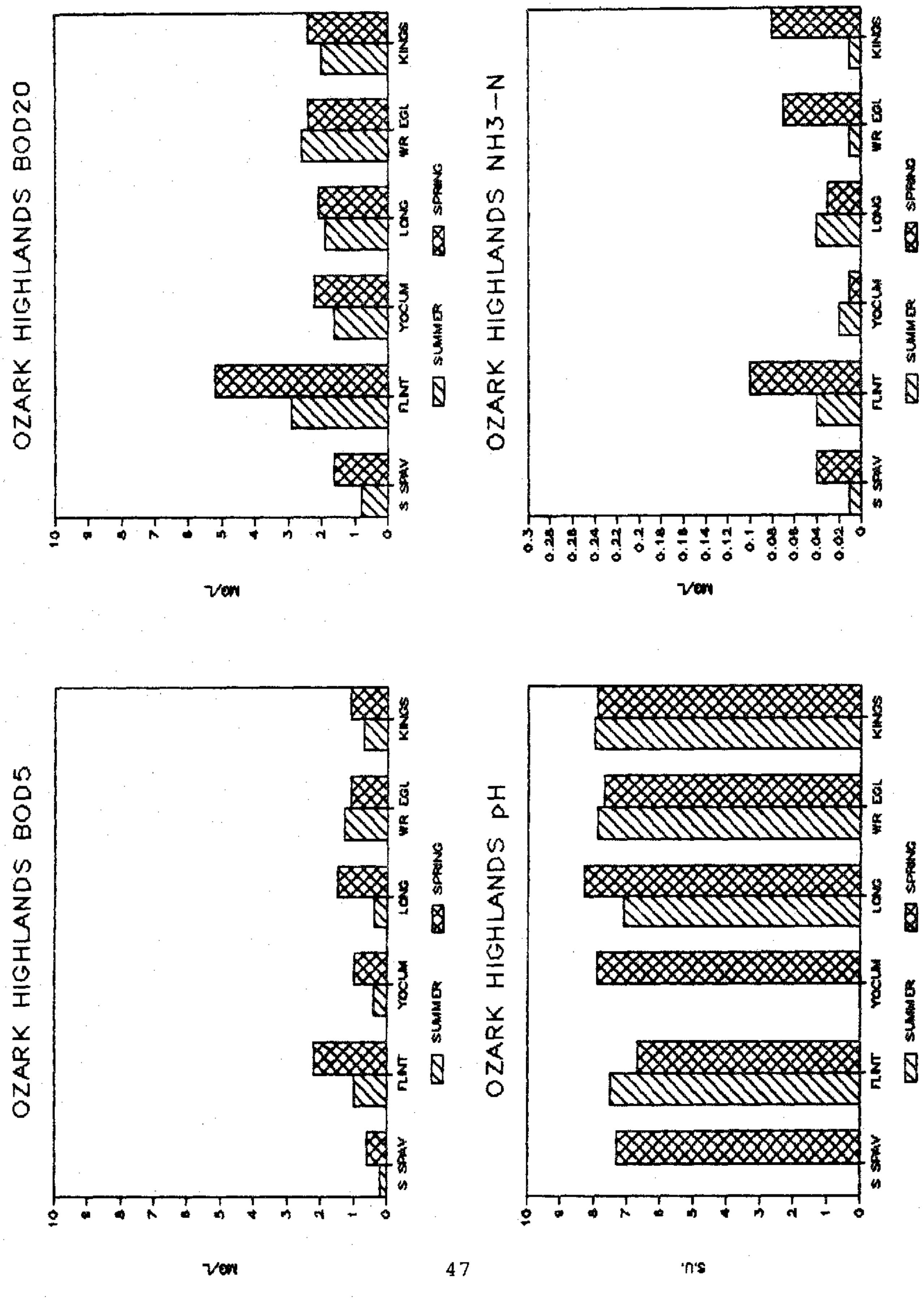
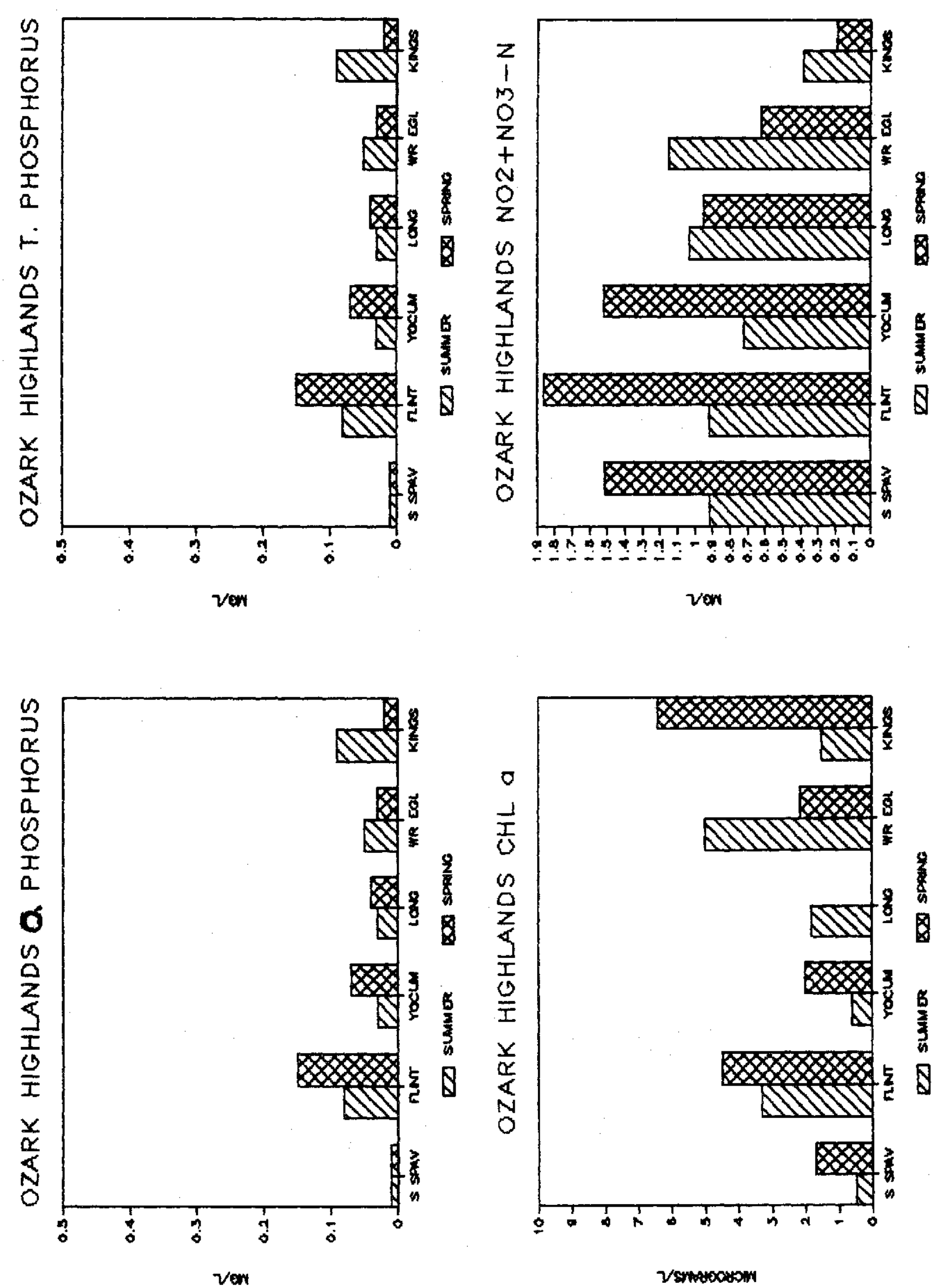


Figure C-25. Water Quality Data for
Ozark Highlands Ecoregion Reference Streams



values are relatively low, except the spring value in Flint Creek, which shows a higher value for total phosphorus and ortho-phosphorus (Figure C-25). Moderate increases in available phosphorus combined with the high nonpoint source nitrogen contributions may cause substantial changes in the environment of these streams.

The water quality of the Ozark Highlands reference streams reflects the natural geologic characteristics of the ecoregion, which produce relatively high mineral constituents. It also reflects the land application of animal waste from concentrated poultry and livestock production facilities to the watersheds. High fecal coliform and nitrite-nitrate nitrogen values result from this practice. High phosphorus values are not apparent and either do not occur in high levels in the nonpoint contributions or are being adsorbed by soil particles and utilized in terrestrial plant production. Biological production in these streams was measured only by chlorophyll a in the water column. These values were low due to water flow velocities; however, observations indicate that periphyton, macroinvertebrate and fish production is high.

Boston Mountains Ecoregion

Reference streams in the Boston Mountains Ecoregion contain very low concentrations of minerals, similar to those of the Ouachita Mountains. In contrast, summer flows in Boston Mountains Ecoregion streams are very low and surface flows in many of the smaller streams (less than 50 mi^2 watershed) cease during every summer. Streams with watershed sizes up to about 400 mi^2 have Q_{7-10} flows of zero and annual summer flows decline as low as 5 cfs (Figure C-26). Only the summer values of chlorides in Lee Creek appear to vary noticeably from the other reference streams. Summer values of sulfates, alkalinity, and hardness also show some increase in Lee Creek (Figure C-27, C-28). These values are not alarmingly high but are relatively high for this ecoregion. The source is unknown although one or more oil wells operated in this watershed in the past.

Biochemical parameters are also very low in reference streams of this ecoregion. Twenty-day BOD values are generally less than 2 mg/l and summer values are slightly higher than spring values because of the "pooled" conditions of most of these streams during the summertime (Figure C-29). A relatively high quantity of fecal coliform bacteria was found in Illinois Bayou in the summer sample (Figure C-28). Homes are occasionally found along the stream bank in this segment and some small pastures for cattle grazing are located in the isolated land tracts that are not in National Forest ownership.

Nutrient values are lowest in reference streams of this ecoregion when compared to all other ecoregions. Nitrite-nitrate nitrogen values are generally less than 0.04 mg/l and may show a slight direct correlation with

Figure C-26. Water Quality Data for
Boston Mountains Ecoregion Reference Streams

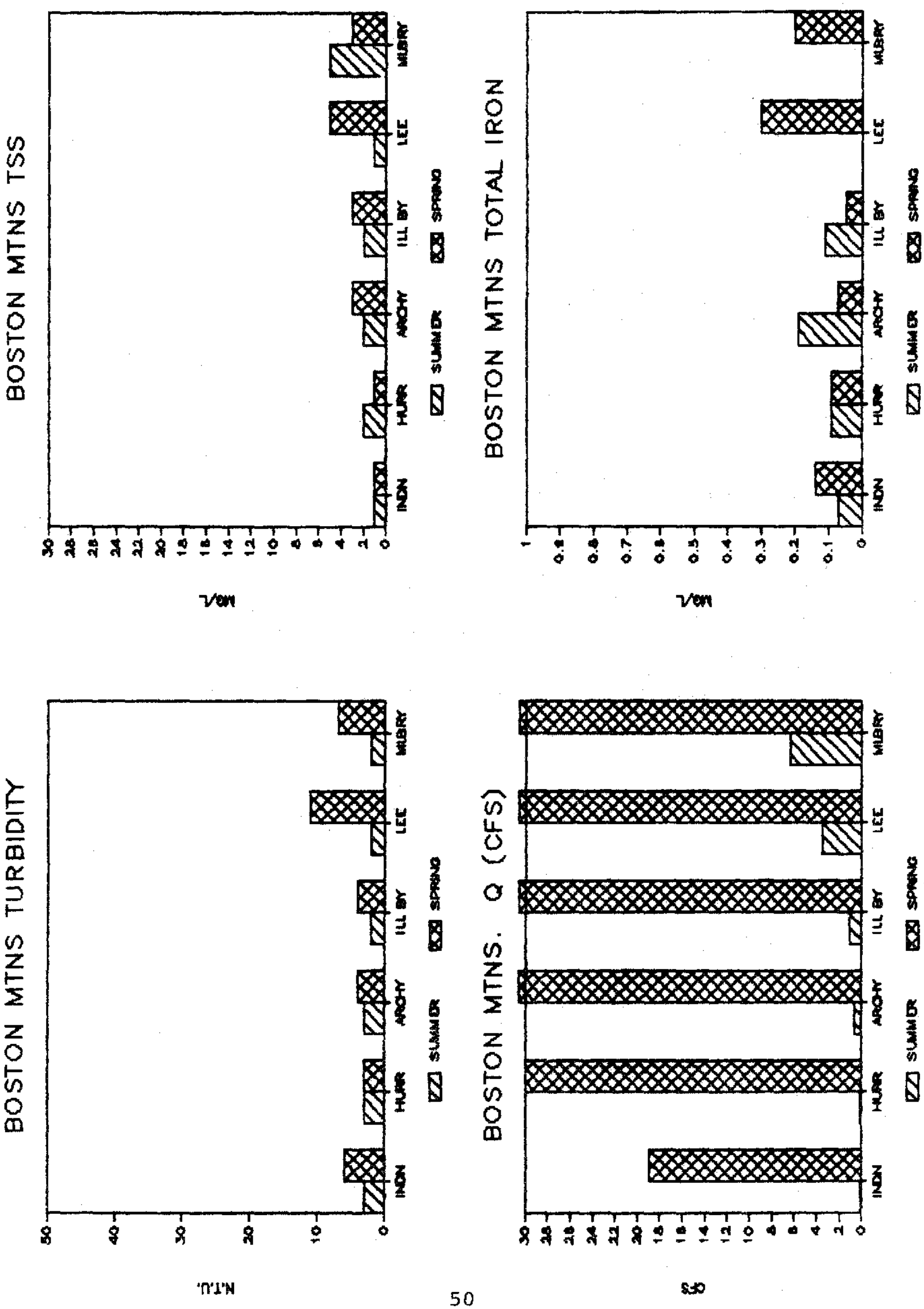


Figure C-27. Water Quality Data for
Boston Mountains Ecoregion Reference Streams

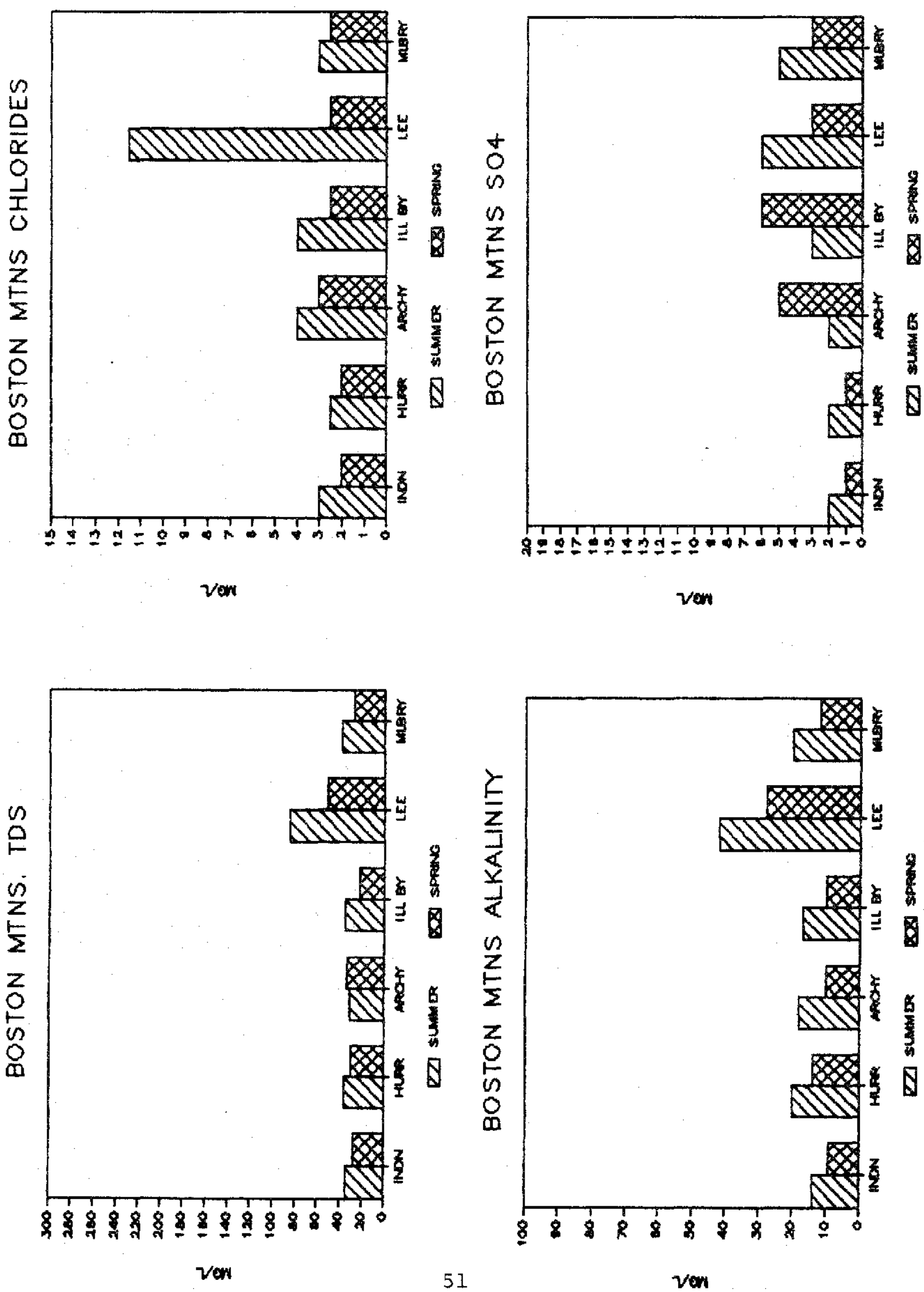
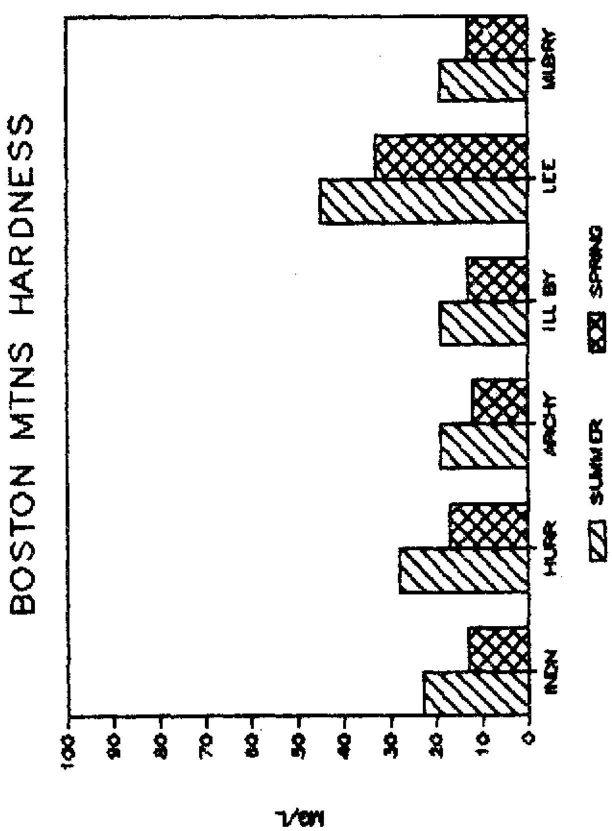
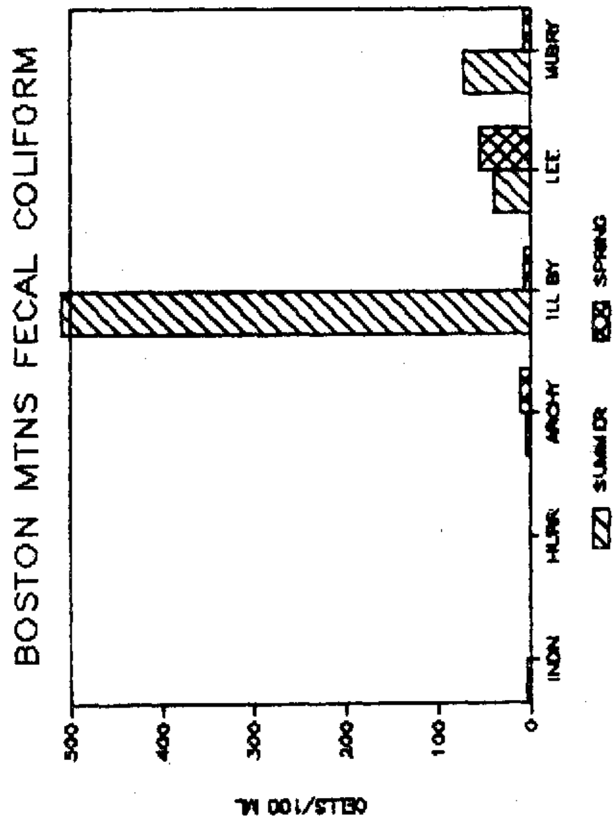


Figure C-28. Water Quality Data for
Boston Mountains Ecoregion Reference Streams





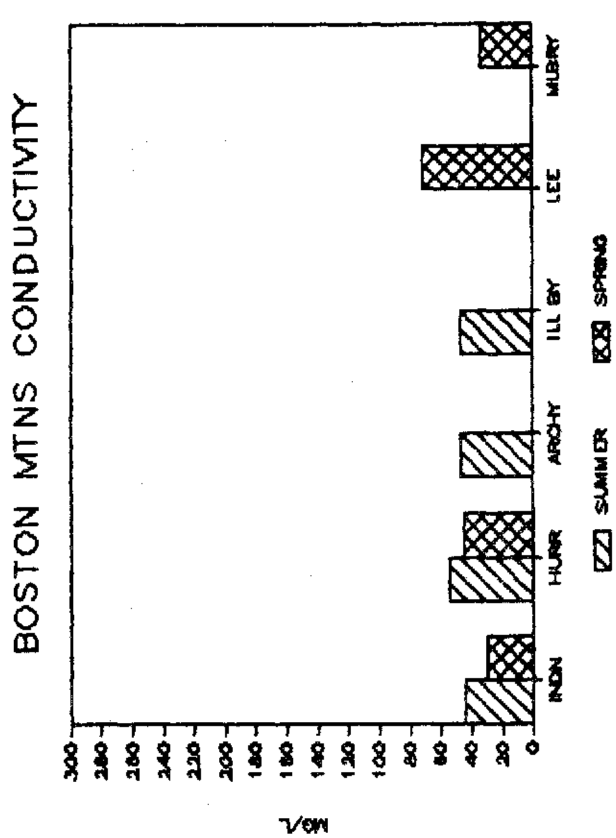
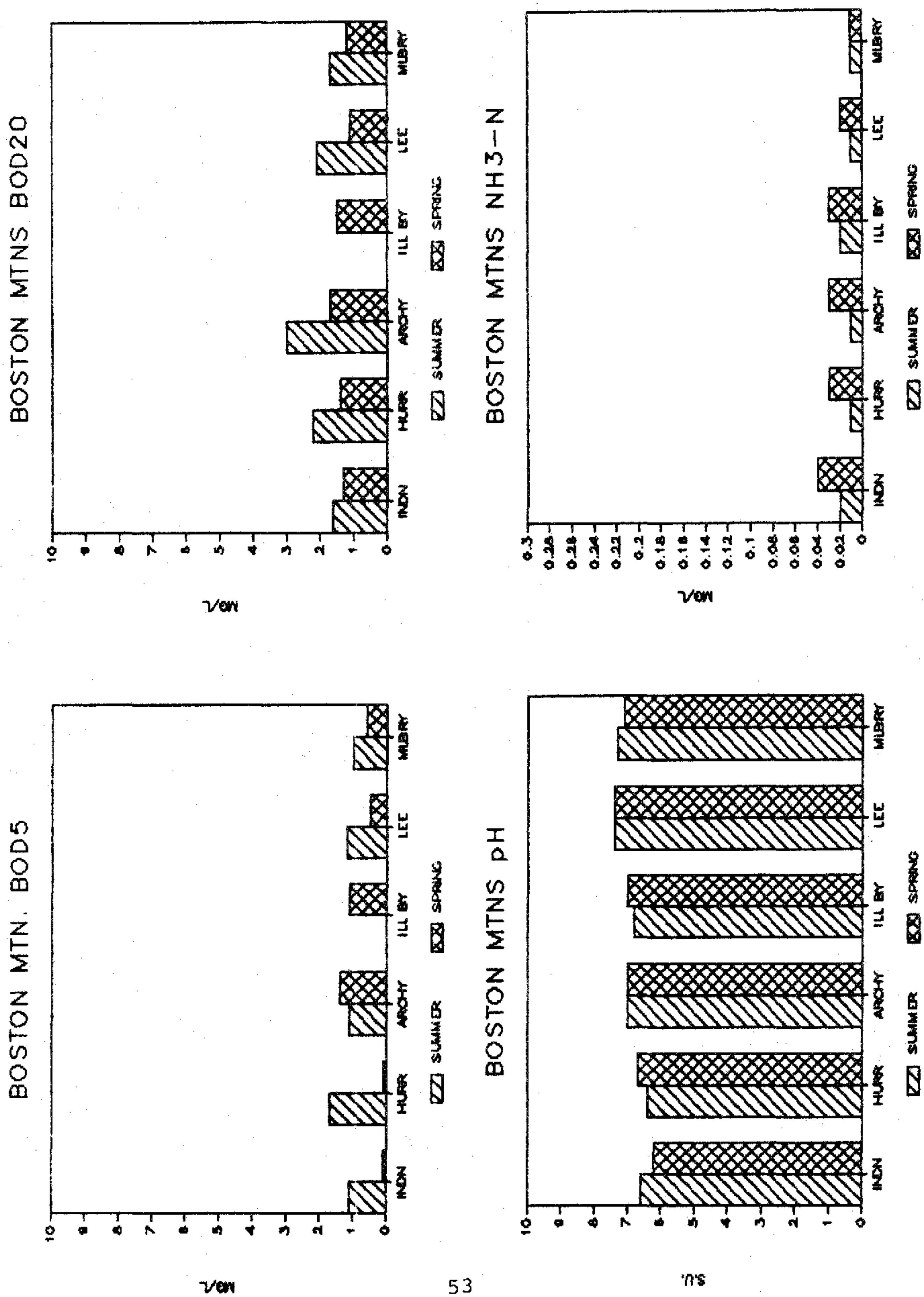


Figure C-29. Water Quality Data for
Boston Mountains Ecoregion Reference Streams



watershed size, particularly during the spring season (Figure C-30). Conversely, ammonia nitrogen values, which are also extremely low, show a slight inverse relationship with watershed size (Figure C-29). Phosphorus also appears to increase with increased flows from the larger watershed streams (Figure C-30).

The streams within the Boston Mountains Ecoregion are probably the most sensitive in the state because of their low flow regime which provides only limited flows during the dry season and a near absence of a mineral buffering capacity. Slight increases in nutrient values could cause significant changes in the chemical and biotic features of these streams. The flow regime of these streams, the physical features which allow maximum exposure to sunlight due to limited stream canopy and the sensitive biota add to the precarious balance of these ecosystems.

Comparison of Ecoregions

The mineral water quality of all ecoregions reflects the geologic characteristics of the region and man's activities within the watersheds. Since the reference streams were chosen for their limited point source discharges, such discharges are not evident in the data, but the potential effects of future discharges can be anticipated from the data collected. The natural geologic contributions reflected in mineral water quality of these reference streams is minimal except in the limestone and dolomite areas, located for the most part in the Ozark Highlands. However, man-induced, nonpoint sources are distinctly apparent in the Ozark Highlands and the Delta Ecoregions.

Alkalinity, hardness, total dissolved solids and conductivity are both spatially and temporally consistent in the Ozark Highland reference streams (Figure C-31). This demonstrates the persistent contribution from the watershed geology. In contrast, turbidity, total suspended solids (most of which is clay particles) and total iron are substantially higher in the Delta Ecoregion during the high flow periods which reflects disruptions in the watershed caused by agricultural activities and drainage projects (Figure C-32). Chloride and sulfate values are generally reflecting only watershed geology in all ecoregions; however, it has been speculated that the use of groundwater for irrigation of crops causes some increase in these minerals in surface waters which receive such discharges. The high sulfate values in the spring data from the Gulf Coastal Ecoregion was caused by high values in only two streams with adjacent watersheds. The cause is unknown (Figure C-33).

BOD values are highest in the three lowland ecoregions (Delta, Gulf Coastal and Arkansas River Valley - Figure C-34). These values are highest during the spring in the Delta which is another indication of disturbed watershed contributions. However, in the Gulf Coastal and Arkansas River Valley, BOD values are highest during the summer as a result of the

Figure C-30. Water Quality Data for
Boston Mountains Ecoregion Reference Streams

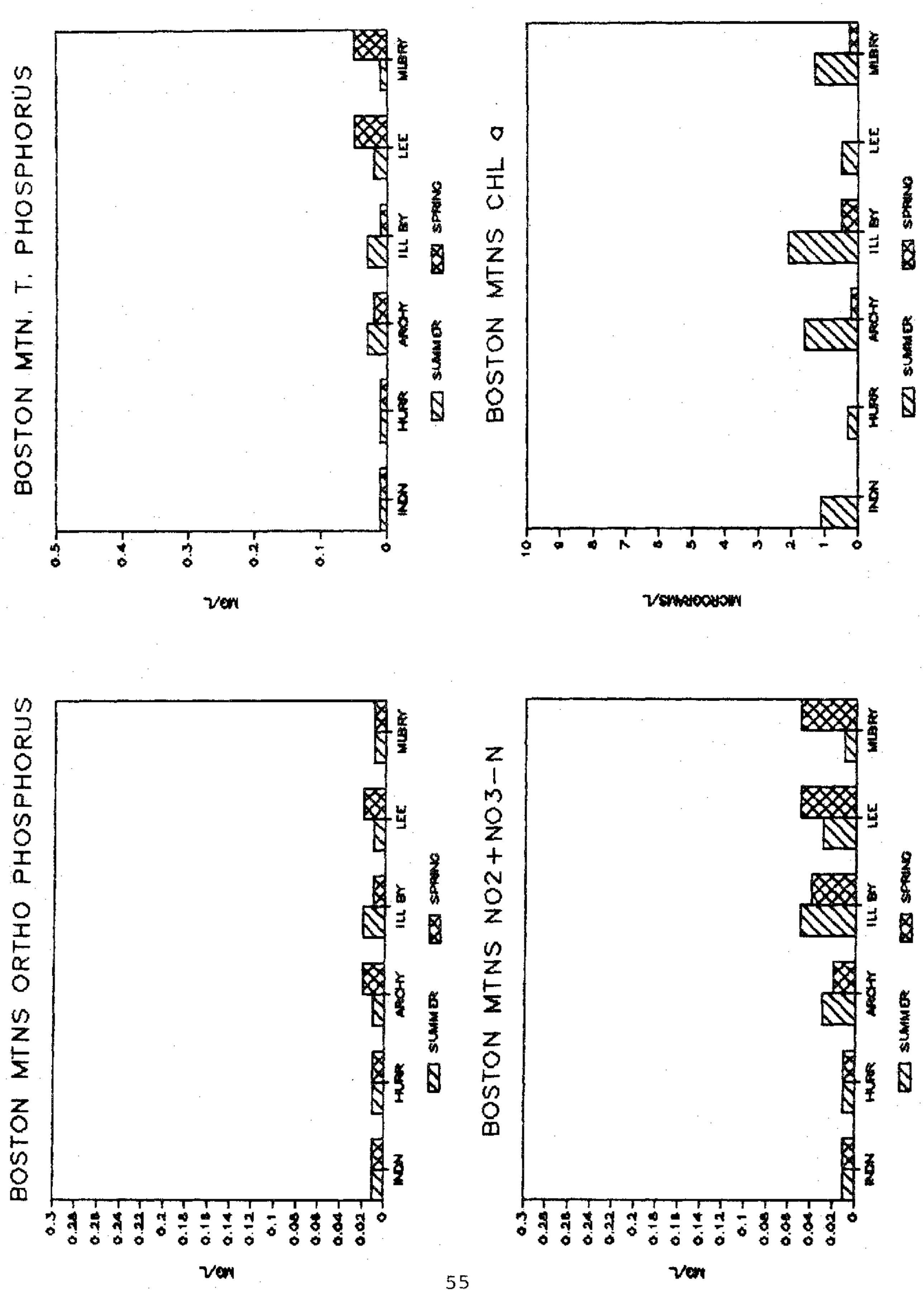


Figure C-31. Comparison of Water Quality
from all Ecoregions

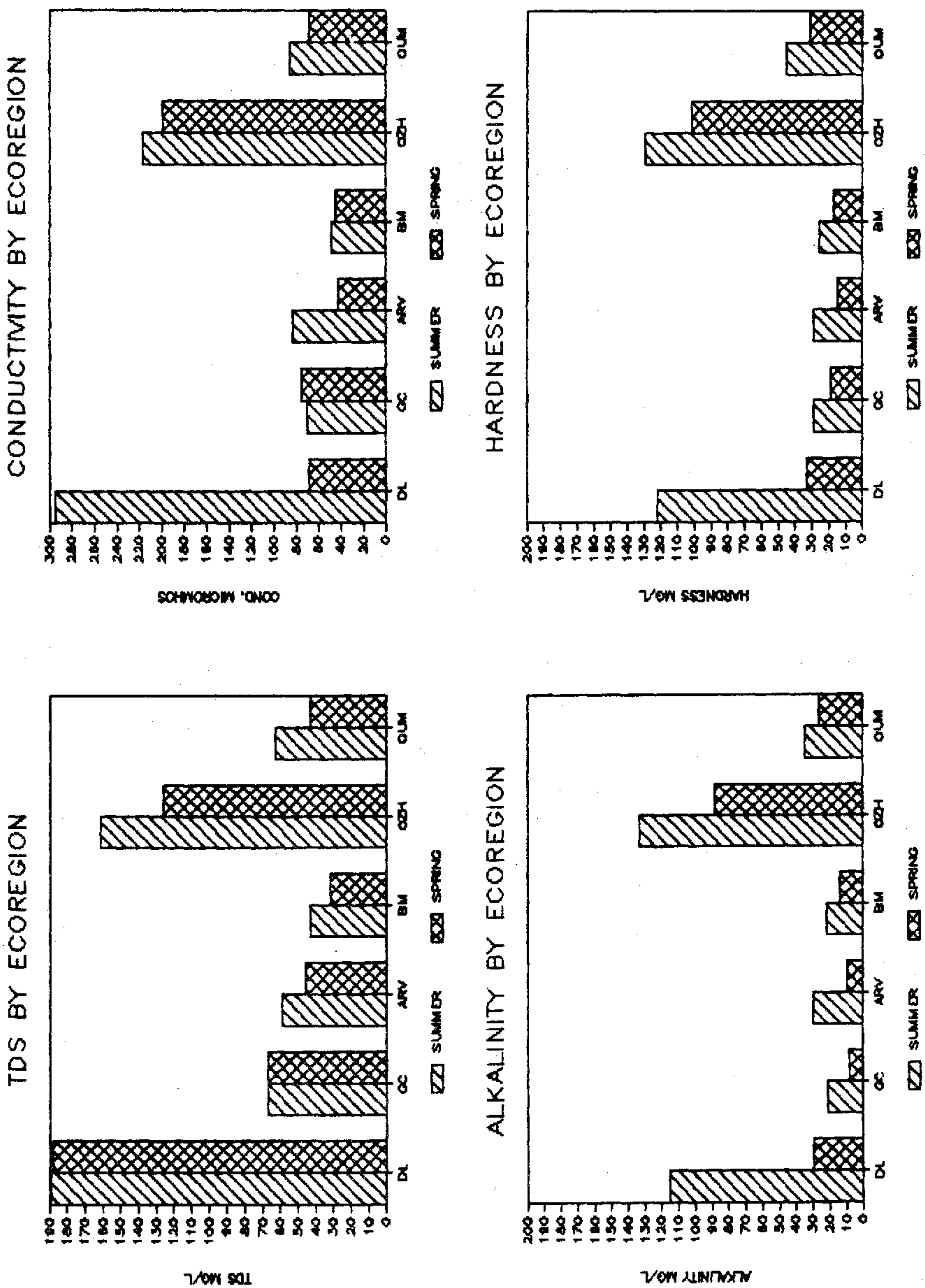


Figure C-32. Comparison of Water Quality Data from all Ecoregions

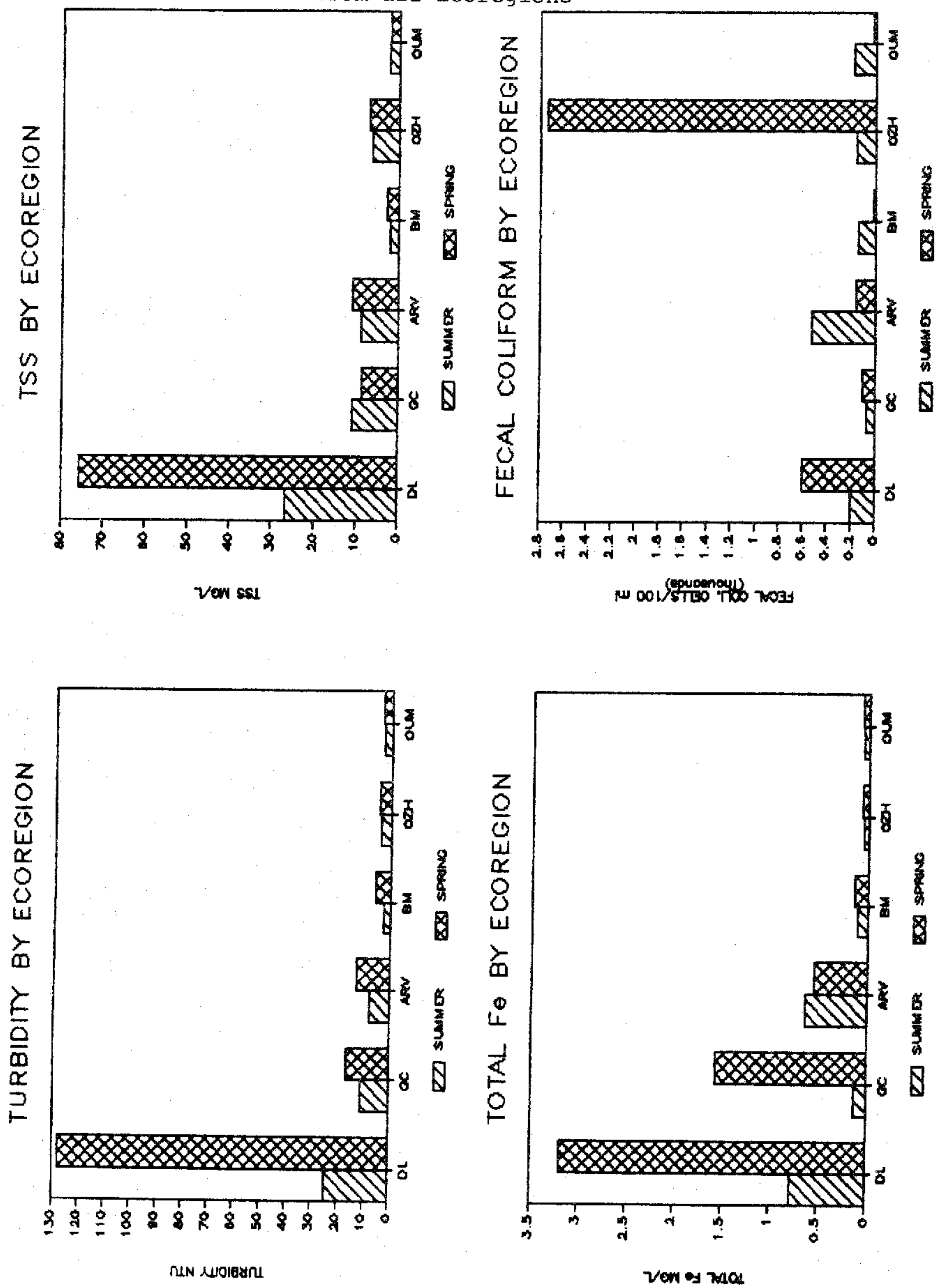
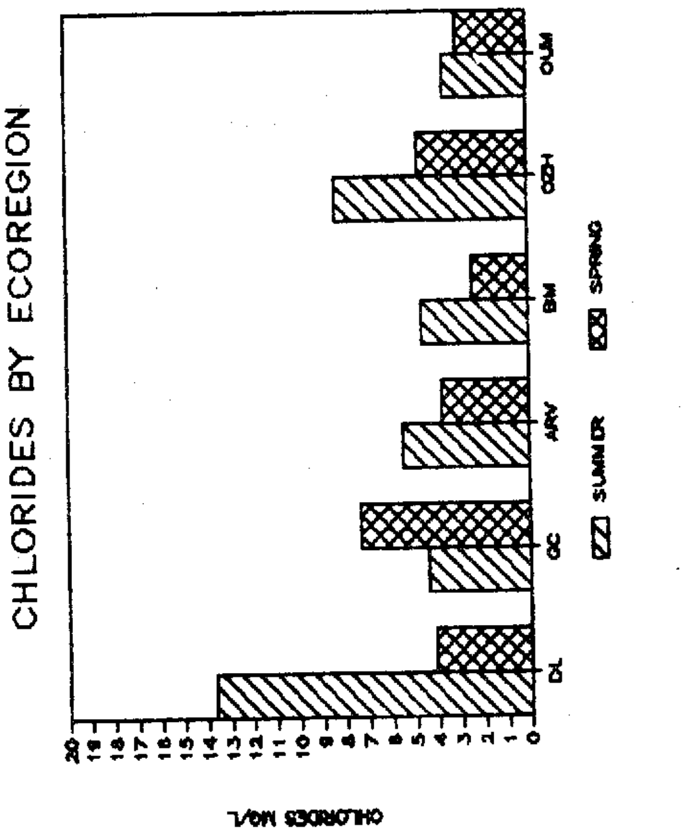


Figure C-33. Comparison of Water Quality Data from all Ecoregions



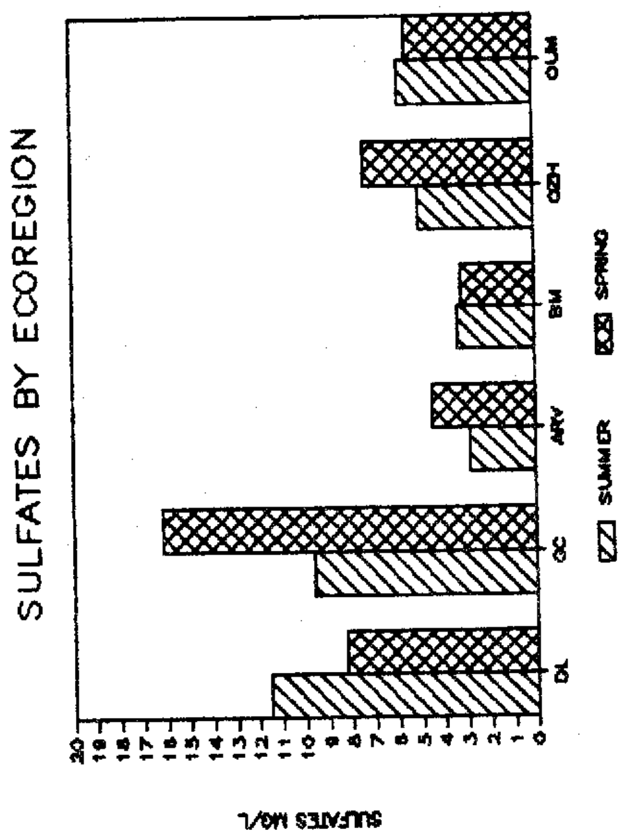
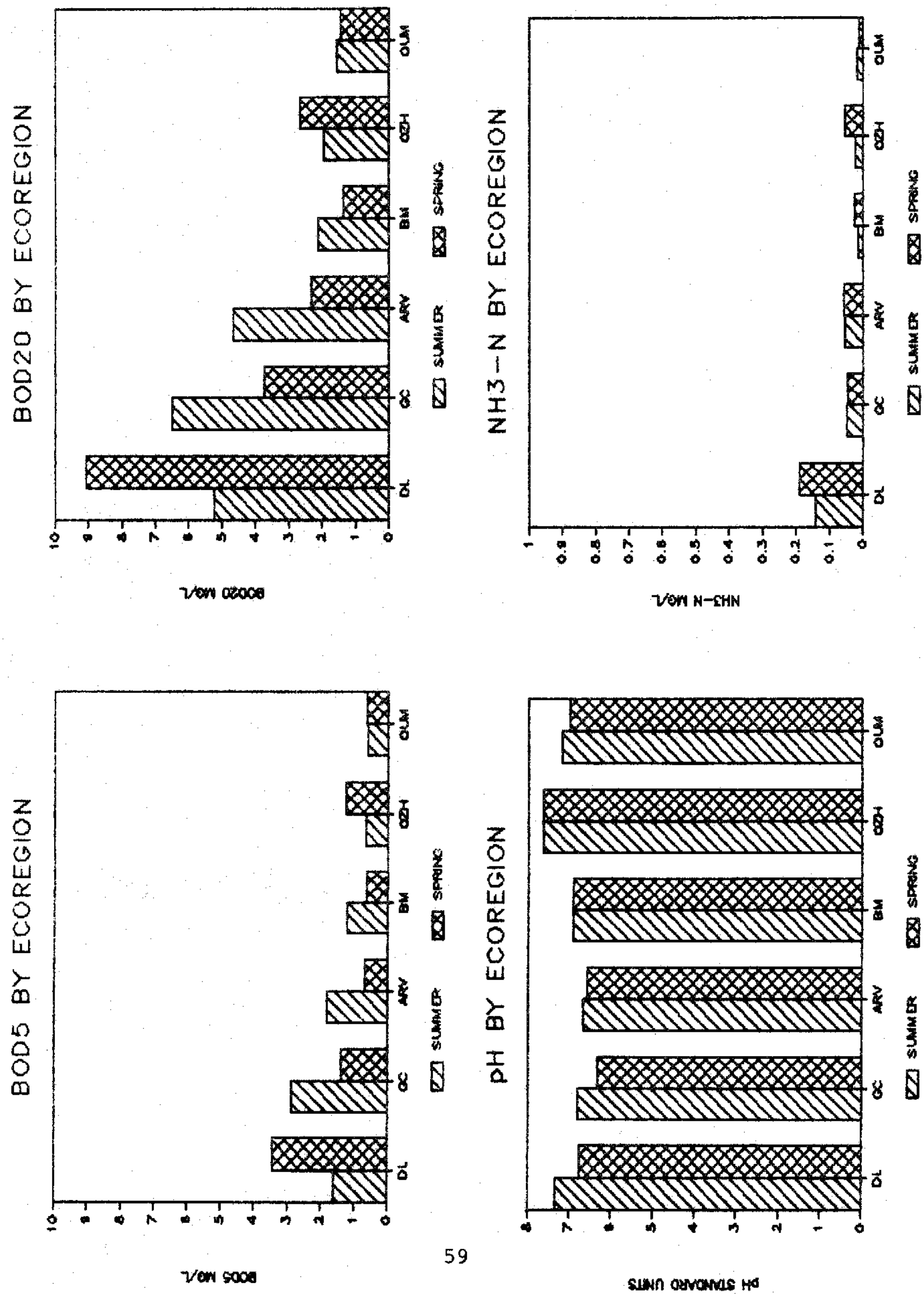


Figure C-34. Comparison of Water Quality Data from all Ecoregions



extremely low flows and/or pooled conditions. In the three remaining ecoregions, the BOD values are very low although the Boston Mountains streams also exhibit the "pooled," summertime, low flow conditions. Chlorophyll a values are similarly much higher in the lowland ecoregions than in the upland regions (Figure C-35). Fecal coliform values are exceptionally high in the Ozark Highlands during the spring (Figure C-32). This is caused by land use activities which are apparently very intensive in the watersheds of three of the six reference streams in this region. These activities include confined animal production facilities and the distribution of waste from these facilities to pastureland.

Phosphorus nutrients are noticeably higher in the Delta Ecoregion and relatively low in the other regions including the Ozark Highlands (Figure C-35). This apparently demonstrates the difference in phosphorus contributions from row-crop agriculture activities in the Delta and the confined animal production activities in the Ozark Highlands. In contrast, nitrite-nitrate nitrogen values are exceptionally high in the Ozark Highlands but are more typical in the Delta and in other ecoregions (Figure C-35).

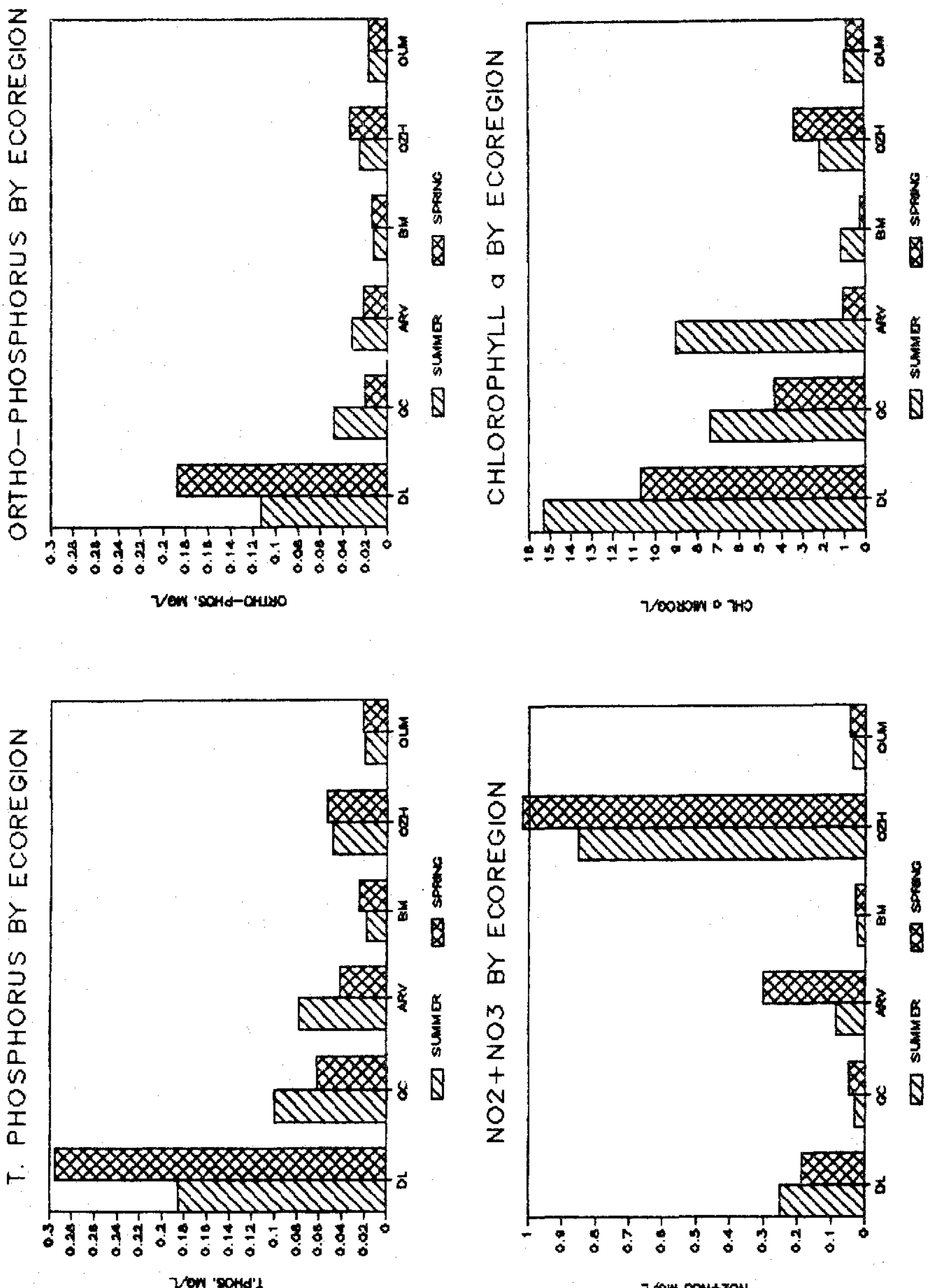
In using water quality data from this project to establish baseline data for ecoregion water quality criteria, it should be recognized that these values reflect measurable impacts of man's activities in the waters of at least two of the ecoregions. It is not likely that these impacts can be eliminated, but the progression of such activities should be abated.

Water Temperatures of Ecoregion Reference Streams

Water temperature at all sample sites was monitored with the continuous DO-temperature meters which also provided the dissolved oxygen data. Temperature calibration of these instruments was not possible in the field; however, the water temperature was checked against the portable, DO-temperature meters each time DO was calibrated. Temperature variations between the meters was within $\pm$ 1°C and the range of accuracy specified for the portable meters is $\pm$ 0.7°C.

Data from the statewide ambient monitoring program indicates that maximum water temperatures normally occur in late June or July. Since summertime sampling for this project extended to early September for some sites, the water temperature data presented may not reflect maximum temperatures. Springtime sampling occurred from late March to late May, and water temperatures varied considerably over short time periods and from the southern to the northern part of the state. Although attempts were made to sample southern waters first and move northward as temperatures rose, substantial variations in water temperatures were encountered. For this reason, the spring temperature data was useful only to relate to fish

Figure C-35. Comparison of Water Quality Data from all Ecoregions



spawning activities and to determine oxygen saturation values. Appendix B provides both spring and summer water temperature data for all reference streams.

Delta Ecoregion

The highest daily summertime values for all Delta Ecoregion reference streams occurred in Bayou DeView and were as follows: maximum 28.5°C, average 27.9°C and 26.6°C (Figure T-1). Atypically high flows existed during the summer sampling at this site and at the other large watershed site. This may have caused slightly cooler water temperatures. The small variation between the maximum and minimum values at Bayou DeView is also a result of the above normal flows. In contrast, the greatest variation in water temperatures was seen in Second Creek which had relatively low flows. The average springtime water temperature in the Delta reference streams ranged from 14.3°C to 21.5°C during the sample periods. These occurred on April 2, 1985, and April 8, 1986, in Second Creek and Bayou DeView, respectively.

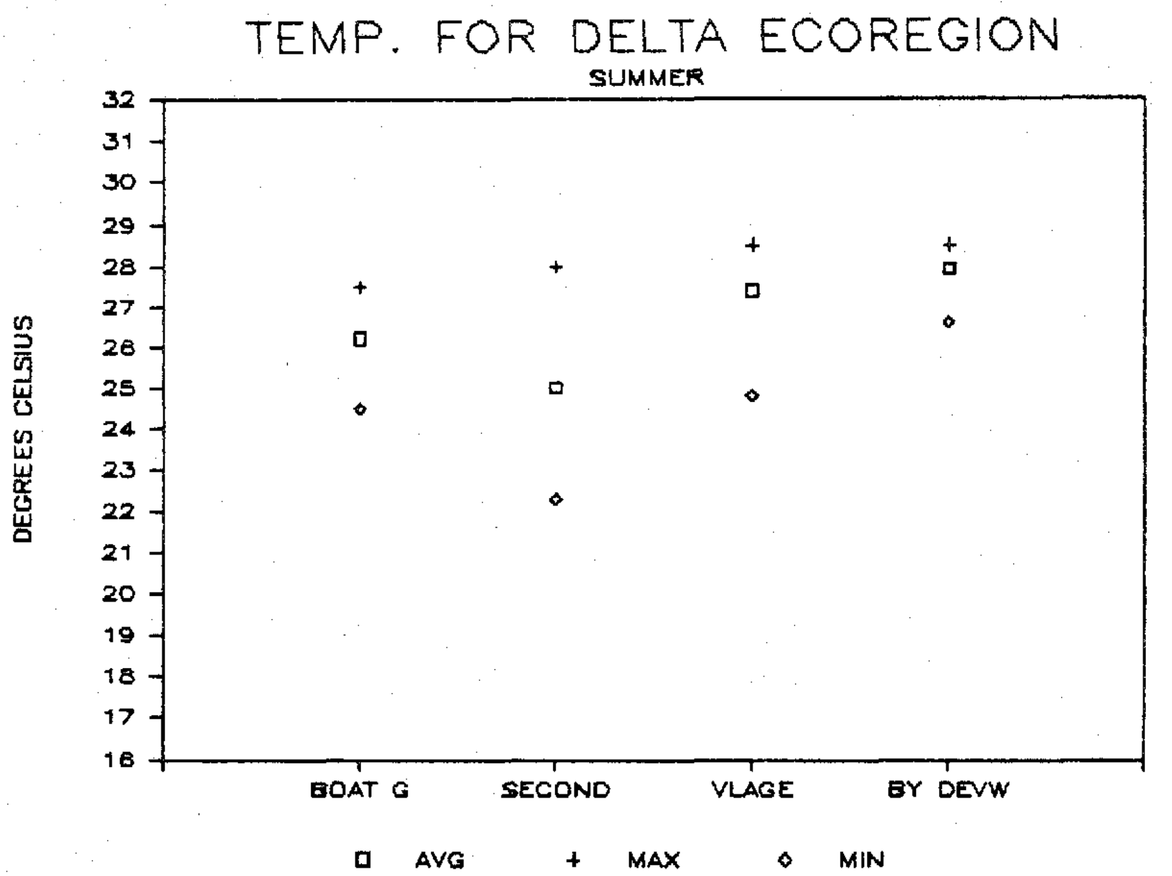
Gulf Coastal Ecoregion

The highest maximum summertime water temperature recorded in Gulf Coastal reference streams was 28.0°C. The highest minimum was 25.6°C and the average was 26.7°C; all of these values occurred in L'Aigle Creek (Figure T-1). Although the maximum values ranged from 23.6°C to 28.0°C among all streams, there seemed to be no correlation to stream size or to springwater influences. The apparent controlling factor was stream canopy which is characteristically high in the Gulf Coastal Ecoregion. A further indication of canopy impact on stream water temperatures is the very small variation in daily maximum and minimum temperatures in this region. Springtime water temperatures encountered in this ecoregion averaged from 13.0°C to 17.1°C and occurred on April 5, 1984, and April 1, 1986, in East Fork Tulip Creek and Freeo Creek, respectively. These differences reflect the annual variations within the spring season.

Arkansas River Valley Ecoregion

The highest maximum daily water temperature recorded in this region was 30.5°C; the highest minimum and average values were 26°C and 28.1°C, respectively (Figure T-2). All of these high values occurred in Cadron Creek which is a large continuous pool at the sample site with very low, sluggish flow and limited stream canopy. Daily maximum temperatures ranged from 26.5°C to 30.5°C among all reference streams in this region and Cadron Creek values are noticeably higher than the other reference streams. Average springtime values ranged from 15.6°C in the Petit Jean River on April 15, 1986, to 16.3°C in Mill Creek on May 1, 1984.

Figure T-1. Temperature Data for
Delta & Gulf Coastal Ecoregion Reference Streams



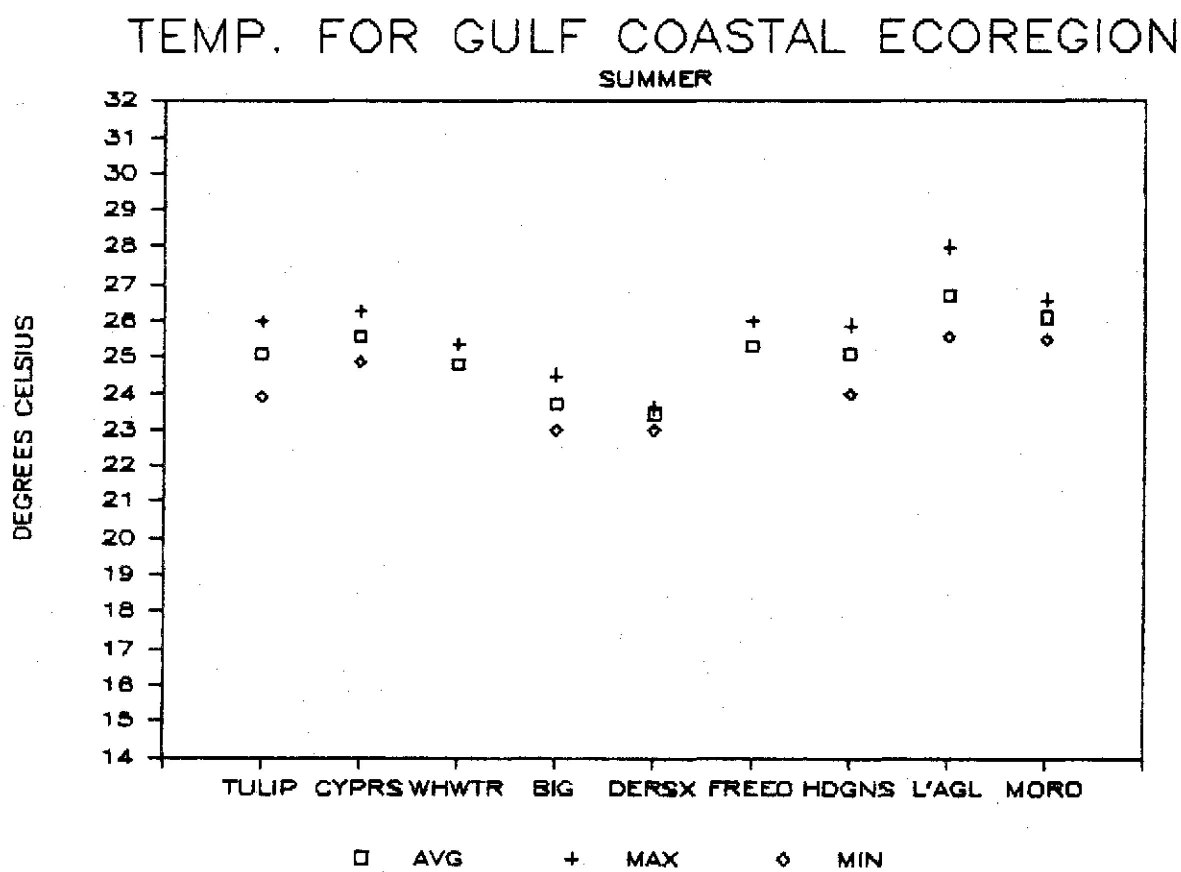
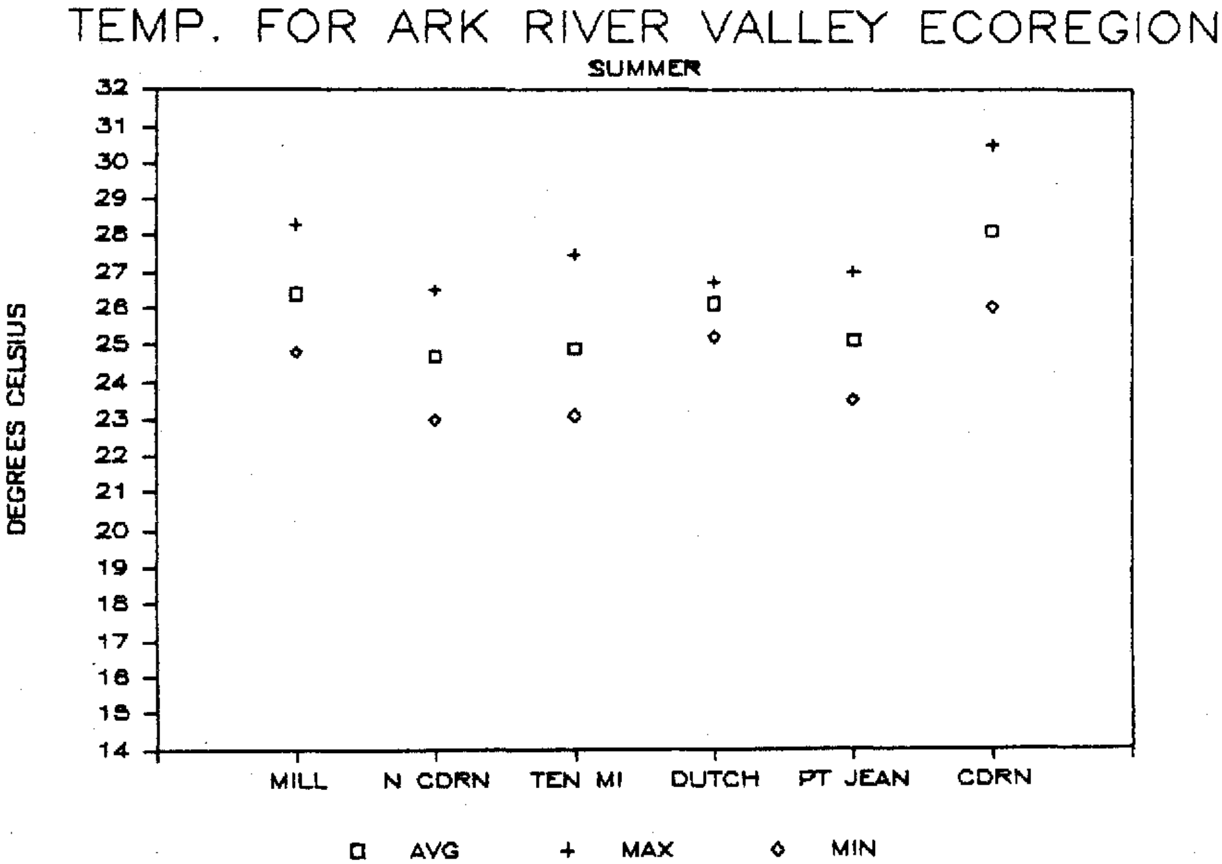
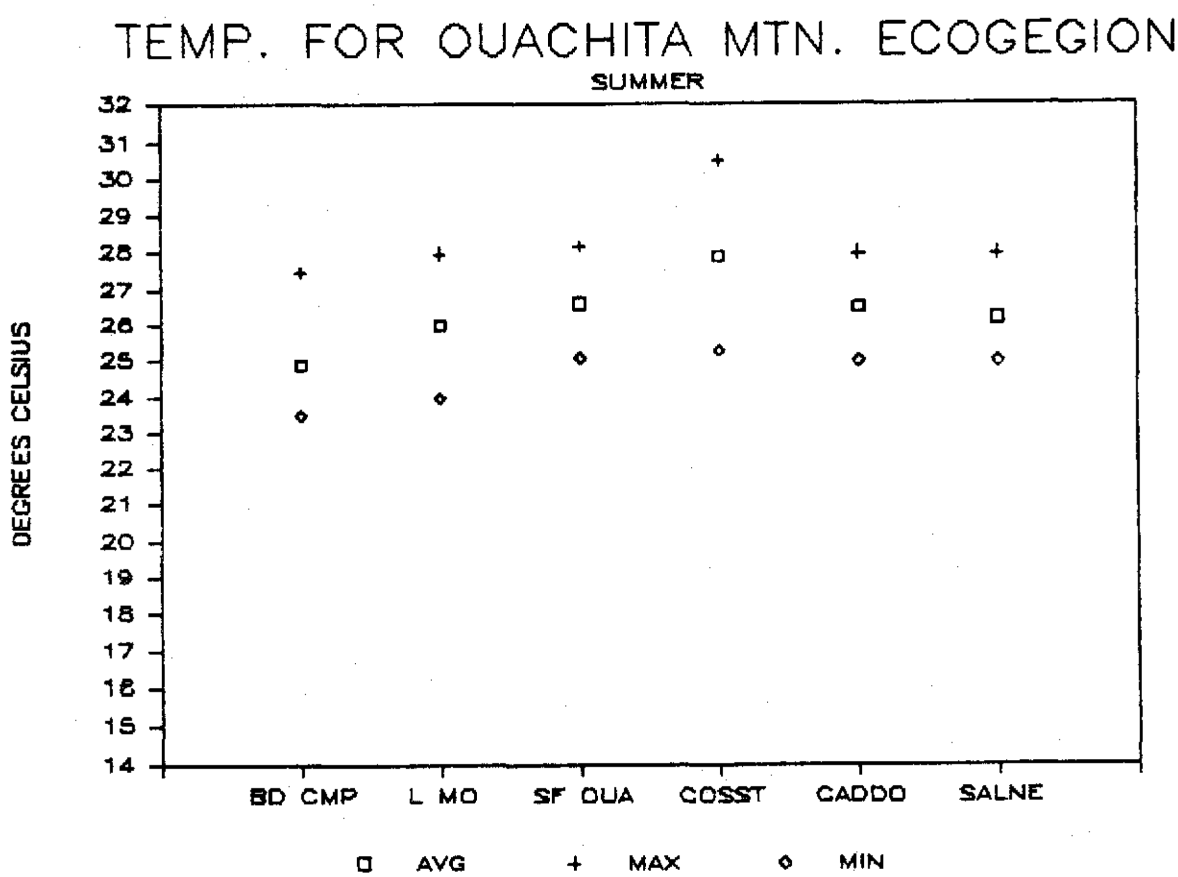


Figure T-2. Temperature Data for Arkansas River Valley & Ouachita Mountains Ecoregion Reference Streams





Ouachita Mountains Ecoregion

Summertime water temperatures were very similar in all reference streams within this ecoregion except at the Cossatot River site (Figure T-2). The highest maximum, minimum and average values were recorded in the Cossatot River and were 30.5°C, 25.3°C and 27.9°C, respectively. This site was devoid of canopy in the sample segment, and this was probably the cause for the elevated temperatures. Slightly cooler values were found in the two smallest watershed sites although all summer sampling in the region was done in mid-August. Average springtime water temperatures sampled in this region ranged from 12.7°C to 19.9°C. These values occurred on April 8, 1985, in Board Camp Creek and on April 30, 1986, in the Caddo River, respectively.

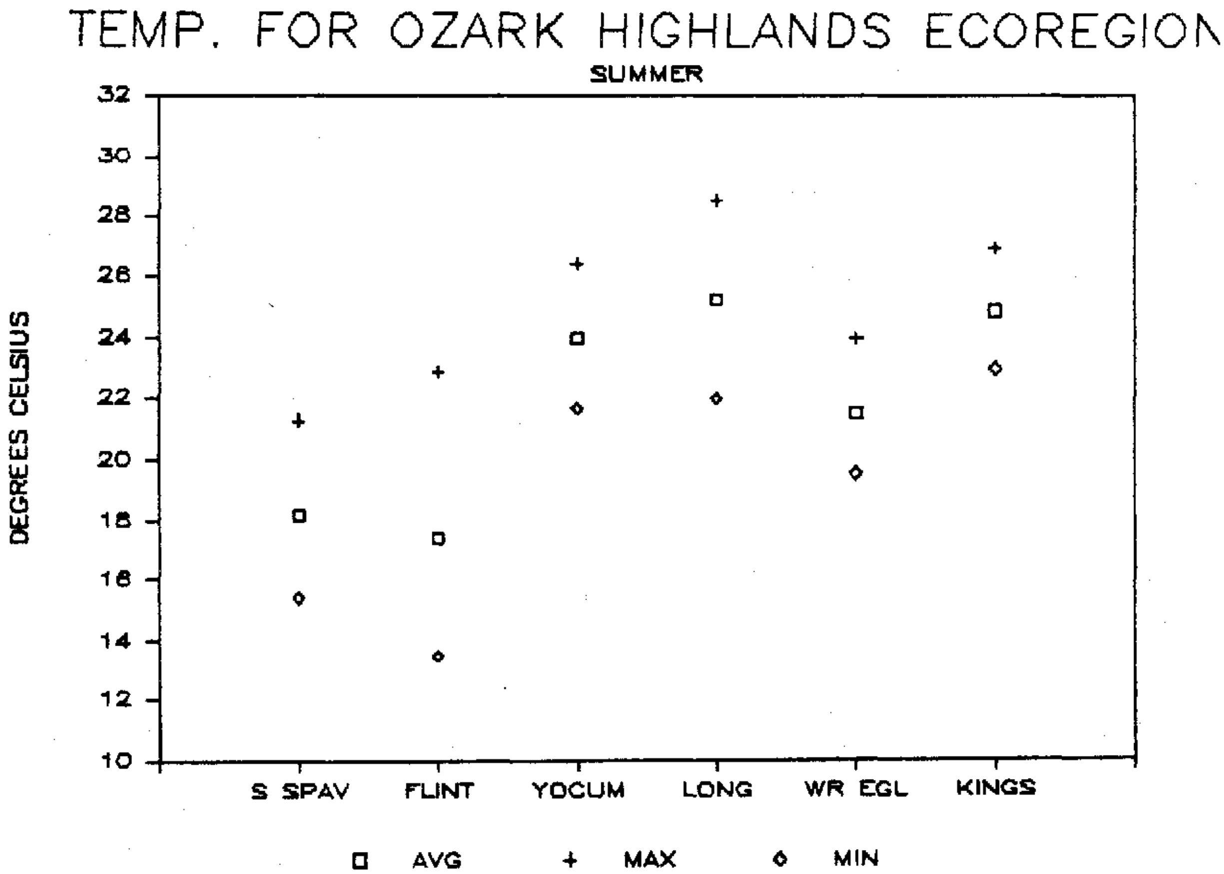
Ozark Highlands Ecoregion

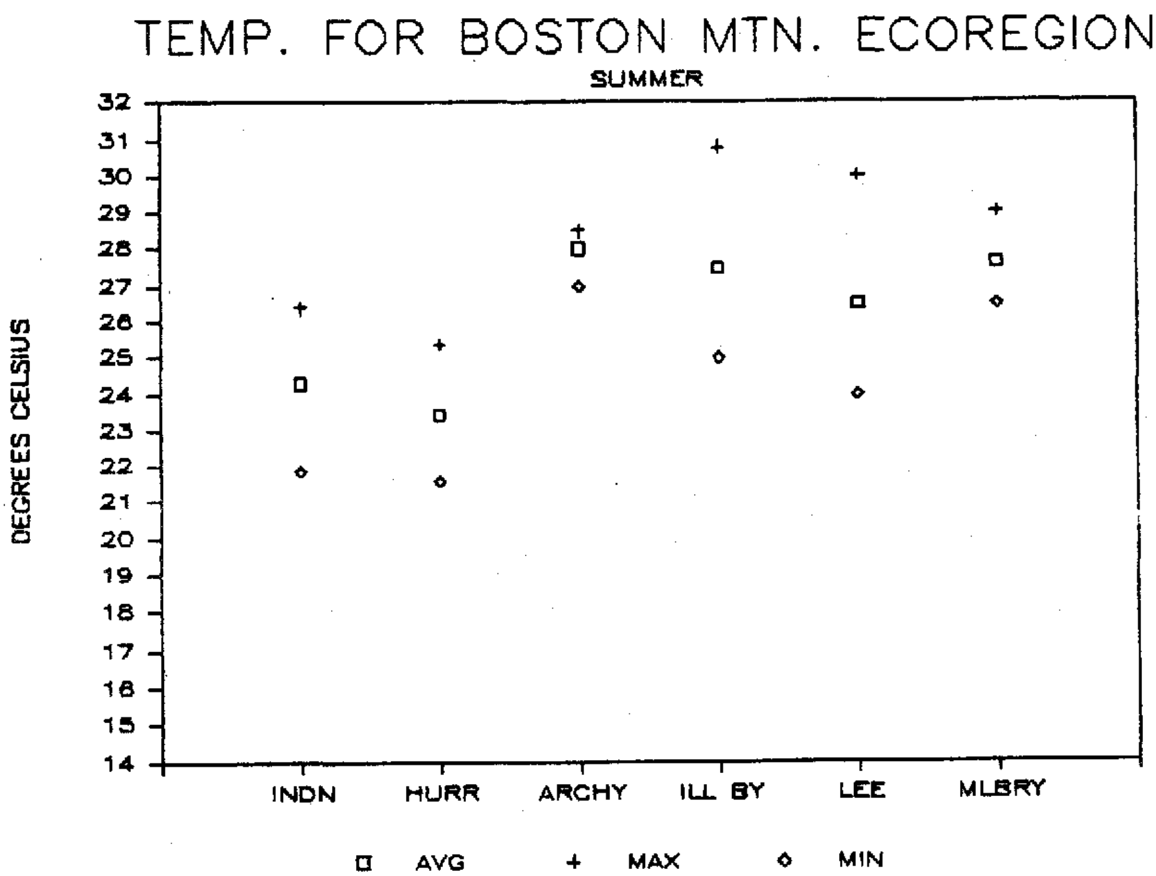
The highest summertime maximum water temperature was 28.5°C for Ozark Highlands reference streams and the highest average and minimum summer temperature values were 25.3°C and 23.0°C (Figure T-3). Notably lower values were found in the South Fork of Spavinaw and Flint Creek. These are small watershed streams with significant groundwater base flows; however, these streams were also sampled in late September for the summer data. The late sampling period may have been the major cause of their low water temperatures. The highest minimum and average values among all of the Ozark Highland reference streams (neither of which occurred in South Fork Spavinaw or Flint Creeks) are lower than the highest minimum and average values of all other ecoregions. Therefore, it can be concluded that Ozark Highlands stream temperatures are the coolest of all regions. Average springtime water temperatures for the region ranged from 16.0°C to 21.4°C. These occurred in the South Fork of Spavinaw Creek on May 15, 1984, and in War Eagle Creek on May 13, 1986.

Boston Mountains Ecoregion

Surprisingly high water temperatures exist in the Boston Mountains reference streams (Figure T-3). Also, considerable variation exists among the sites and between the daily minimum and maximum values. This is most likely related to stream canopy. Since canopy is characteristically low in this ecoregion, these variations may be caused by extremely localized canopy variations. The highest maximum daily water temperature during the summer period was 30.8°C in Illinois Bayou; the highest average and minimum values were 28.1°C and 26.0°C in Archey Creek. This site also had a very small daily temperature variation. The reason for this is unknown and may be related only to meter placement. Variation in the average springtime water temperatures between the sample site was 17.7°C to 19.5°C. These values occurred on May 6, 1986, in Mulberry River and May 22, 1984, in Hurricane Creek, respectively.

Figure T-3. Temperature Data for Ozark Highlands & Boston Mountains Ecoregions Reference Streams





Comparison of Ecoregions

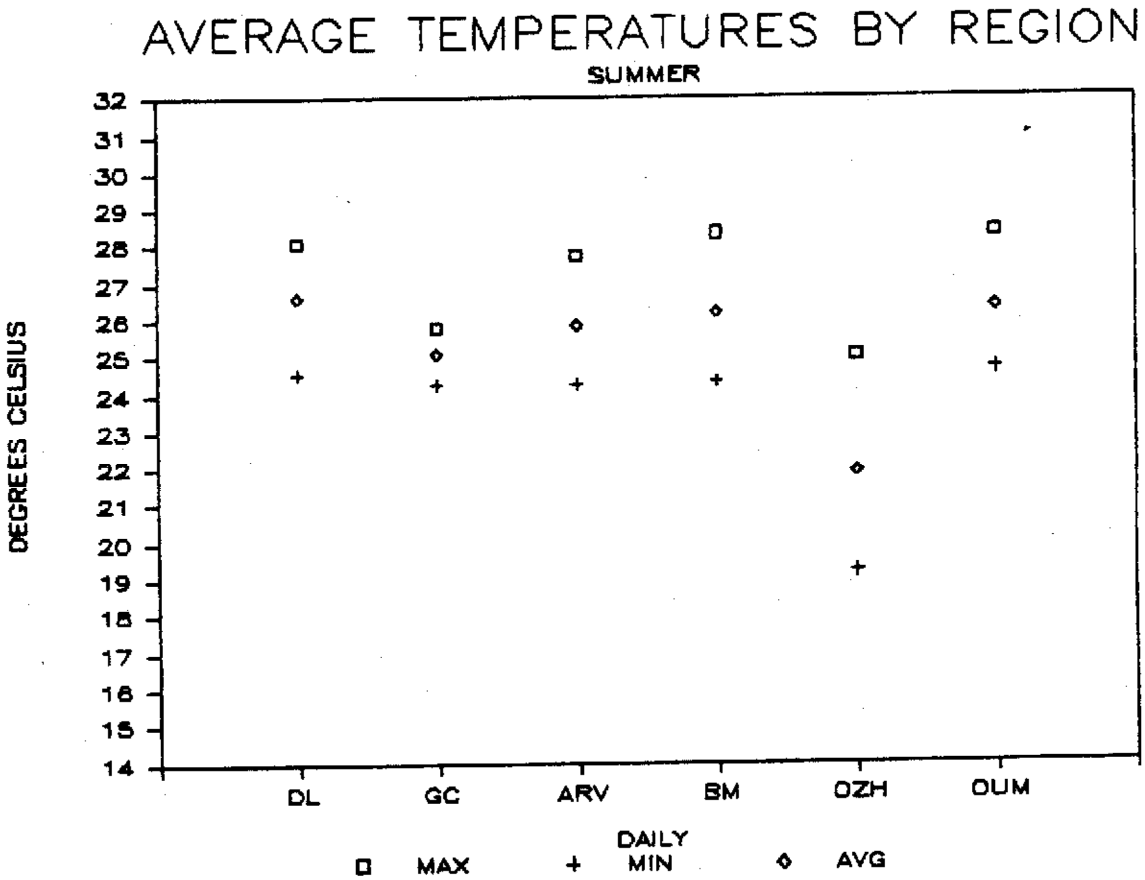
Summertime temperatures from all reference streams within each region indicate that the Ozark Highlands has the coolest values (Figure T-4). This results from moderate stream canopy and substantial groundwater and intergravel flows. The Gulf Coastal region also has notably cool summer water temperatures with very little diurnal fluctuation. This is caused by the extensive stream canopy which shades most of the stream the entire day. Springwater flows have very little, if any, additional cooling effect on Gulf Coastal streams. Both Ouachita Mountains and Boston Mountains streams have higher than anticipated summer temperature values. This is strongly influenced by the sparse stream canopy, particularly in the high gradient streams where high flow scouring has reduced riparian and in-channel vegetation canopy. Boston Mountains streams also have much lower summer flows and/or exhibit restricted, pooled conditions which further recedes from the stream canopy and allows increased warming of the water. Arkansas River Valley streams show substantial variation in summertime water temperatures as stream canopy varies primarily with the size of the stream. This region has characteristically low summer flows which also impact its water temperatures. Delta summer temperatures appear atypically low for low gradient, slow flowing streams. The cause was probably the higher than normal summer flow in the two largest reference streams. The smallest stream had nearly 100% stream canopy which provided cooler water temperatures at this site.

The water temperature data base from this project is perhaps some of the best available in the state; however, because of the dynamic nature of stream water temperatures and the numerous influences such as diel variations, seasonal variations and variations caused by physical features instream and adjacent to the stream, considerable judgment is necessary in interpretation of the data.

Dissolved Oxygen Results

Of the various objectives of this project, perhaps the foremost purpose was the recording of continuous dissolved oxygen concentrations and temperatures from selected sites throughout the state. This was made possible by the use of six YSI Model 56 Dissolved Oxygen Meters. These meters were capable of continuously recording dissolved oxygen concentrations and temperature during the survey period. Extensive efforts in daily calibrations and verification procedures were performed throughout the entire project to assure the quality of the data generated. At each sampling site, meters were located so that pool and riffle conditions were monitored. A review of all the data shows that slight insignificant differences exist between pools and riffles (Figure D-1). Also, the three regions with relatively low

Figure T-4. Comparison of Water Temperature Among All Ecoregions



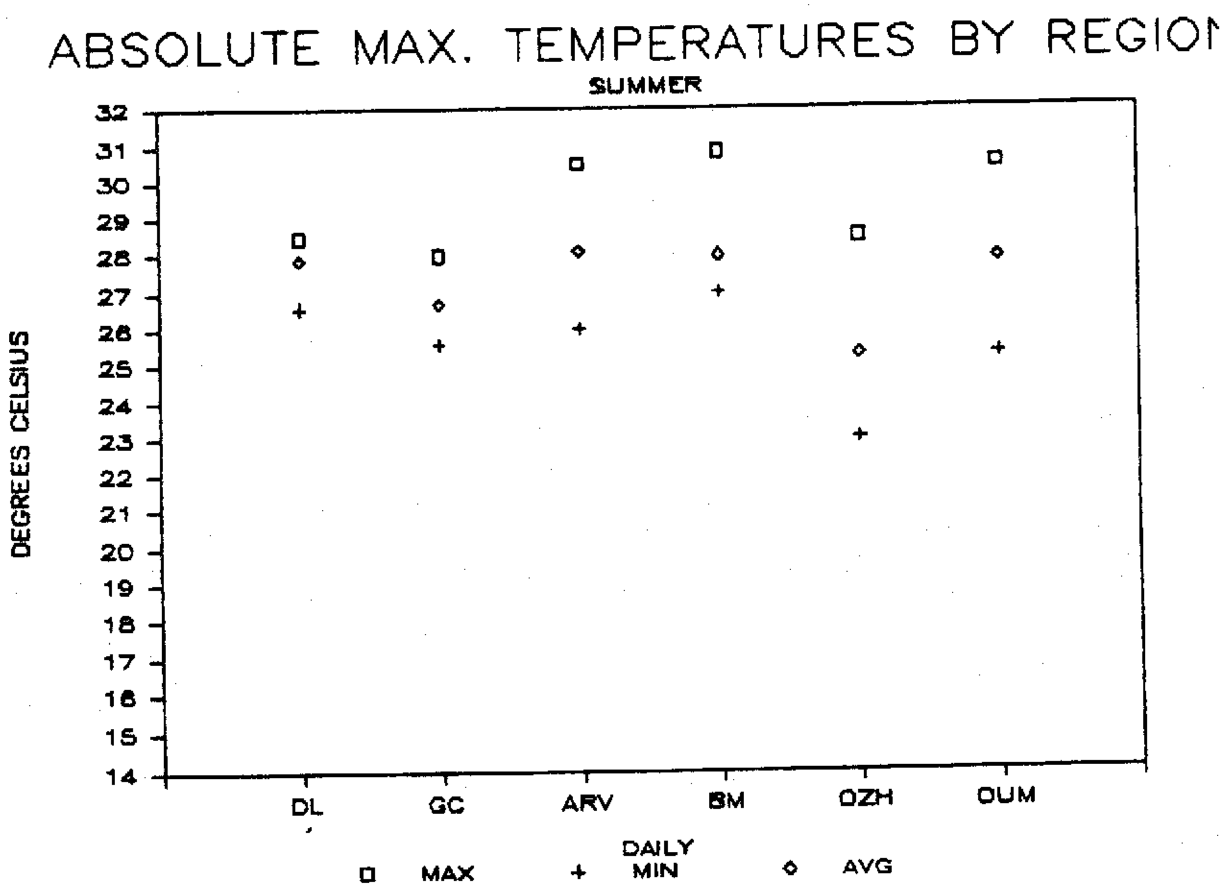
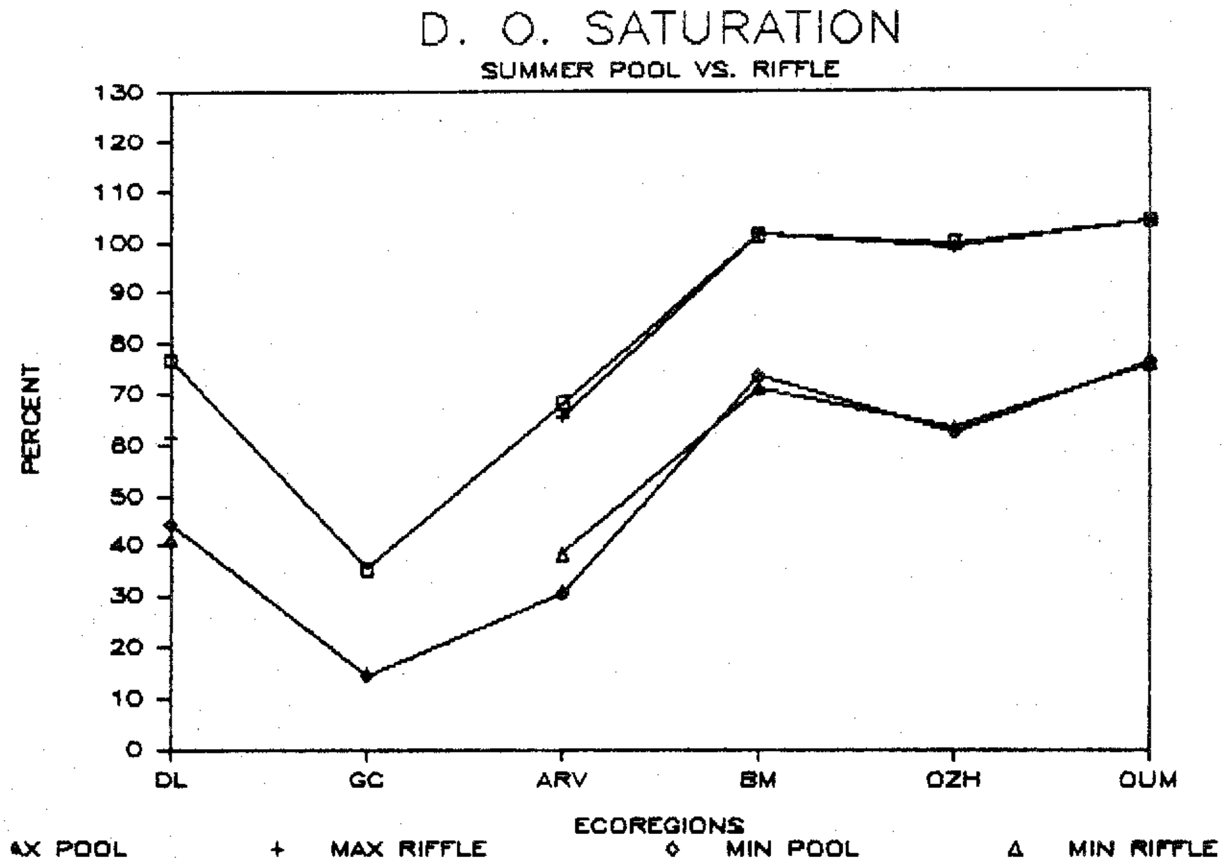
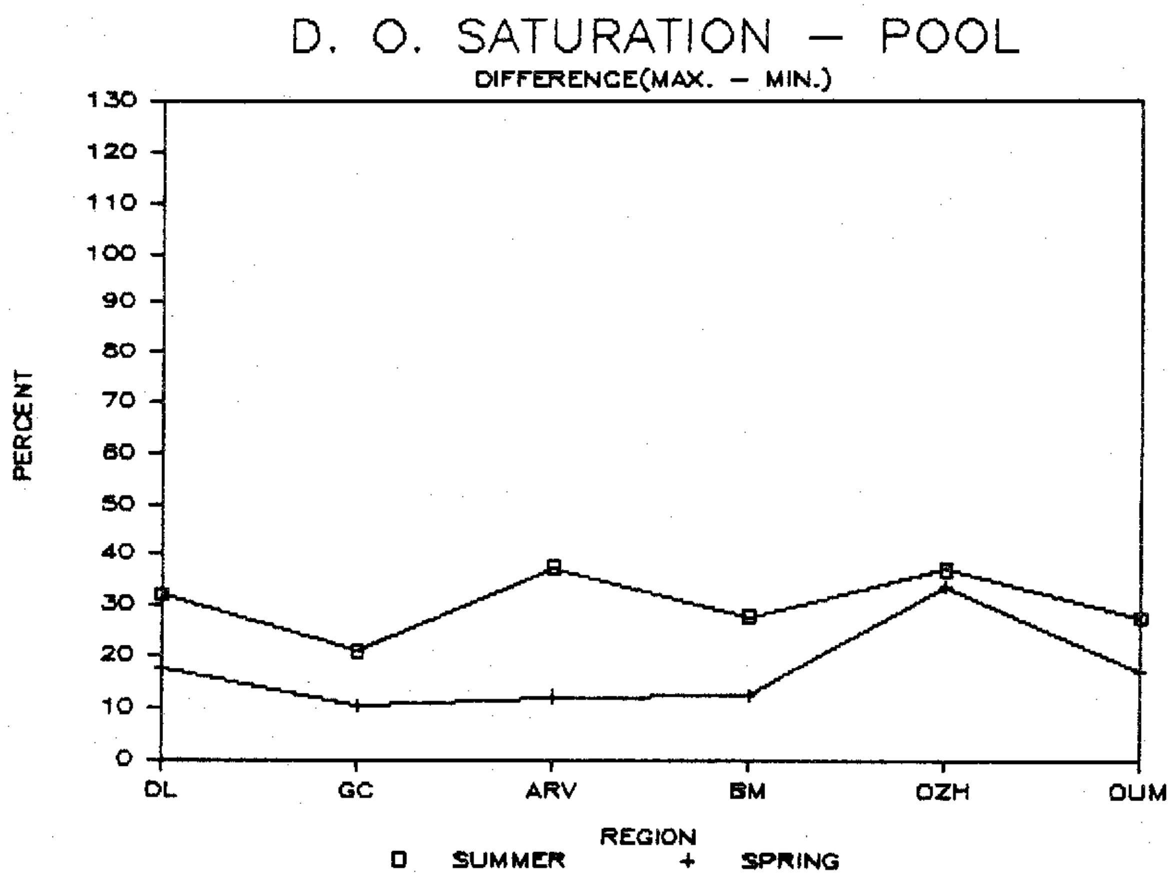


Figure D-1. Comparison of D.O. Saturation between Pools and Riffles for all Ecoregions





stream gradients, the Delta, Gulf Coastal and Arkansas River Valley, were void of riffles during the dry summer period. For these reasons, comparisons are confined to pool conditions from all sites. Where duplicate or triplicate meters were set up at a site, the data set was selected from the meter which performed consistently, had fewest calibrations and/or provided the most protective (highest) dissolved oxygen values.

Delta Region

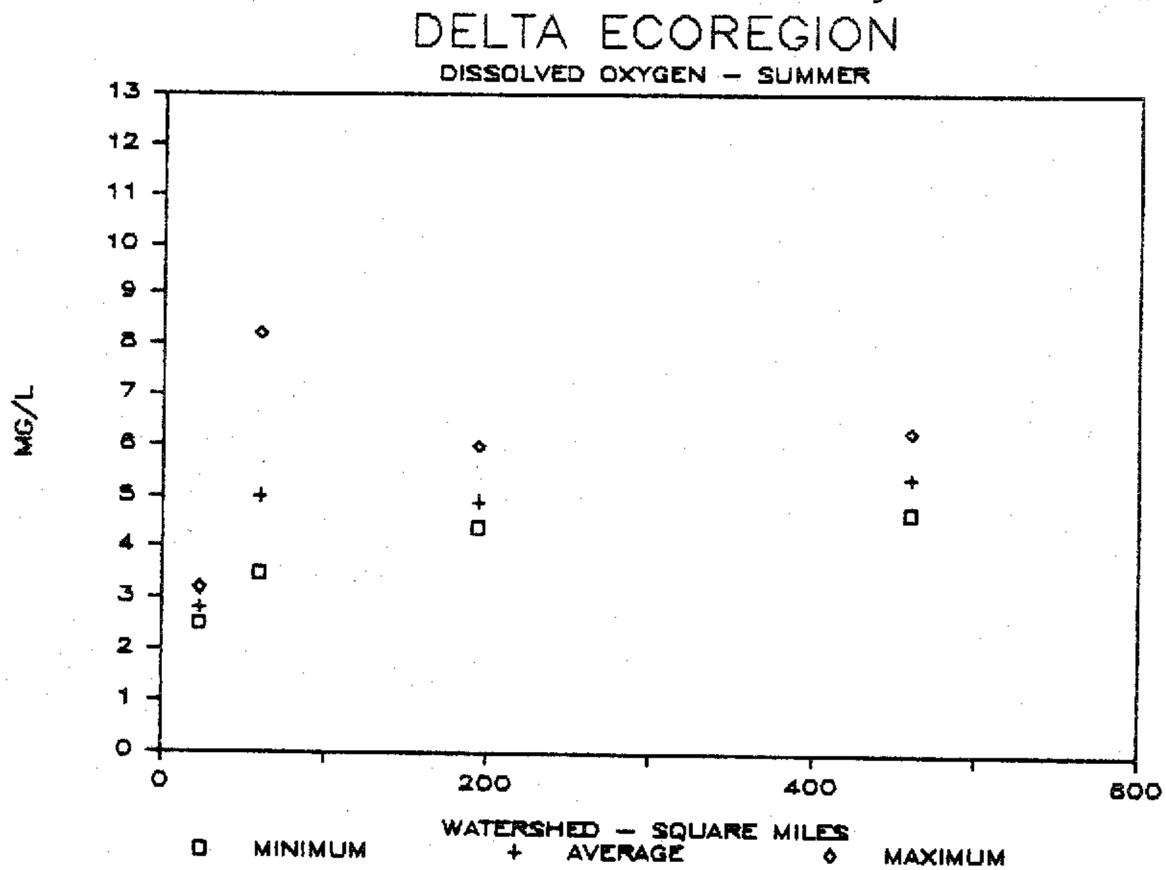
The Delta Region has the least amount of supporting data of all regions studied. Only four sites were sampled and atypical flow conditions may have been experienced at two of these sites. "Least-disturbed" is a relative term, and within this region all sites studied were unquestionably affected by nonpoint source agricultural runoff. Some were affected more noticeably than others.

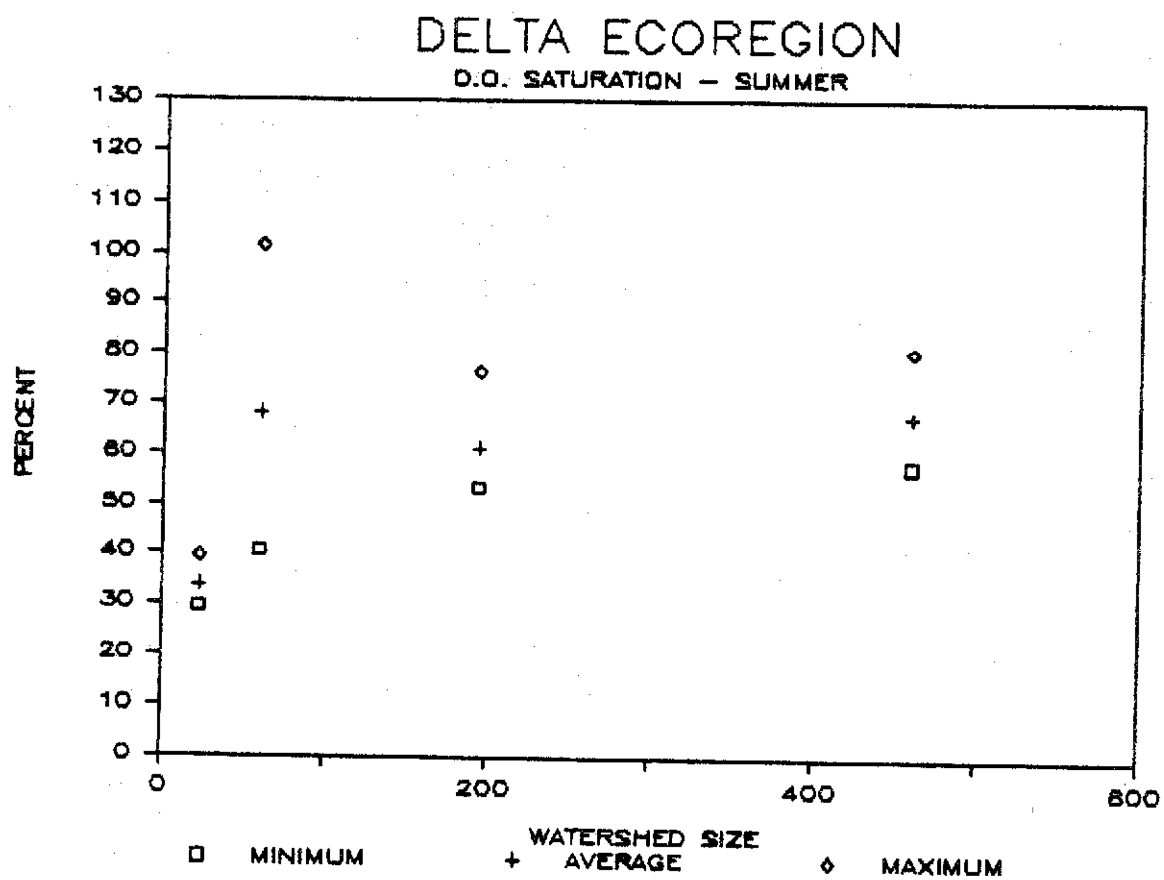
Dissolved oxygen data during the summer season indicates a slight positive correlation to size of watershed. This is apparent for the minimum and average D.O. concentrations, but the daily maximum concentrations do not show the same pattern (Figure D-2). The summer, minimum D.O. concentrations were below the current water quality standard at all sites except Bayou DeView where the minimum was 0.2 mg/l above the standard. These D.O. values are a result of naturally occurring conditions within the Delta Ecoregion. Important factors related to these low concentrations are the mud/silt substrate type, the low stream gradients and the relatively high nutrient values. The smallest watershed stream had the lowest D.O. concentration and the least D.O. fluctuation. More similarity existed among the remaining three sites. They had D.O. concentrations ranging from approximately 3.5 mg/l to 8.2 mg/l, with an average of very near 5 mg/l. However, the two largest watershed sites had smaller, diurnal D.O. fluctuations caused by the much higher flows.

The dissolved oxygen percent saturation values for the summer period are also displayed in Figure D-2. The smallest watershed studied revealed the lowest overall saturation values, ranging from 30% to 40% saturation. The next to smallest watershed site, Second Creek, had a range of saturation values from 40% to over 100% and produced large diurnal fluctuations. This site was predominantly pools with very little flow and the stream canopy was only 55%. The two largest watershed sites had stream canopies of 85% and 60%, but also had substantial flows. This caused much less fluctuation in the D.O. saturation which ranged from about 50% to 80%.

There is also some question as to the representiveness of the spring flow data in one of the two largest watersheds studied within the Delta region. The flow in Village Creek appeared low and was believed to be atypical of normal spring

Figure D-2. Dissolved Oxygen and Saturation Values for Delta Ecoregion Reference Streams during Summer Period





conditions. Dissolved oxygen in both Village Creek and Bayou DeView was lower than expected (Figure D-3). Only one of the four sites maintained the D.O. standard of 5 mg/l during the spring season and stream flows appeared to be a major factor in controlling spring D.O. values.

The D.O. percent saturation values for the spring period are also displayed in Figure D-3. The site with the smallest watershed studied shows a significant increase in saturation values due to higher flows. However, the two largest sites reveal lower saturation values with a very narrow range of fluctuation. One of these sites had atypically low flows while the other had more typical spring flows.

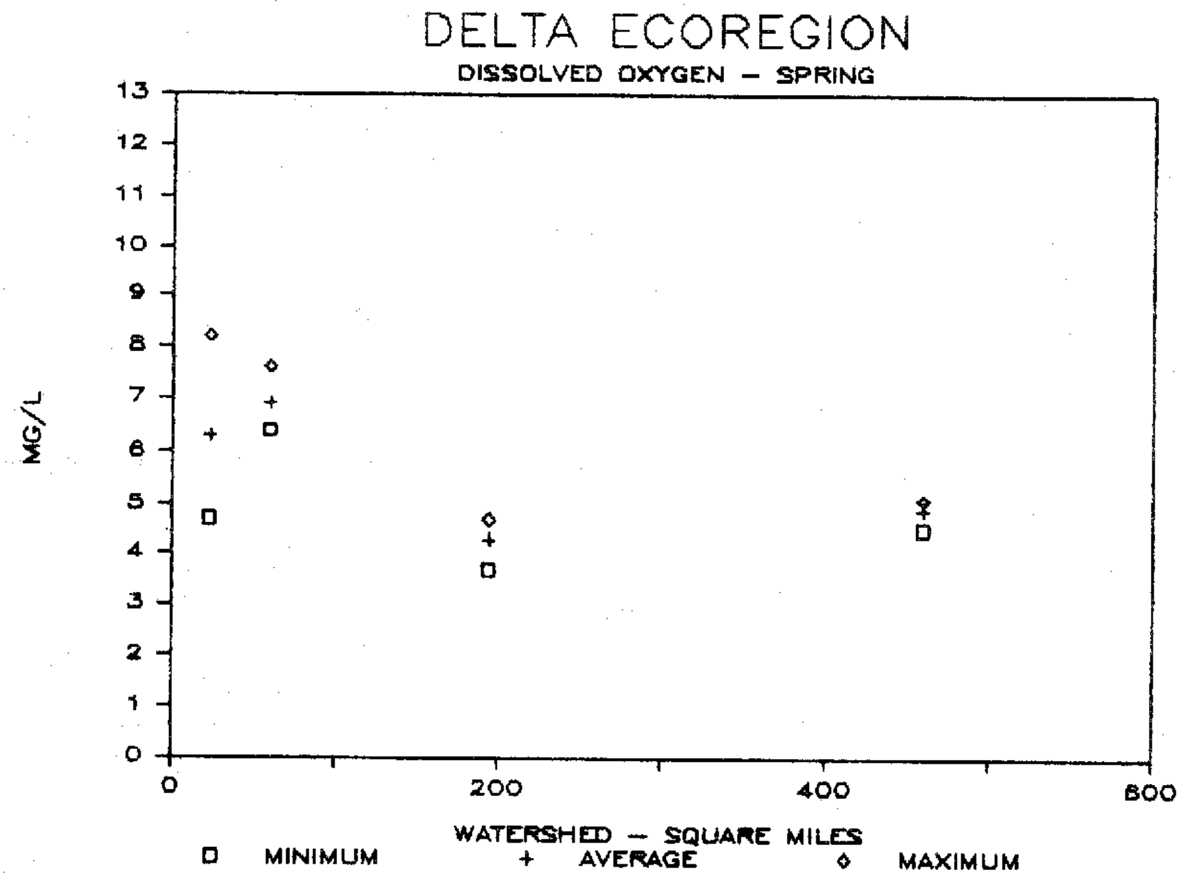
The average D.O. percent saturation of all reference streams was approximately 60% for both the summer and spring season. The low saturation values observed during the spring are not consistent with the findings in other ecoregions. At this time it is not known if this finding was due to atypically low spring flows in some of the reference streams or is a natural condition for this ecoregion. It should be recognized that most of the streams within this ecoregion are affected by land use practices and are also intermittently channelized. These conditions affect the attainable fishery community and water quality-related parameters including dissolved oxygen. With few exceptions, the fishery community found throughout the Delta Ecoregion is altered due to the physical modifications associated with land use and channelization.

Gulf Coastal Ecoregion

Dissolved oxygen concentrations for reference streams studied within the Gulf Coastal Ecoregion during the critical summer period are displayed in Figure D-4. The data distinctly shows that Tulip and Cypress Creeks are notably different from the remaining streams. It has been verified that these two streams represent a unique group of springwater-charged streams within this ecoregion. The other reference streams studied represent the typical streams of this region which enter an enduring pool stage during the dry seasons of each year.

The Gulf Coastal Ecoregion is another region where naturally occurring dissolved oxygen concentrations are low in typical streams. The predominant factors causing the low dissolved oxygen concentrations are cessation of surface flow, low stream gradient, low reaeration rates, extensive stream canopy, low nutrients and relatively high instream biochemical oxygen demand. The instream biochemical oxygen demand is most likely caused by bacterial decomposition of allochthonous deposits from high spring flows. The smallest reference stream in this region shows the greatest fluctuation of dissolved oxygen concentrations. Typical streams of this region are characterized by extremely low dissolved oxygen during the hot, no flow season; there is essentially no

Figure D-3. Dissolved Oxygen and Saturation Values for Delta Ecoregion Reference Streams During Spring Period



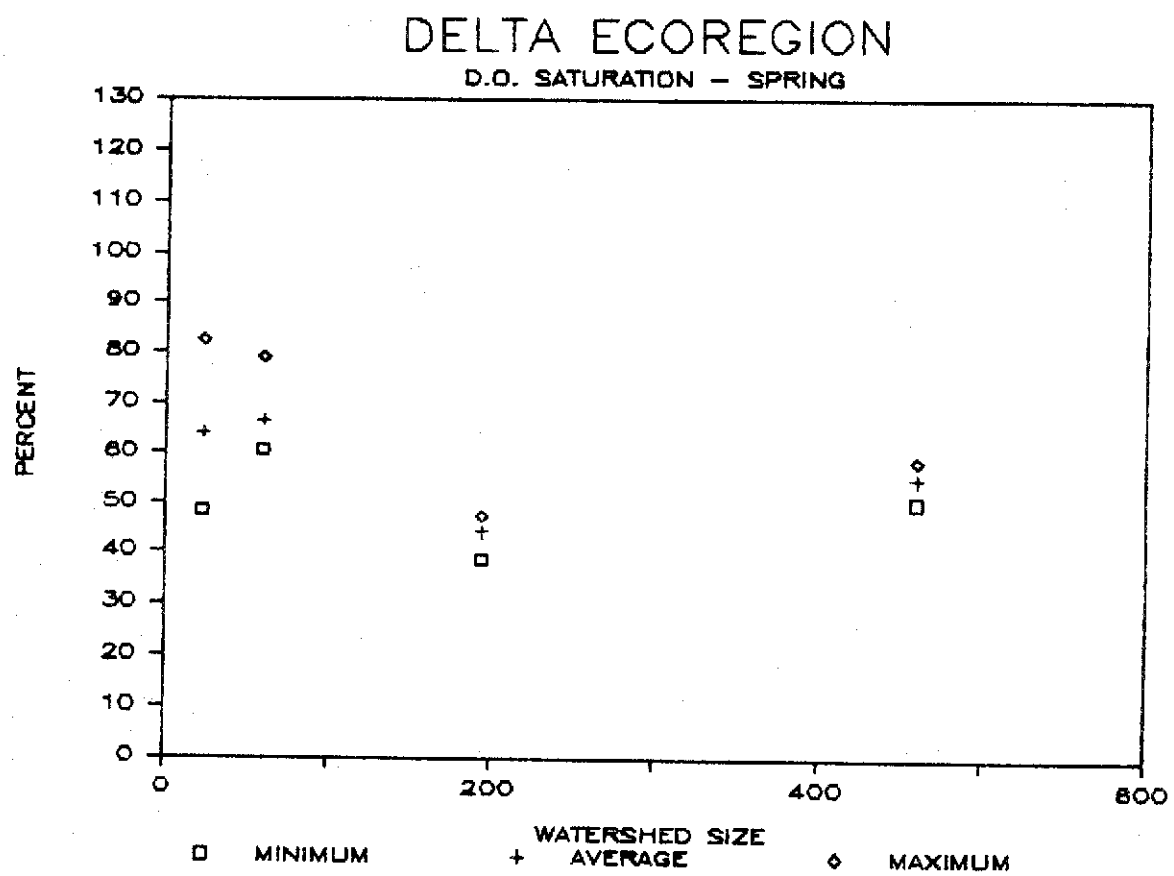
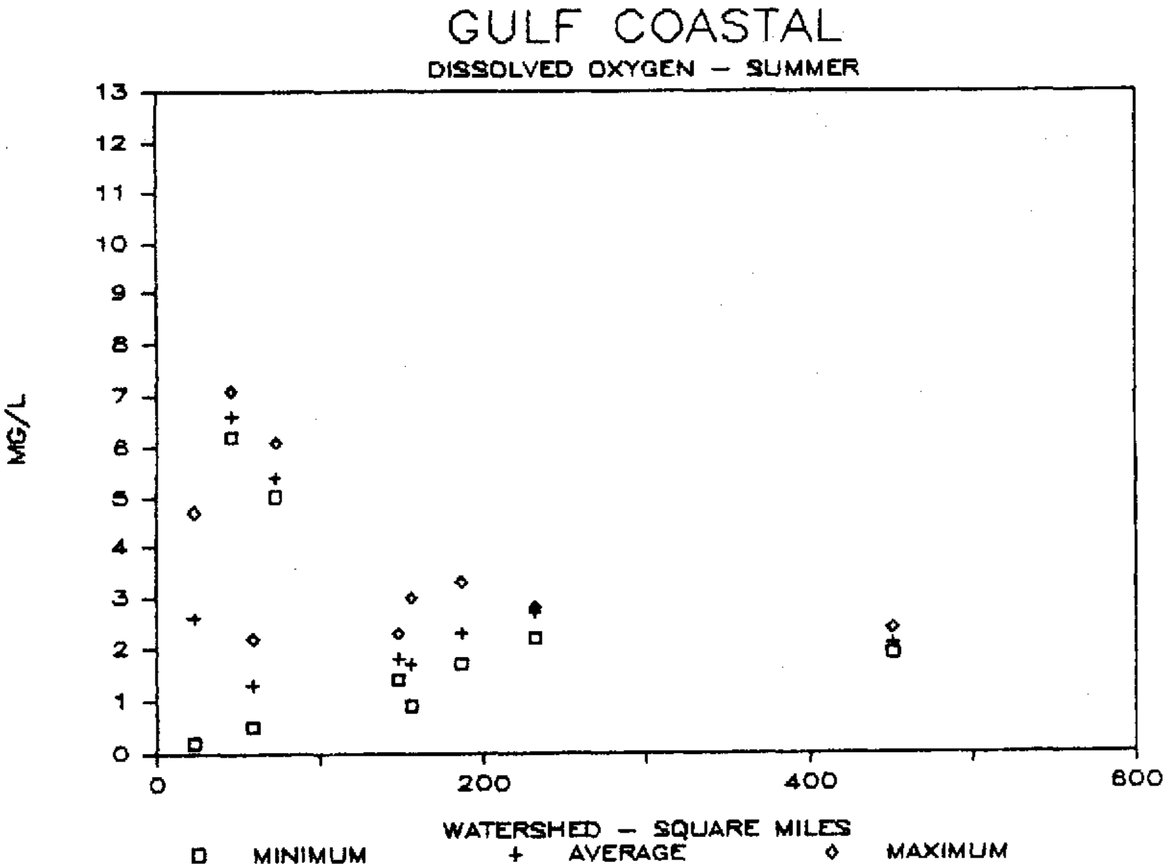
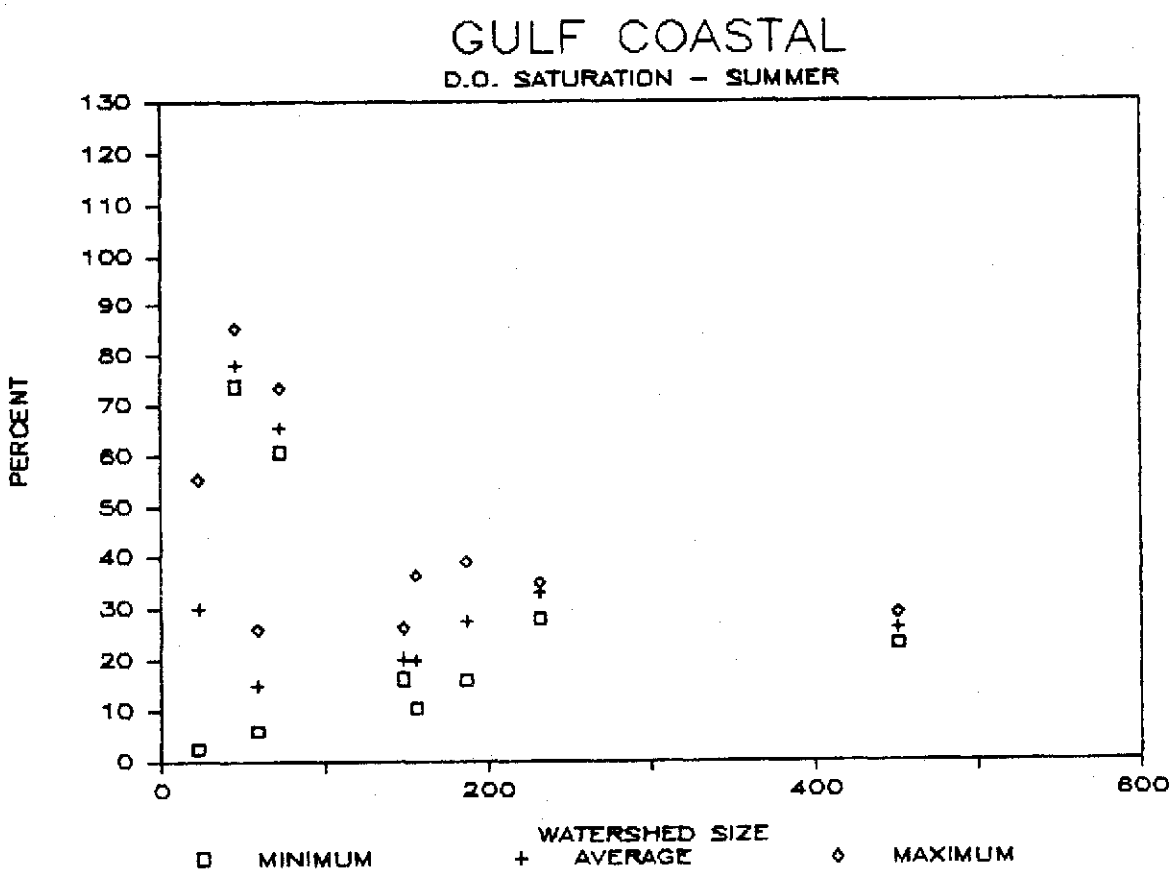


Figure D-4. Dissolved Oxygen and Saturation Values for Gulf Coastal Ecoregion Reference Streams during Summer Period





difference in the dissolved oxygen concentrations between the smallest and the largest reference streams of this type during the critical season. Of the seven typical reference streams, none approached the current water quality standard during the critical season. However, the two springwater-charged streams exceeded the current water quality standard.

Dissolved oxygen percent saturation values for the critical summer period are displayed in Figure D-4. The percent saturation fluctuated most in the stream with the smallest watershed. The range of fluctuation in Whitewater Creek varied from a low of less than 5% to a high of approximately 60%. Summer saturation values within the two groundwater charged streams were substantially higher than in the typical streams. They ranged between 60% and 80% saturation.

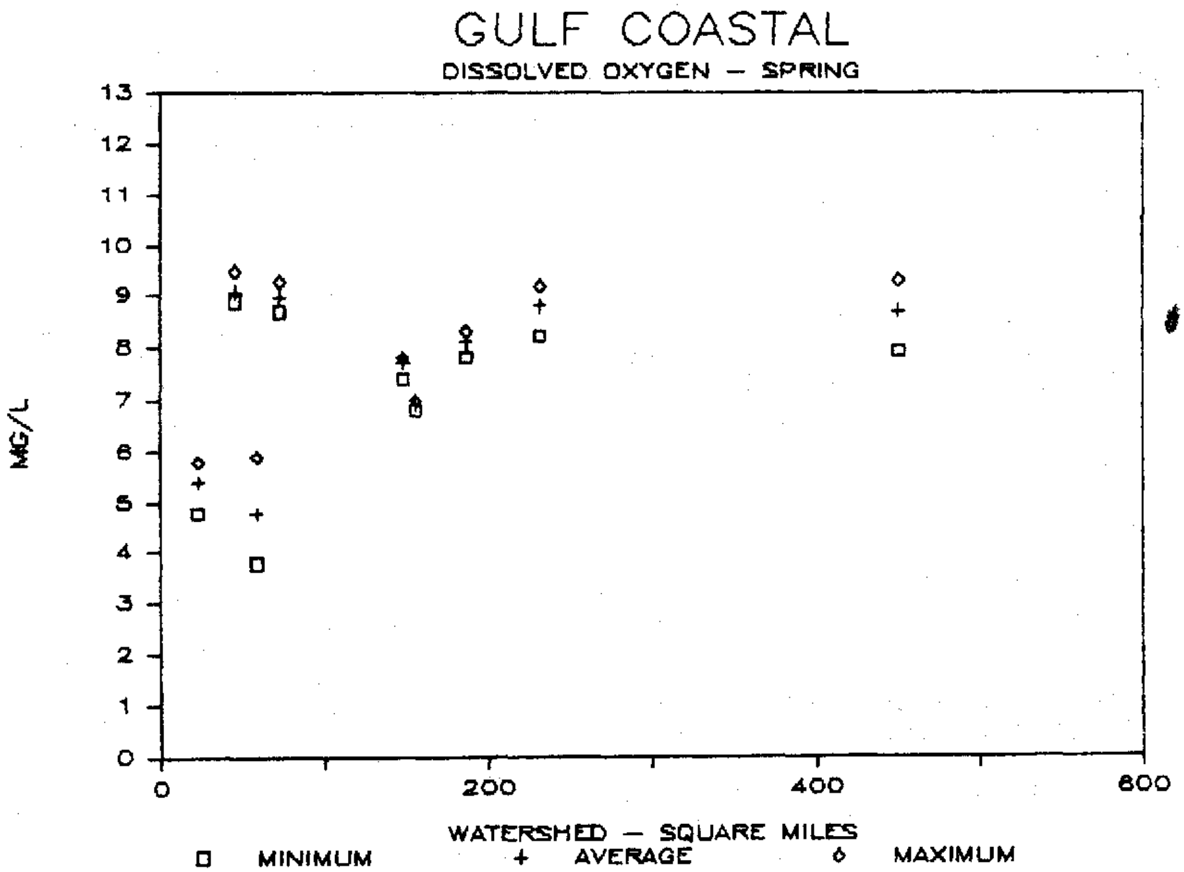
Normally, during spring conditions these streams are continually flowing with frequent out-of-bank flows, and the data indicates that stream flows are the major factor influencing dissolved oxygen concentration during the spring (Figure D-5). Two of the smallest watershed streams had unseasonably low spring flows during the period sampled, and their data is not representative of typical spring conditions. With the exception of these streams, all Gulf Coastal Ecoregion sites exceeded the current water quality standards during the springtime period.

Dissolved oxygen saturation values for the spring period are displayed in Figure D-5. Saturation was enhanced during this period due to flow. In the two small watershed sites which had atypically low spring flows, the dissolved oxygen saturation ranged from 40% to 60%. In contrast, the saturation values ranged from 70% to 90% in all other reference streams. In the two springwater-charged streams, springtime surface flow dominated and saturation values were similar to the typical Gulf Coastal streams.

Arkansas River Valley Ecoregion

The Arkansas River Valley Ecoregion is one in which the naturally occurring dissolved oxygen concentrations are below the current standard. The extremely low stream flows during the critical season appear to be the dominant factor involved. Dissolved oxygen concentrations for the critical summer period are displayed in Figure D-6. The minimum dissolved oxygen concentration during this period ranged from 1.9 mg/l to 4.3 mg/l in the reference streams of this region. Only the Petit Jean River site achieved the current water quality standard. The average minimum concentration of all sites during the summer sampling was 2.7 mg/l. The greatest D.O. fluctuation occurred within the largest watershed site. It was approximately 6 mg/l and was at a site that was a continuous, wide, deep pool with almost no flow. At the remaining five sites, the summertime D.O. fluctuated from 2 mg/l to 4 mg/l.

Figure D-5. Dissolved Oxygen and Saturation Values for Gulf Coastal Ecoregion Reference Streams during Spring Period



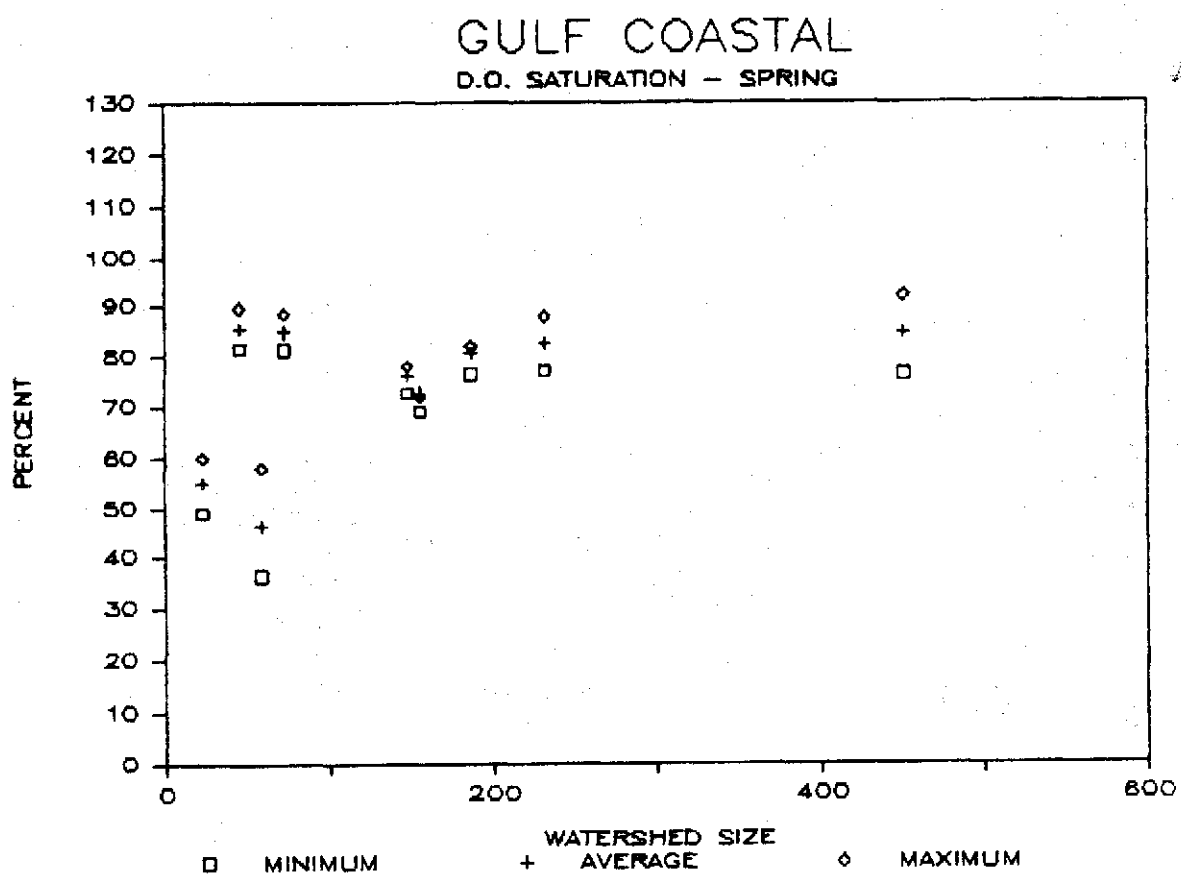
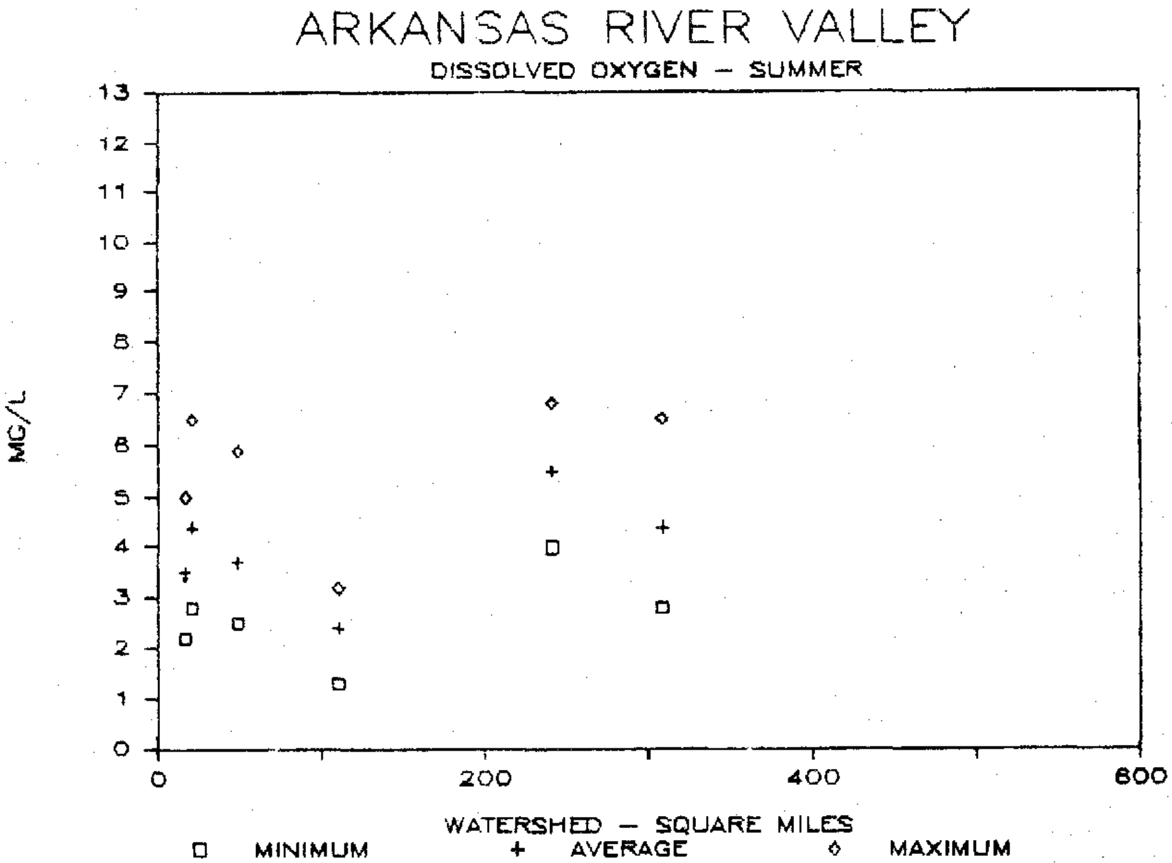
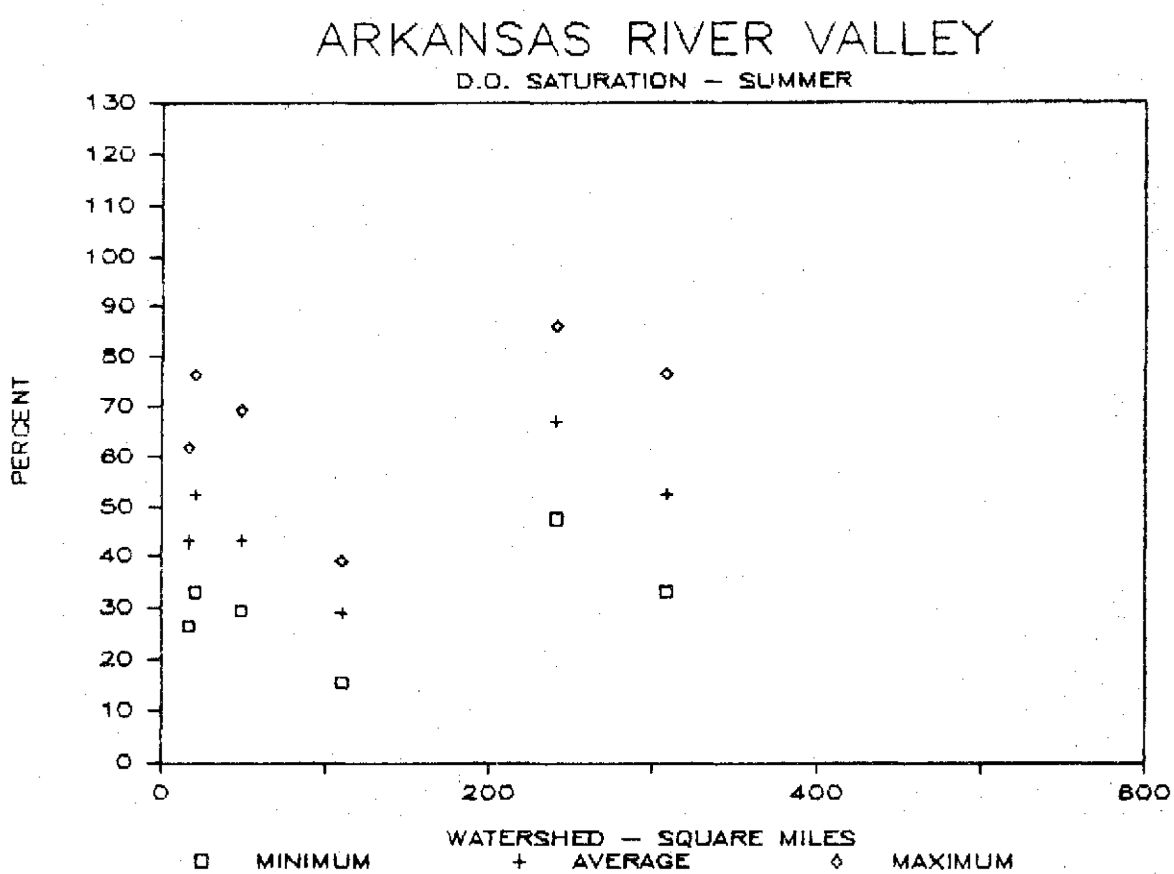


Figure D-6. Dissolved Oxygen and Saturation Values for Arkansas River Valley Ecoregion Reference Streams during Summer Period





There is a distinct seasonal difference in the percent saturation values measured within the Arkansas River Valley Ecoregion. Figure D-6 displays the dissolved oxygen percent saturation values for the summer period. Minimum values ranged from a low of approximately 15% in the Dutch Creek watershed to a high of 85% in the Petit Jean River watershed. Each site displayed a distinctive, wide range of fluctuation indicating substantial photosynthetic activity.

The spring season revealed a significantly higher dissolved oxygen concentration. The average minimum value of all sites was approximately 8 mg/l. The lowest spring season D.O. measured was 7.4 mg/l at the Dutch Creek site. The daily fluctuation was much narrower in the spring season compared to the summer season, and there was a high level of consistency among the sites (Figure D-7). The greater flow during the spring is the dominant reason for the higher dissolved oxygen concentrations.

Figure D-7 also displays the dissolved oxygen percent saturation values for the spring period from this ecoregion. The much higher saturation values during the spring further substantiate the effect of flows in increasing the stream dissolved oxygen. The spring values ranged from 80% saturation to near 100% with a very narrow range of fluctuation.

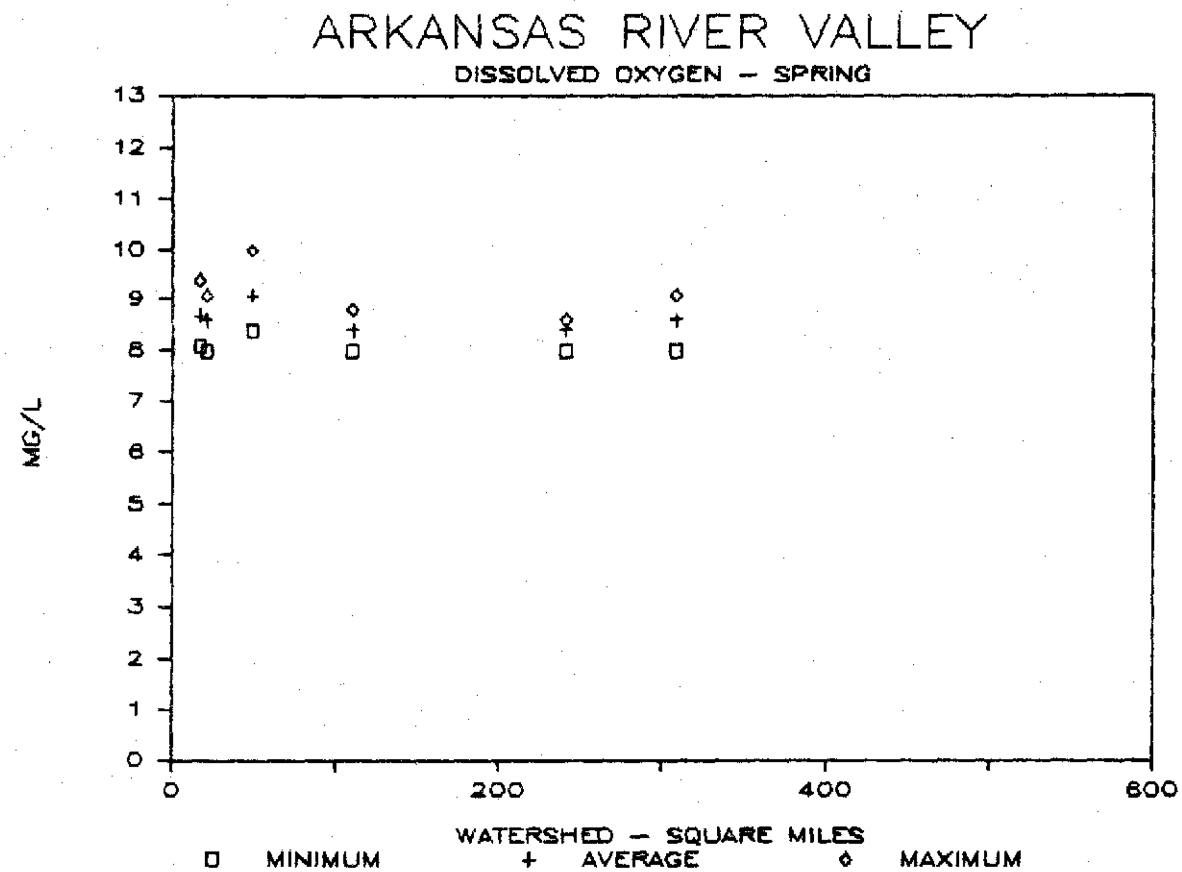
Ouachita Mountains Ecoregion

The dissolved oxygen concentrations measured in reference streams of the Ouachita Mountains Ecoregion during the summer period are displayed in Figure D-8. These values are consistently high at all sites studied within this ecoregion. The minimum D.O. concentrations recorded were from 5.6 mg/l to 6.7 mg/l. All exceed the current water quality standard. The daily maximum D.O. value of all sites averaged approximately 8 mg/l. The daily D.O. fluctuation remained fairly constant among all sites. It averaged approximately 2 mg/l.

The dissolved oxygen percent saturation values for the summer period are displayed in Figure D-8 . These values remained consistently high for all reference sites. All sites except the South Fork Ouachita River reached or exceeded 100% saturation for a daily maximum. Minimum saturation values were 70% to 80% and the daily fluctuation was approximately 30%.

The dissolved oxygen concentrations for the reference sites during the spring period are displayed in Figure D-9 . Due to increased flows and cooler temperatures, the spring dissolved oxygen concentrations were predictably higher than those of the summer period. The minimum D.O. concentrations ranged from 7.3 mg/l to 9.5 mg/l with the lower concentrations being recorded in the larger watershed streams where the gradients were lowest. A 2-3 mg/l D.O. fluctuation was consistent

Figure D-7. Dissolved Oxygen and Saturation Values for Arkansas River Valley Ecoregion Reference Streams during Spring Period



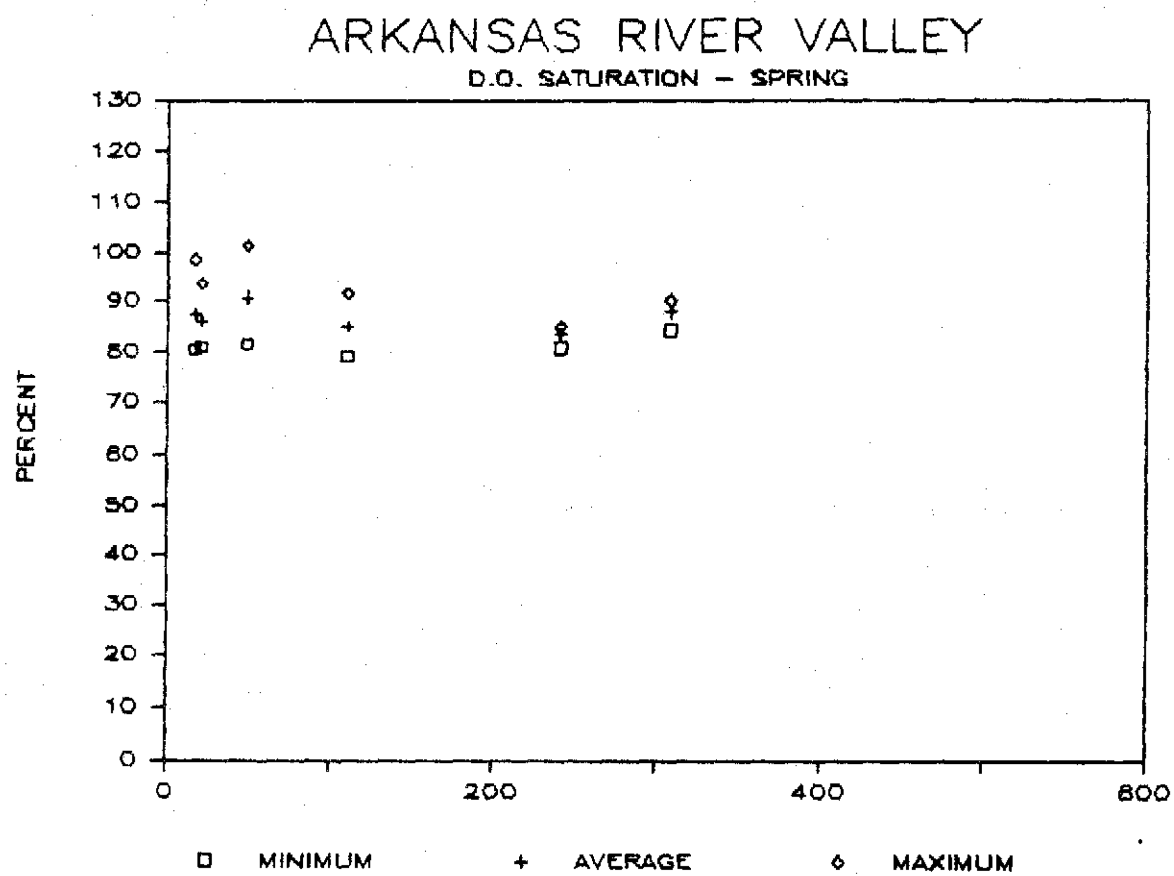
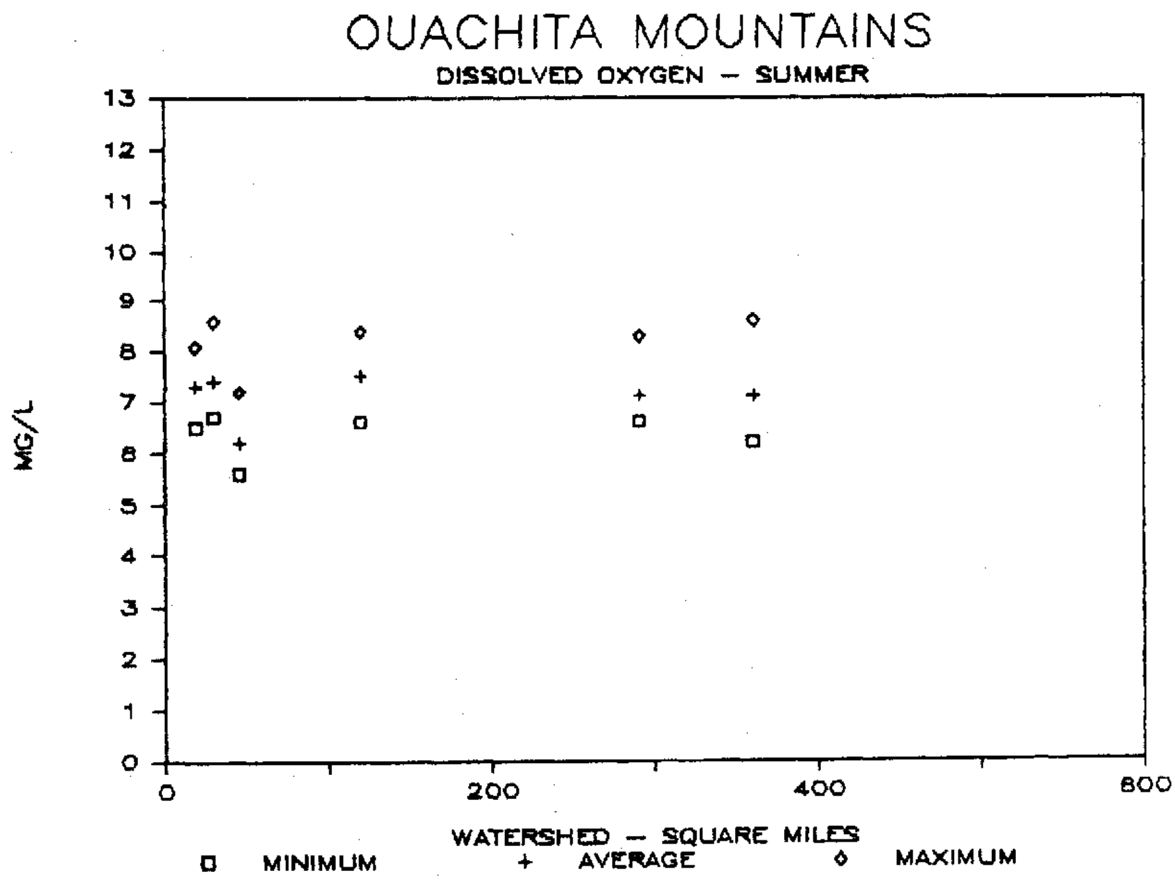


Figure D-8. Dissolved Oxygen and Saturation Values for Ouachita Mountains Ecoregion Reference Streams during Summer Period



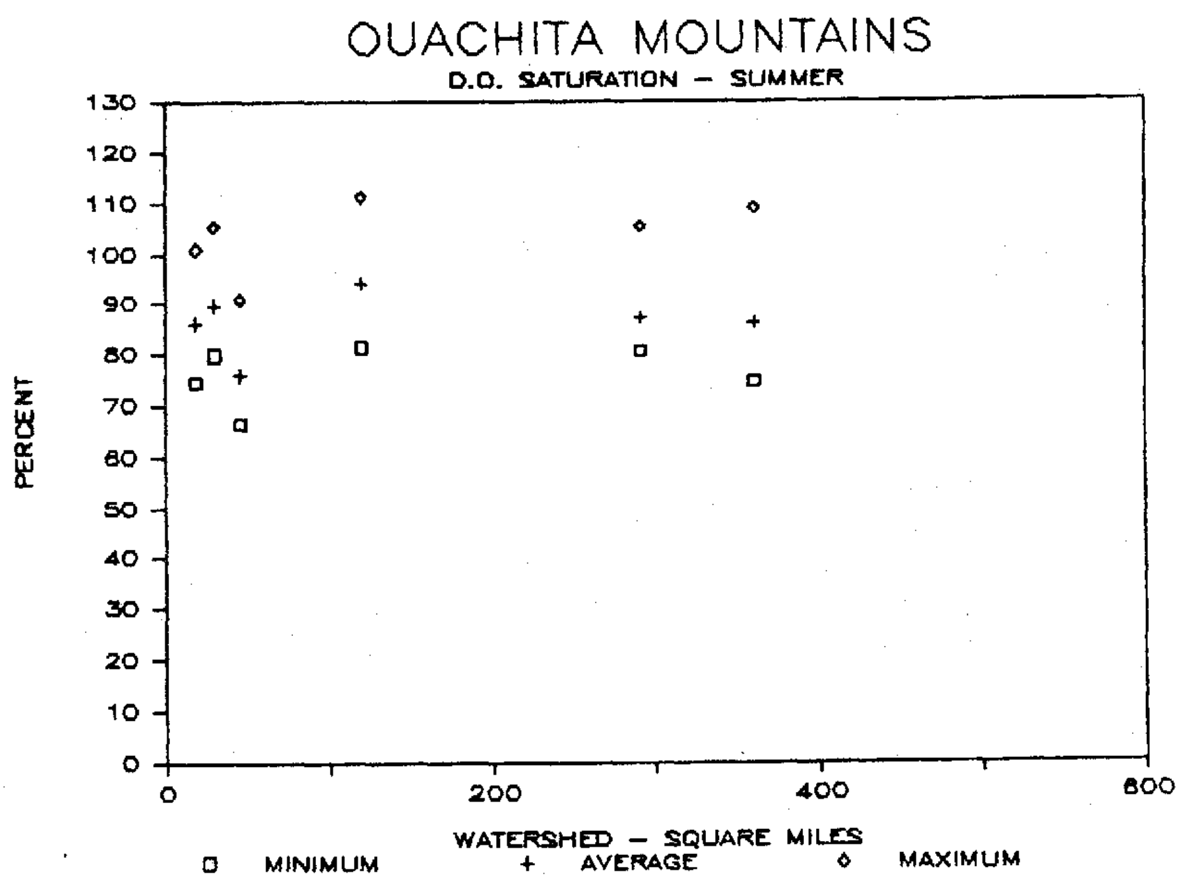
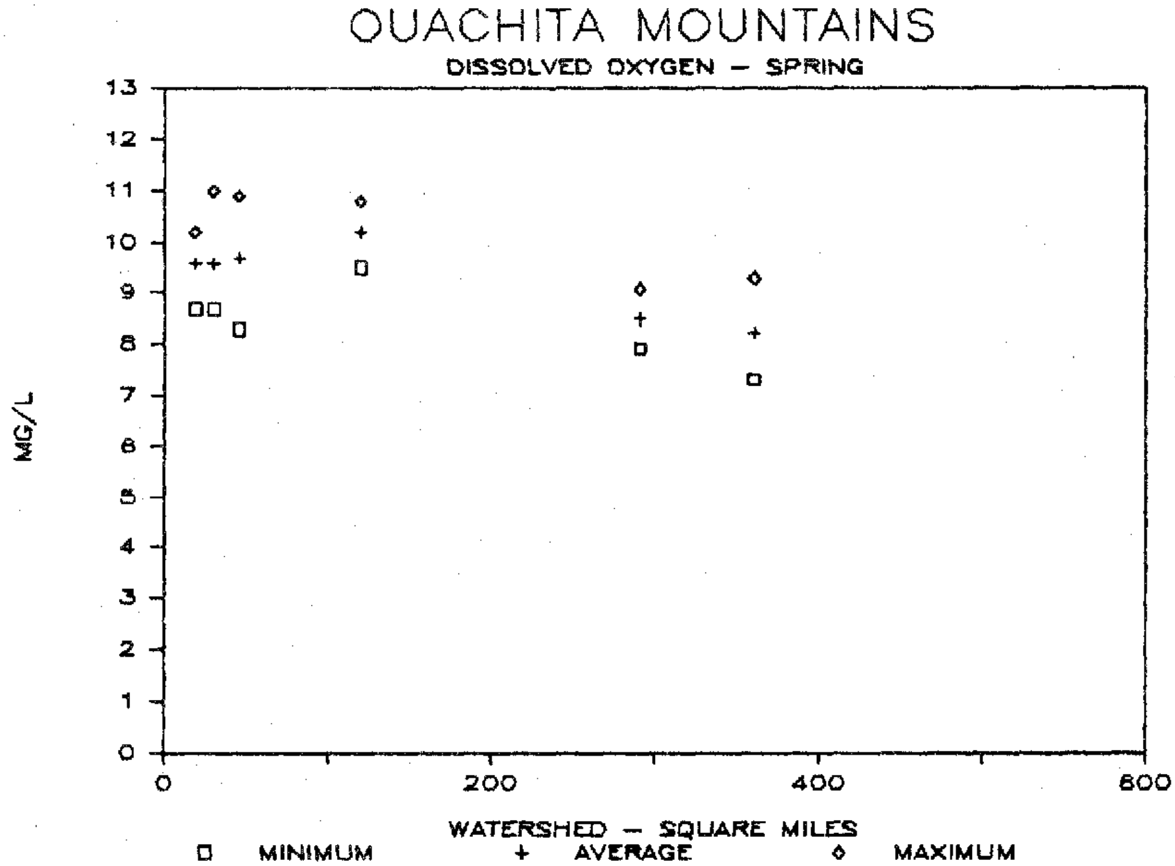
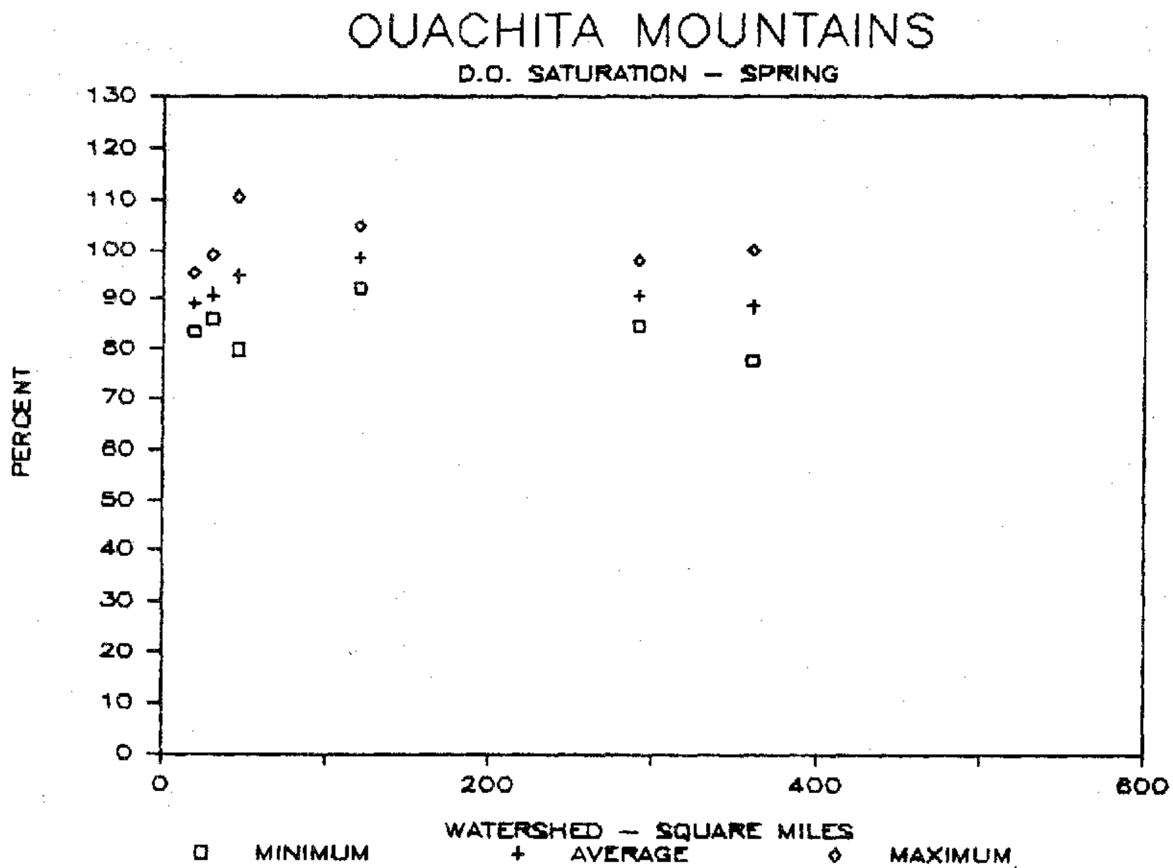


Figure D-9. Dissolved Oxygen and Saturation Values for Ouachita Mountains Ecoregion Reference Streams during Spring Period





within these reference streams.

The D.O. saturation values for the spring period are displayed in Figure D-9. The spring values are very similar to the summer values. This implies that the higher spring D.O. values are caused by temperature differences. The daily fluctuation of D.O. saturation is slightly less during the spring period. This may be influenced by the high reaeration rates of higher spring flows or by more constant water temperatures.

Ozark Highlands Ecoregion

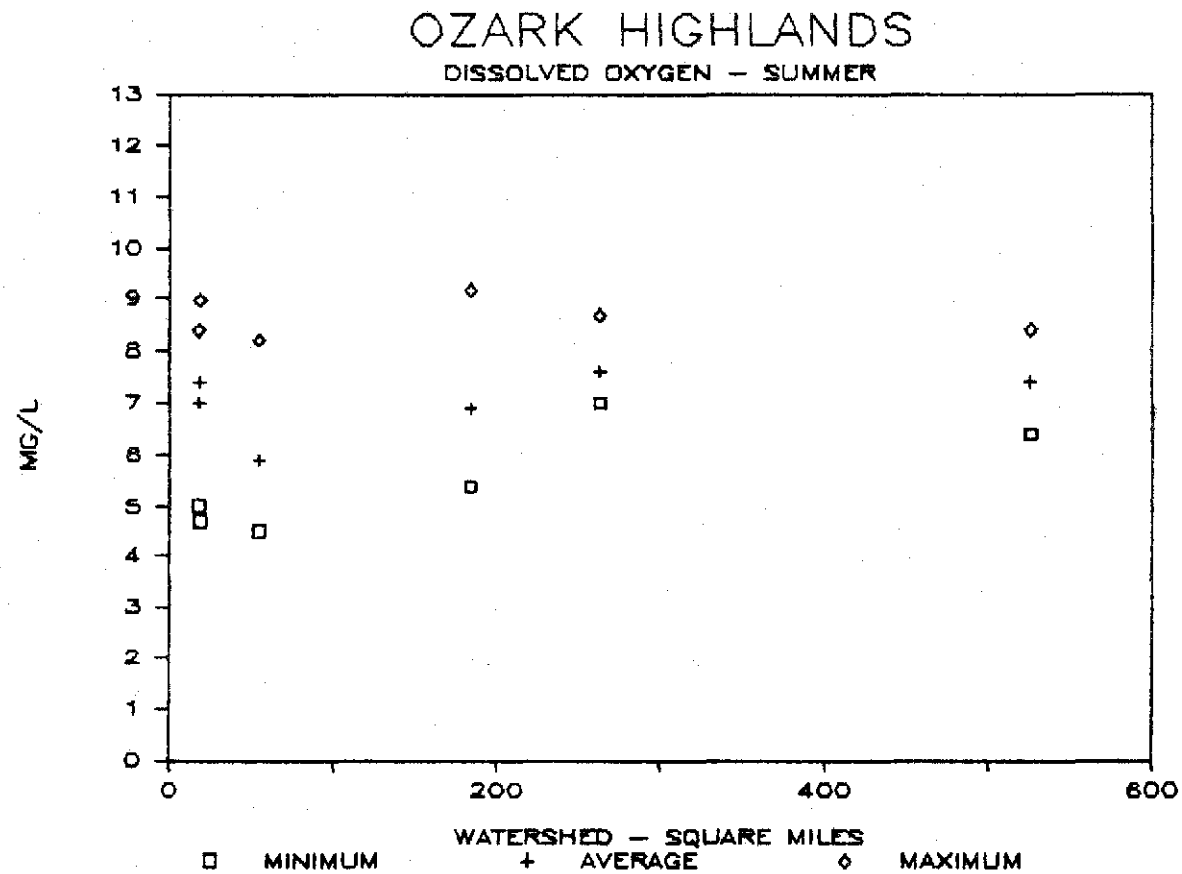
Figure D-10 displays dissolved oxygen data from the reference stream sites within the Ozark Highland Ecoregion during the critical summer period. There appear to be two different groups of streams within this ecoregion. The data indicates that streams with watersheds greater than approximately 100 mi^2 have a minimum dissolved oxygen values between 5 mg/l and 6 mg/l. The streams with less than 100 mi^2 watershed had minimum D.O. concentrations between 4 mg/l and 5 mg/l. The daily fluctuation of D.O. during the summer period ranged from about 2 mg/l to about 4 mg/l. The two largest watershed sites had the smallest fluctuation. This may have been related to their higher flows.

The dissolved oxygen percent saturation values for the summer period are displayed in Figure D-10. Percent saturation during the summer season averaged approximately 70% for reference streams in this region. These values range from slightly greater than 50% to over 100%. The larger watershed streams had generally higher percent saturation values. This is possibly due to the higher flows in these streams and to the larger pools which tend to allow greater phytoplankton production.

Figure D-11 displays dissolved oxygen data from the Ozark Highlands reference streams during the spring season. The substantial flows during the spring season are believed to be the primary reason for the consistently high dissolved oxygen concentrations in this region during the spring season. Minimum D.O. values ranged from 7 mg/l to 8 mg/l. The difference in minimum and maximum D.O. values was quite large in these streams. The range in some streams was approximately 4 mg/l. This wide range of fluctuation is not consistent with observations from other regions. The greater flows during the spring conditions generally tend to narrow the range of D.O. fluctuation. A possible explanation for this occurrence are the elevated nutrients associated with the spring flows, and the utilization of these nutrients in algae production.

The dissolved oxygen saturation values for the spring period are displayed in Figure D-11. These values averaged approximately 90% for all reference streams. Saturation values ranged from 70% to over 120%. It appears evident that

Figure D-10. Dissolved Oxygen and Saturation Values for Ozark Highlands Ecoregion Reference Streams during Summer Period



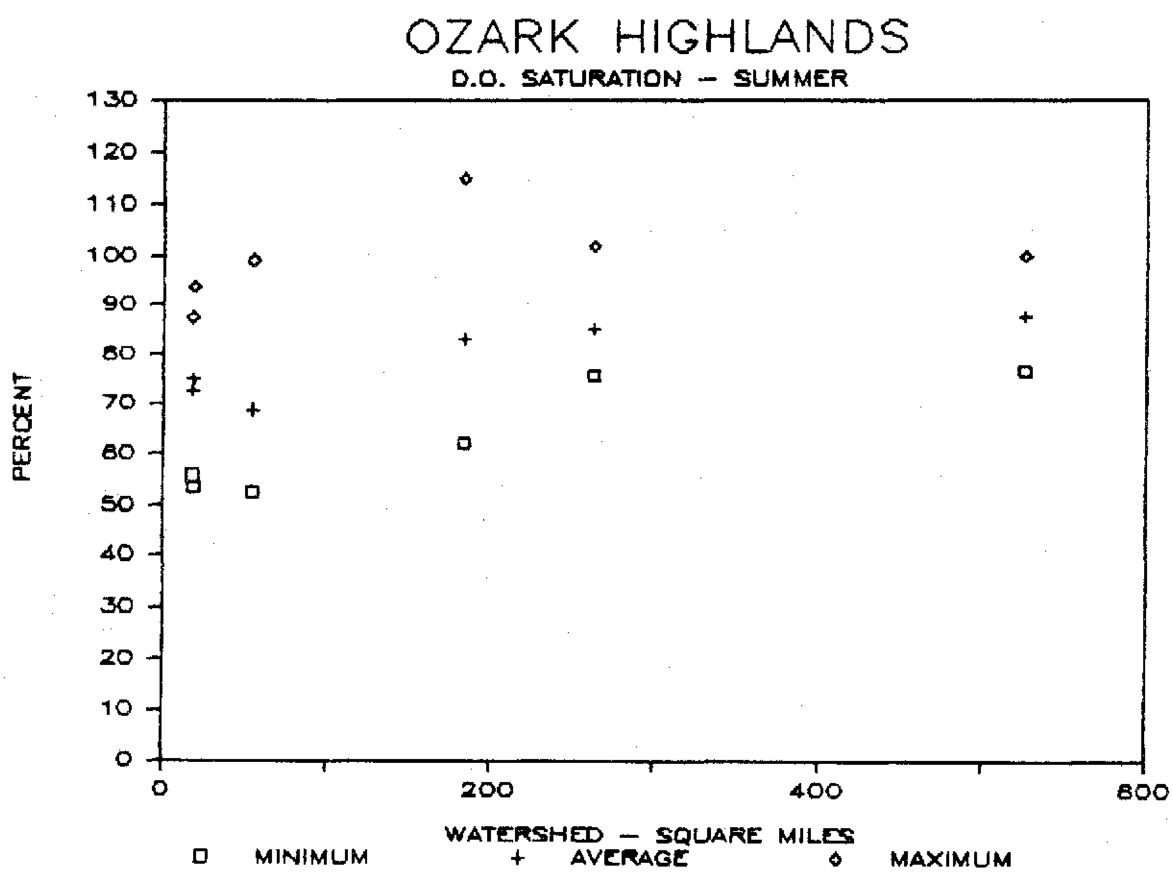
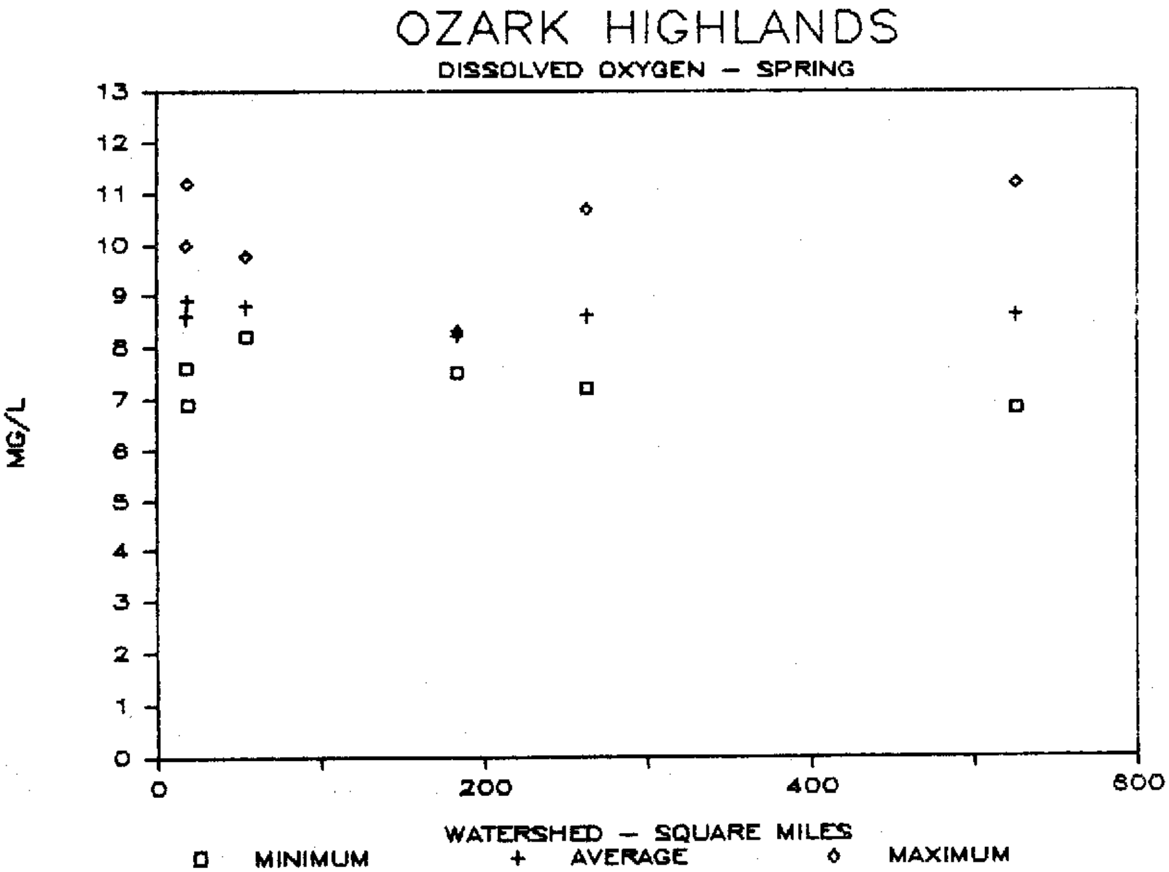
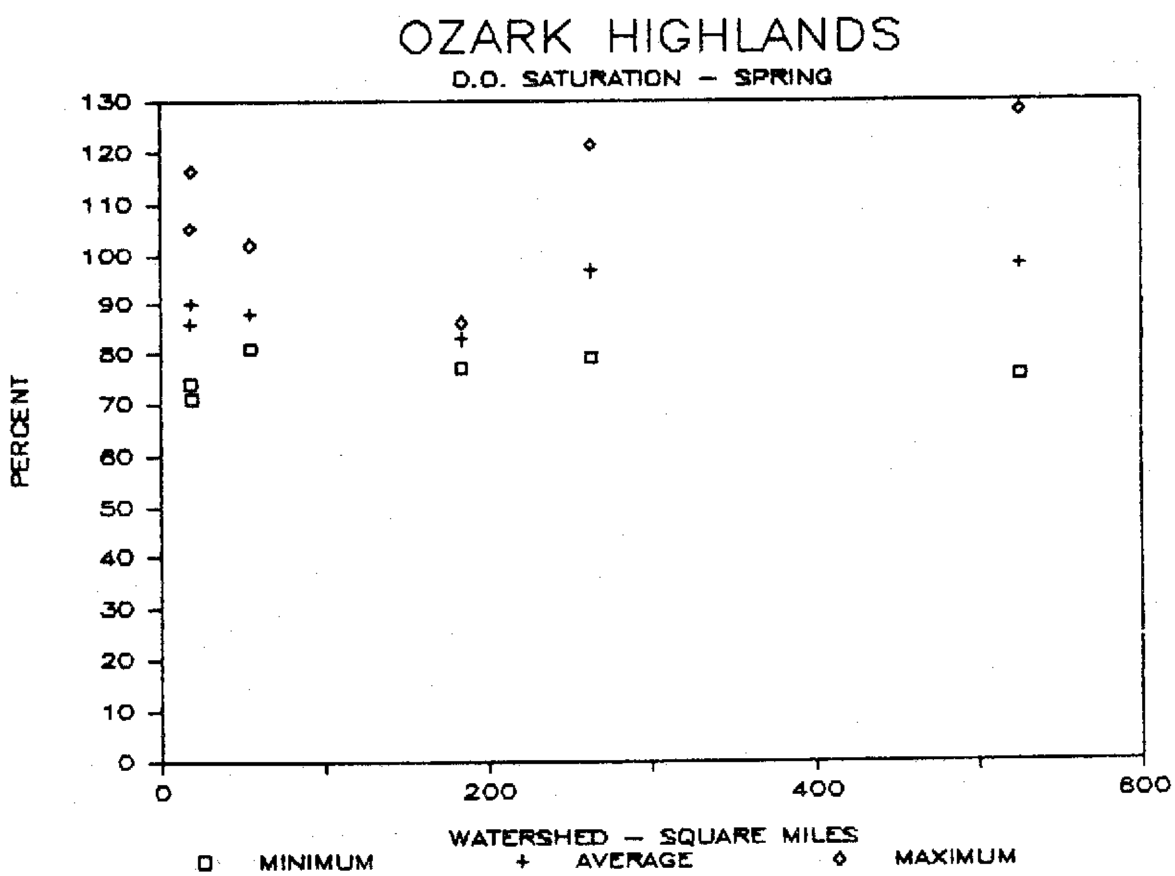


Figure D-11. Dissolved Oxygen and Saturation Values for Ozark Highlands Ecoregion Reference Streams during Spring Period





photosynthesis is a major factor influencing these dissolved oxygen patterns. The turbulence associated with high stream flows of this region could maintain saturation of D.O.; however, the supersaturation values are most likely photosynthesis aided.

Boston Mountains Ecoregion

Dissolved oxygen concentrations in the Boston Mountains Ecoregion reference streams for the summer period are displayed in Figure D-12. These concentrations are consistently higher than all other sites studied. Minimum values are around 6 mg/l and maximum values range from 8 mg/l to 10 mg/l. Also, the daily fluctuation is low and consistent among the sites. All sites studied exceeded the current water quality standard.

Dissolved oxygen saturation values are also consistently high within these streams. The summer saturation values range from approximately 70% to 90% in the smaller watershed streams, and there is some indication that the larger streams exhibit some photosynthetic activity which widens the range of saturation and produces supersaturation in some streams (Figure D-12). These larger watershed streams have lower gradients which produce more and larger pool conditions. Additionally, the wider stream widths have a lower percentage of canopy which allows more sunlight to reach the water column. These conditions will enhance photosynthetic oxygen production and cause the wider ranges and higher D.O. saturation values.

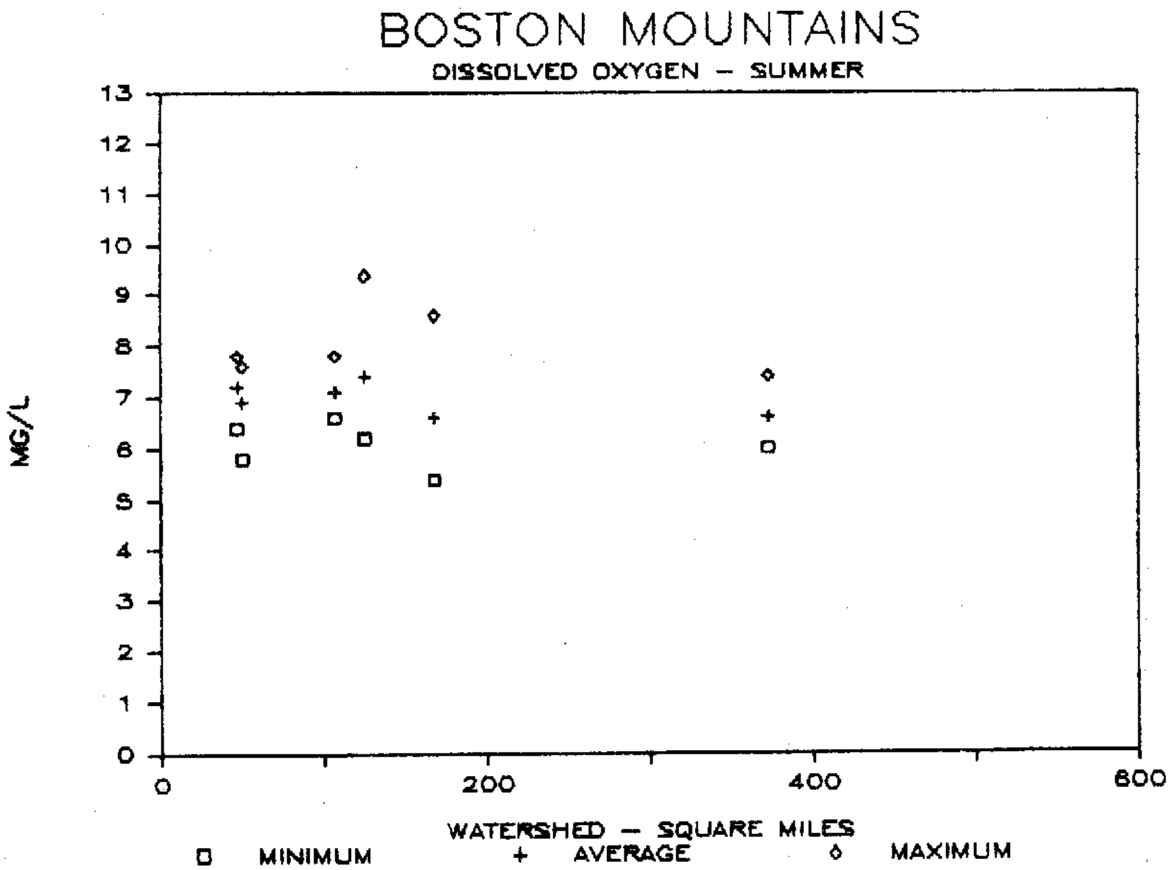
The dissolved oxygen concentrations for the spring period are displayed in Figure D-13. The spring sampling revealed slightly higher dissolved oxygen concentrations than during the summer. The minimum D.O. ranged from 7.8 mg/l to 8.5 mg/l and the daily fluctuation was only about 1 mg/l.

The spring D.O. saturation values of all sites have a maximum value of near 100% (Figure D-13). The factors which cause these high saturation values without supersaturation are: high aeration rates from the turbulence of high flows, low nutrient quantities and the scouring of attached algae by spring flows. These factors also result in a narrow range of fluctuation of the saturation values.

Macroinvertebrate Population of Reference Streams

Benthos can best be described as those aquatic organisms which live on or burrow into the bottom of bodies of water. By strict definition, a benthic community is restricted in scope when compared to the aquatic macroinvertebrate community, which includes non-bottom-dwelling and free-swimming invertebrates that are visible to the naked eye. In this report, the term benthic community refers to the entire aquatic macroinvertebrate community which was sampled at each

Figure D-12. Dissolved Oxygen and Saturation Values for Boston Mountains Ecoregion Reference Streams during Summer Period



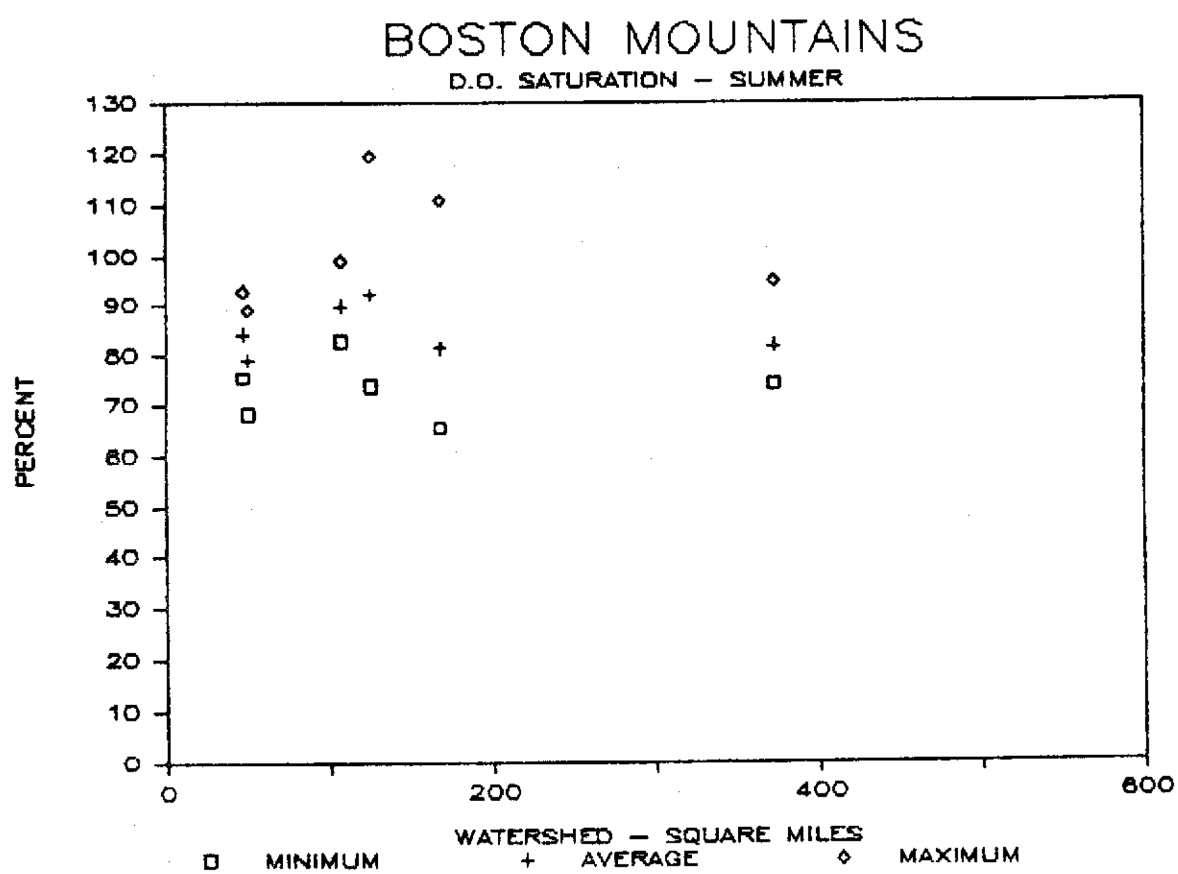
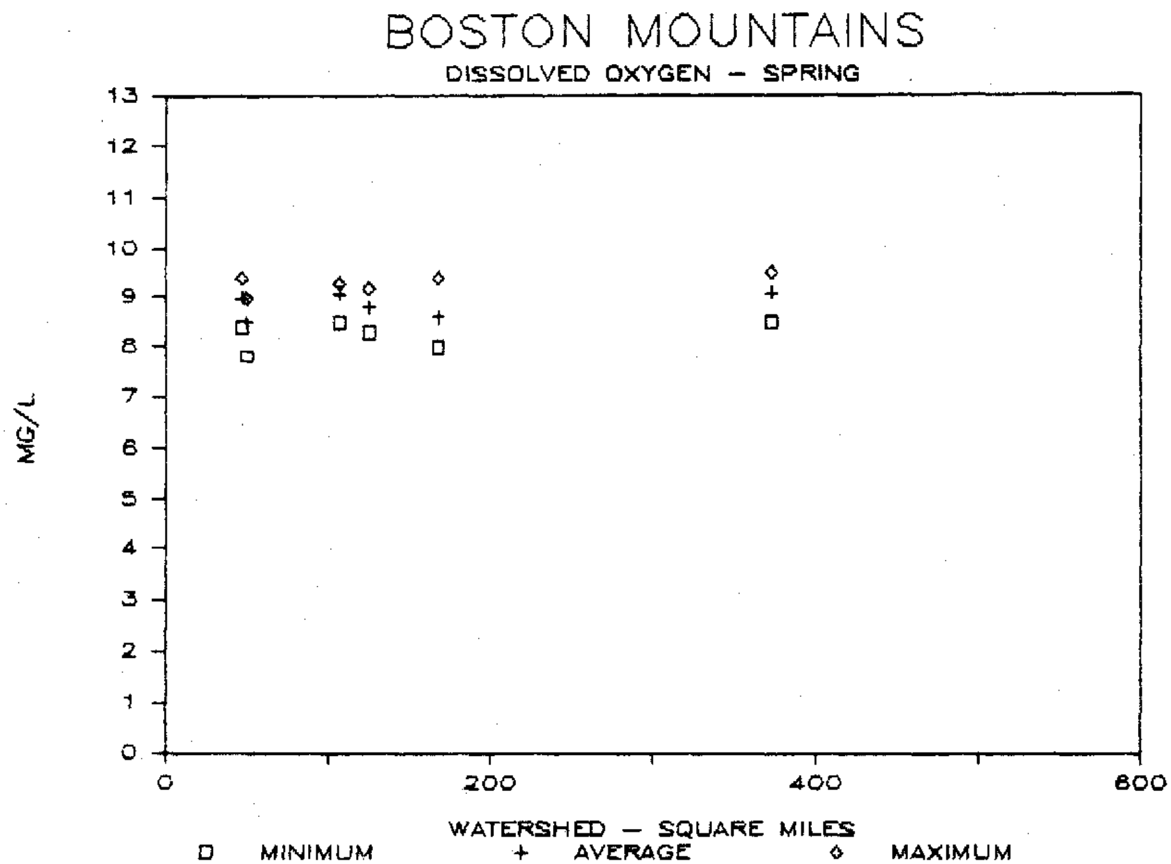
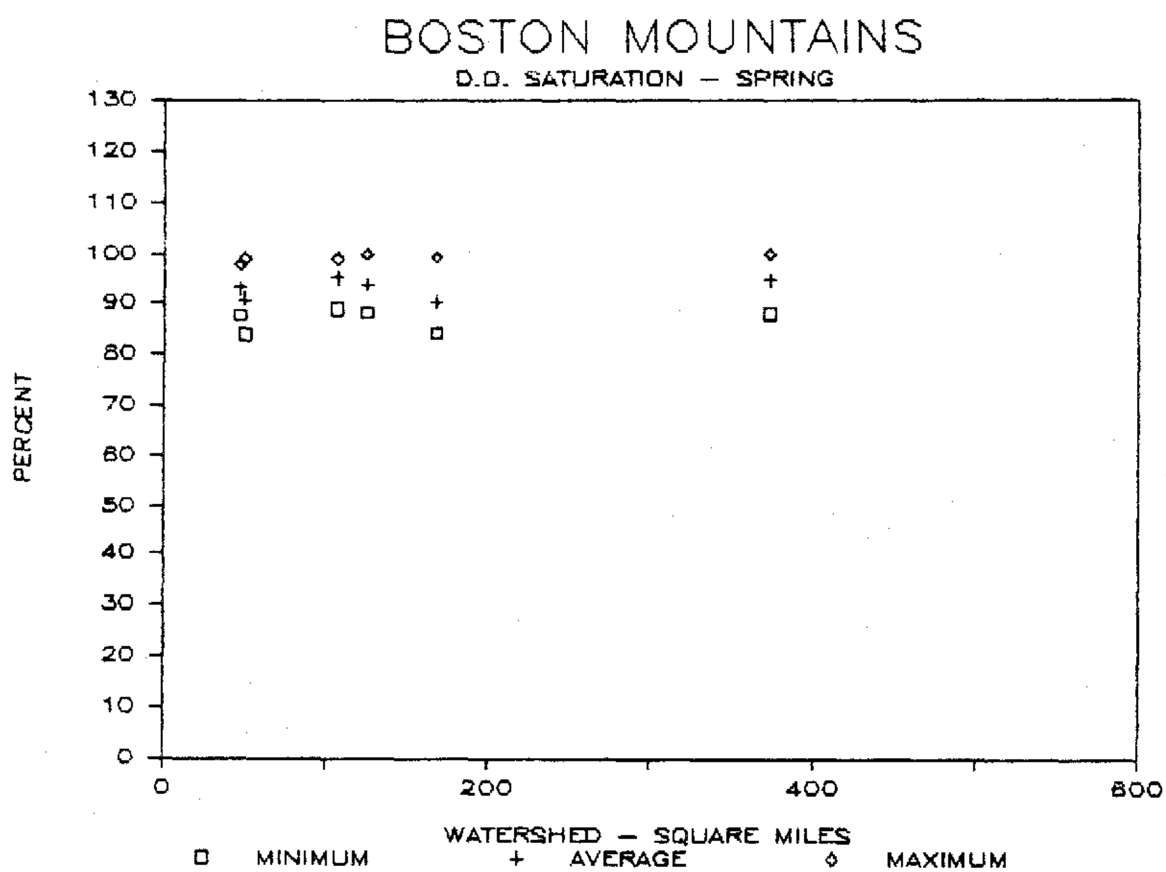


Figure D-13. Dissolved Oxygen and Saturation Values for Boston Mountains Ecoregion Reference Streams during Spring Period





study site.

Survey streams were selected to reflect the best water quality available within each of the ecoregions in order to characterize the best possible condition under which naturally occurring populations exist. Because of this, all benthic populations sampled exhibited diversities indicative of high quality water. Benthic invertebrates demonstrate a wide range of adaptations which allows maximum utilization of the wide variety of naturally occurring aquatic conditions within Arkansas.

Due to the basic nature of benthic organisms, the substrate upon which benthic communities exist and subsist is the single greatest factor in determining its composition and success. It has been shown that no matter how "good" water quality is, if the variety of substrate and ecological niches is reduced or limited, the variety (diversity) and stability of the benthic community is also limited. Other factors may enhance or prohibit the ability of the benthic community to ultimately achieve the maximum diversity (stability) possible. These factors include substratum relationships, nutrient availability, fish predation, hydrologic features of the watershed, environmental pollution and water quality.

Benthic samples were collected during both the summer and spring surveys at each site. Because most field investigations are conducted during summer low flow conditions, the summer collections are utilized in the primary description of the benthic community. The spring samples were evaluated and any seasonal differences and/or trends are discussed. The samples of the benthic community were taken in a qualitative manner and the only quantitative measure of the community was the restricted time element. The initial collecting methodology was found to be inadequate to characterize benthic assemblages. As a result, collections from small watersheds within each ecoregion may be abbreviated and the results may under-report actual numbers of organisms and the number of taxa characteristic of these streams. However, the percent composition of orders and major taxonomic groups are comparable to later samples within the same ecoregion. Due to these factors, the numerically dominant and the taxonomically dominant orders did not always concur. To better characterize the benthic community, both taxonomical and numerical dominants were evaluated and ecologically distinctive groups or orders were chosen to characterize each ecosystem. In addition, a group of individual taxa which were most characteristic of the benthic communities from each ecoregion were identified (Table M-1).

Delta Ecoregion

The characteristic dominant orders of the Delta Ecoregion summer samples were Decapoda, Coleoptera and Amphipoda, respectively (Figure M-1). In addition, Ephemeroptera were

Table M-1

Summary of Benthic Communities from the Aquatic Ecoregions in Arkansas

	Delta	Gulf Coastal	Arkansas River Valley	Ouachita Mountains	Ozark Highlands	Boston Mountains
Avg. # Taxa	50	59	48	62	54	54
Avg. # Org	790.0	816	552	761	943	723
Avg. Diversity	4.17	4.67	4.40	4.59	4.26	3.86
# Dominant Orders*	6	7	10	6	6	5
Top Dominant Orders	Decapoda 17% Ephemeroptera 15% Coleoptera 13% Amphipoda 12%	Coleoptera 21% Decapoda 15% Odonata 11%	Coleoptera 18% Diptera 16% Ephemeroptera 13%	Ephemeroptera 34% Trichoptera 18% Coleoptera 14%	Ephemeroptera 24% Trichoptera 14% Gastropoda 13%	Trichoptera 26% Ephemeroptera 20% Odonata 12%
Distribution of Functional Groups	Collectors 79% Predators 14% Shredders 2% Scrapers 3%	Collectors 51% Predators 40% Shredders 2% Scrapers 4%	Collectors 66% Predators 21% Shredders 5% Scrapers 6%	Collectors 67% Predators 18% Shredders 3% Scrapers 10%	Collectors 51% Predators 15% Shredders 5% Scrapers 25%	Collectors 61% Predators 26% Shredders 4% Scrapers 7%
Characteristic Taxa	Argis Caenis Hyalella azteca Palaemonetes kadiakensis	Enallagma Hydrovatus Palaemonetes kadiakensis Sialis Uvarus	Ancyronyx variegata Chironomus Stenelmis crenata Stenacron interpunctatum Tribelos	Chimarra obscura Corydalus cornutus Isonychia Psephenus herricki Stenonema mediopunctatum	Cheumatopsyche Dubiraphia vittata Helicopsyche borealis Isonychia Viviparus	Chimarra obscura Helichus Hetarinia Isonychia Stenonema terminatum
Seasonal Variation	Pronounced in smaller water-sheds. Limited in larger water-sheds.	Pronounced in all size water-sheds.	Pronounced in all size watersheds, both taxonomically & functionally.	Mayflies dominated both summer and spring but species composition varied significantly. ---------------- Diversity significantly increased in smaller water- & decreased in larger watersheds from summer to spring.	Taxonomic shift among mayfly species from summer to spring. ---------------- No change in standing crop or diversity due to seasonal variation.	Increase in taxonomic diversity from summer to spring. ---------------- Mayflies dominate in both periods but sub-dominant orders demon-strated seasonal affinity.

Table M-1, cont.

Summary of Benthic Communities from the Aquatic Ecoregions in Arkansas

	Delta	Gulf Coastal	Arkansas River Valley	Ouachita Mountains	Ozark Highlands	Boston Mountains
Characteristic Trends	Increase in taxonomic variability as watershed size increases. -------- A significant decrease in collectors & an increase in predators as watershed size increased.	No definite trend associated with watershed size. -------- Springtime sampling generally limited due to high flows. -------- Benthic community of springwater streams distinctively different from other Gulf Coastal populations.	Increase in both standing crop & taxonomic variability as watershed increases. -------- Spring flows not inhibitive to effective sampling.	Increase in both standing crop & taxonomic variability as watershed increases. -------- No shift in functional feeding groups as related to watershed size.	Increase in both standing crop & taxonomic variability as watershed increases.	General increase of taxonomic variability & standing crop as watershed size increases.
Ecoregion	Greatest % of collectors & smallest % of predators. -------- Only ecoregions in which Decapoda was the dominant order.	Highest diversity index of all regions. -------- Greatest % predators of any ecoregion.	Lowest average # of taxa & lowest average standing crop of all ecoregions. -------- Only ecoregions where Diptera was a dominant order.	Benthic assemblage was dominated by mayflies & was more restricted on an ordinal level than any other ecoregion.	Greatest average standing crop of all ecoregions. -------- 2.5X the percentage of scrapers present than in any other ecoregion.	Lowest diversity of any ecoregion. -------- Two orders comprised almost 1/2 all organisms collected. -------- Fewer dominant orders than any other ecoregion.

*Total number of orders which comprised dominant percentages in at least one sample.

Figure M-1. The Distribution of the Major Taxonomic Groups in the Summer Benthic Community of the Delta Ecoregion

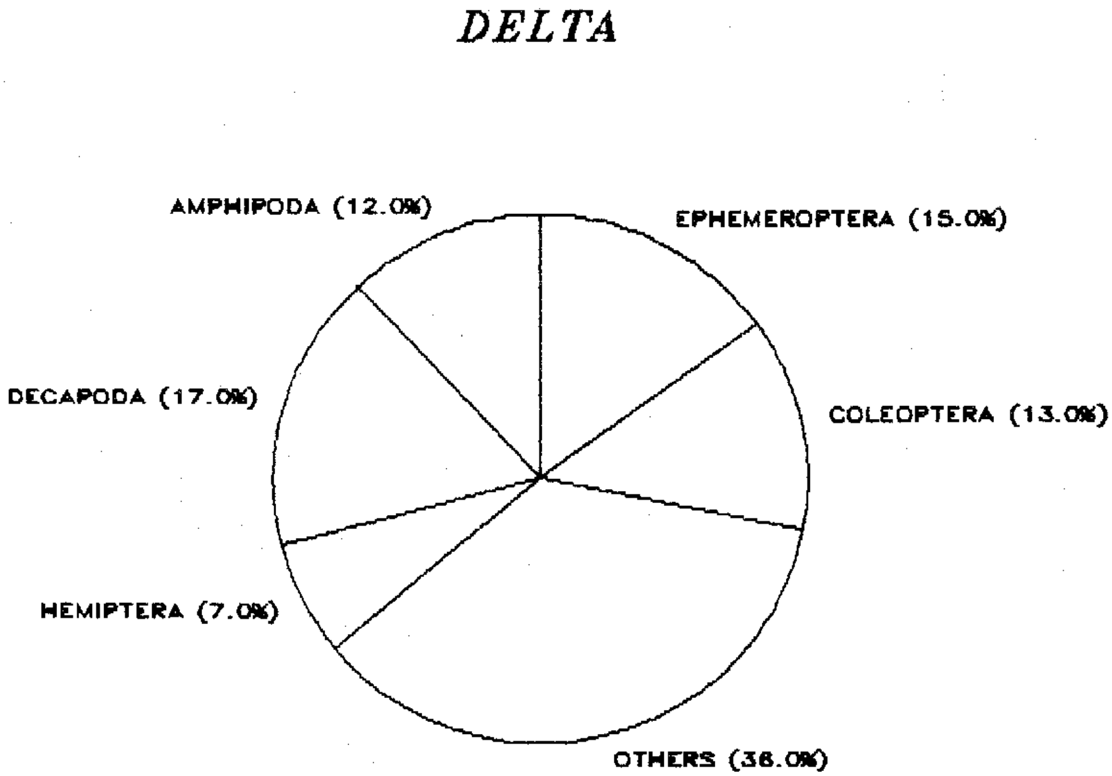
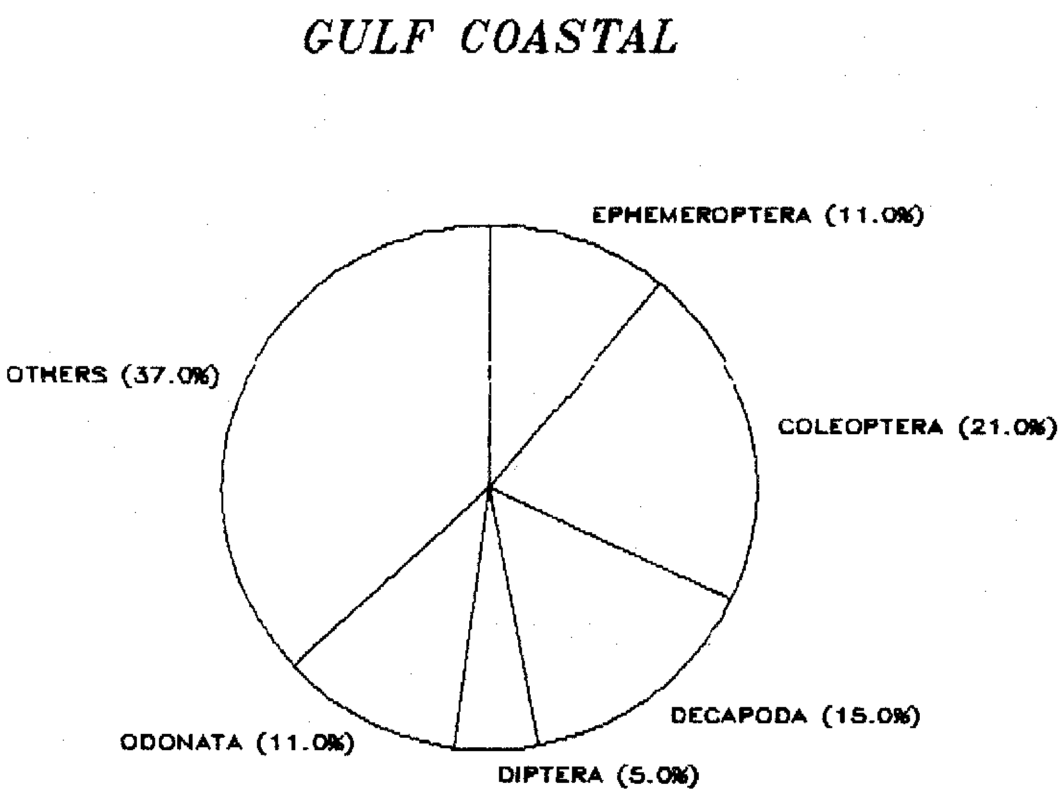


Figure M-2. The Distribution of the Major Taxonomic Groups in the Summer Benthic Community of the Gulf Coastal Ecoregion



numerically dominant in 3 of the 4 samples, primarily due to the large populations of a single taxa, Caenis. A typical summer benthic assemblage would include many beetles, a single taxa of Amphipoda (Hyalella azteca or Gammarus fasciatus), large population of glass shrimp (Palaemonetes kadiakensis), a damselfly (Argia), and a variety of true bugs which were present in limited numbers. These taxa are typical inhabitants of permanently wetted streams which have a mud/silt-dominated substrate with significant amounts of emergent littoral vegetation.

There was no clear dominant order within the reference streams sampled. Only 4% separated the top 4 orders. Coleoptera dominated taxonomically, but only because of the inherent diversity of the group (many identifiable species). No order was dominant in more than one sample and eight different orders were found to be a co-dominant in at least one of the samples.

There was a pronounced increase in the taxonomic diversity as watershed size increased. Thirty-eight taxa were collected from the smallest stream and 60 taxa were taken in the largest stream. Also associated with the increase in watershed size was a gradual but constant change within the functional feeding assemblages of the benthic communities. The percentage of collectors which utilize fine particulate organic matter (FPOM) as a food source decreased and the percentage of predatory organisms increased as watershed size increased.

Seasonally, the spring benthic communities consistently reflected greater taxonomic diversity and numerical abundance. Seasonal variation of dominant taxa was exhibited by the 3 smallest watersheds. The benthic community of Bayou DeView exhibited a greater degree of uniformity between the summer and spring samples. This illustrates the reduced variability of seasonal populations as larger watershed streams become more homogeneous in both substrate types and water quality parameters.

Gulf Coastal Ecoregion

The ecologically characteristic groups of the Gulf Coastal Ecoregion were Coleoptera, Decapoda and Odonata (Figure M-2). There were 6 orders which appeared as sub-dominants in at least one of the seven samples. Coleoptera was the only order that comprised a significant portion of all samples. The decapods, primarily Palaemonetes kadiakensis, were a distant second and were co-dominant in six of the seven samples. A typical benthic assemblage would consist of several dytiscid beetles including Uvarus, Hydrocanthus, and Celina, Palaemonetes kadiakensis, Enallagma and Sialis (Table M-1).

There was no apparent trend in taxonomic diversity or in ecologically characteristic taxa as stream size increased. The total number of organisms per sample did increase in the larger watershed streams. This numerical increase caused a decrease in the overall diversity index. This increase was also a response to the increase in habitat and permanently wetted areas and the decrease of extreme fluctuation of seasonal flows. The lack of variation due to watershed size may have been a result of beaver activity throughout the region. The pools created by beaver dam construction in the smaller streams provide year-round wetted areas and at least trickle flows where otherwise dry streambeds would dominate during the summer low-flow period.

Spring sampling was hampered by high water levels at seven of the nine study areas. Due to extremely high flows during the surveys of Hudgin and Derrieusseaux Creeks, the taxonomic diversity was greatly reduced. Other samples, where stream flows were high but not restrictive, exhibited only limited increases of taxonomic diversity due to the presence of spring insect taxa. However, the benthic samples from the two sites where sampling efficiency was not reduced because of high flows exhibited significant increases in taxonomic diversity. Because high spring flows often prohibit effective sampling in this region, benthic communities are best definable outside this time period.

Two of the Gulf Coastal streams sampled were substantially influenced by springwater. The benthic community of these streams were significantly different from the benthic assemblages of the other reference streams of the ecoregion. The dominant orders were the same, but the ecologically characteristic taxa within these orders were different. The coleopteran taxa present in the springwater streams were the types with total aquatic existence. The dominant beetle taxa of these streams utilize cuticular respiration, a process by which oxygen is diffused from the water over an exchange gradient which allows the beetle to remain submerged indefinitely. In contrast, the dominant beetles of the typical Gulf Coastal streams utilize air bubble respiration. Their air supply is taken from surface air and must be replaced when supply is exhausted. Sub-dominant orders in the springwater streams included Ephemeroptera, Plecoptera and Megaloptera. These are characteristic of streams where dissolved oxygen is not a limiting factor.

Arkansas River Valley Ecoregion

The dominant order of the reference streams in this ecoregion was Coleoptera while Diptera and Ephemeroptera were co-dominants (Figure M-3). There were eight orders which were sub-dominant in at least one of the selected streams. Coleoptera, Diptera and Ephemeroptera were co-dominants and comprised significant portions of all but two samples. A characteristic benthic assemblage of streams in this ecoregion

Figure M-3. The Distribution of the Major Taxonomic Groups in the Summer Benthic Community of the Arkansas River Valley Ecoregion

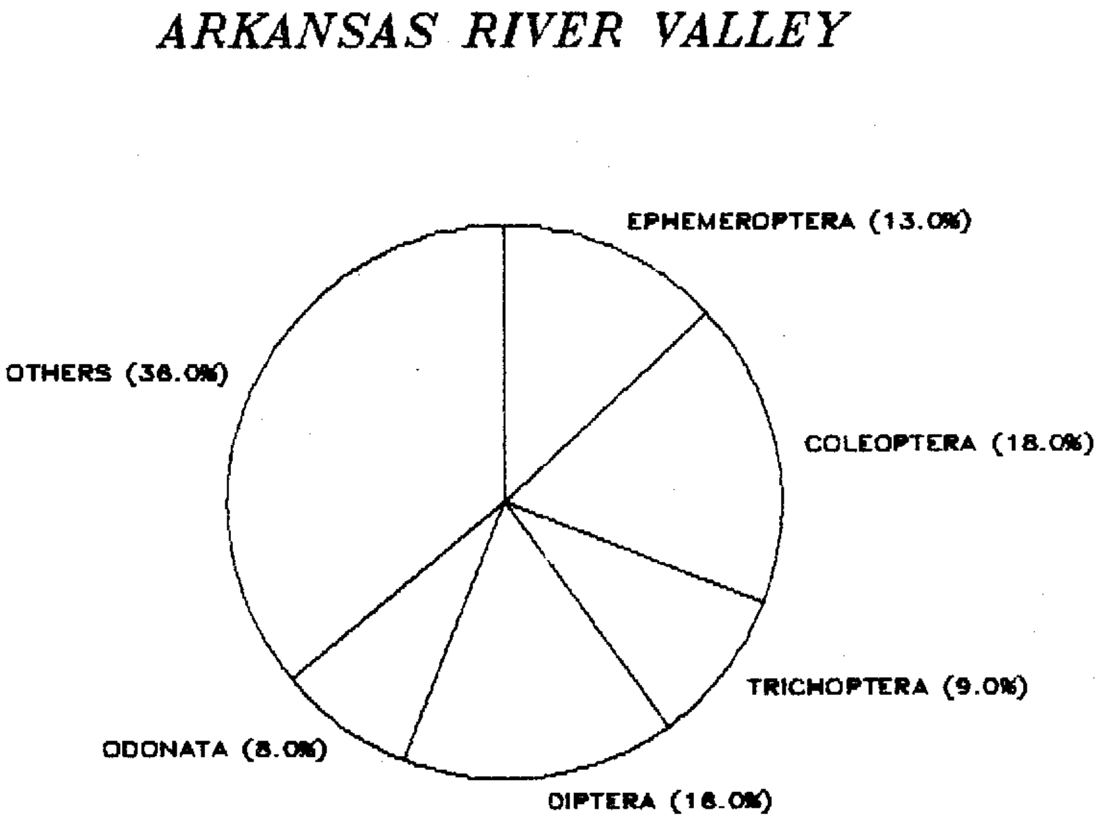
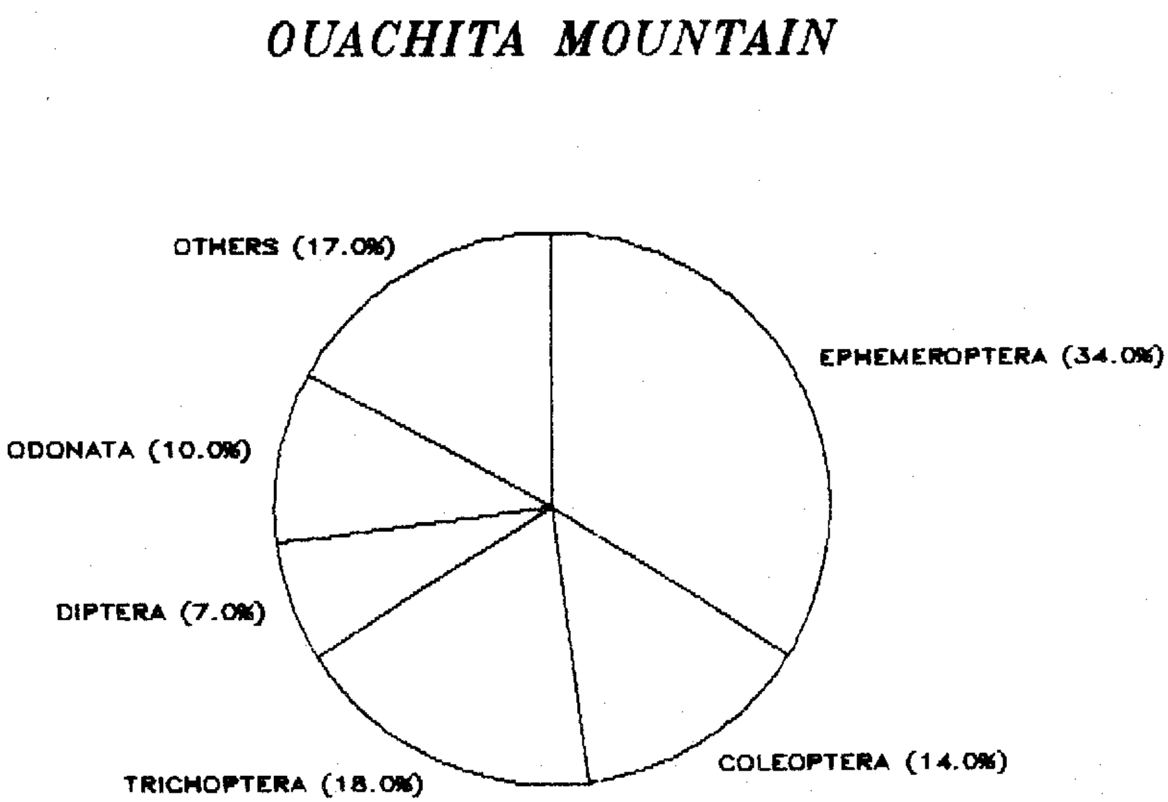


Figure M-4. The Distribution of the Major Taxonomic Groups in the Summer Benthic Community of the Ouachita Mountains Ecoregion



would include *Ancyronyx variegata*, *Chironomus*, *Ischnura*, *Stenacron interpunctatum*, *Stenelmis crenata* and/or *Tribelos* (Table M-1). The Arkansas River Valley was the only ecoregion in which Diptera was found to be a dominant portion of the benthic assemblage. Generally, the benthic assemblages were composed of taxa which show wide tolerances for a variety of water quality parameters. In some instances, taxa described as characteristic of organic enrichment were found. The dominant functional groups were collectors followed by predators, scrapers and shredders. Numerically, they comprised 66%, 21%, 6% and 5% of the population, respectively.

The number of taxa increased with an increase in the stream's watershed size with the exception of Cadron Creek where the number of taxa declined significantly. There was also an increase in the total number of organisms collected with increasing stream size, except in Cadron Creek where numbers decreased greater than 50% when compared to the next smaller stream sampled. The reduction in variety of taxa at Cadron Creek can be attributed to the reduced microhabitat diversification. At this location the gradient declines to 0.6 ft/mi; instream cover was only 6% and the substrate was composed entirely of mud and silt. Despite these factors, the diversity index calculated for Cadron Creek was the highest of any other Arkansas River Valley location. This indicates that water quality was not a limiting factor. There was no apparent shift in functional feeding group composition of the macroinvertebrates among the reference streams.

Seasonally, there was only insignificant variation in taxonomic multiplicity, and the total number of taxa per sample increased at all sites except Cadron Creek. All sites exhibited an increase in numerical standing crop, except the Petit Jean River where sampling efficiency may have been reduced due to high spring flows. However, spring flows generally did not prevent or limit sampling. There was a definite shift in the dominant taxonomic groups from summer to spring. Ten different orders were found to be sub-dominant in the spring samples. The seasonal variation was more pronounced in the smaller watershed streams due to the greater magnitude of extremes between seasons. Stoneflies and caddisflies replaced beetles and dipterans and joined mayflies as springtime co-dominants. This pattern was reflected in the functional groups as shredders became co-dominant with collectors.

Ouachita Mountains Ecoregion

The characteristic, dominant order of the Ouachita Mountains Ecoregion was Ephemeroptera, which numerically comprised 34% of all samples. Trichoptera and Coleoptera were considered as sub-dominants and comprised 18% and 14% of the samples. The benthic community of the Ouachita Mountains Ecoregion was less diverse than in any other ecoregion. Five orders comprised 81% of all organisms collected (Figure M-4), and they were the only ones collected in quantities or with sufficient regularity to be considered characteristic of the ecoregion. Mayflies were the dominant or co-dominant in all surveys conducted. Caddisflies were co-dominant in two samples and, along with beetles, were distant sub-dominants in the remaining samples. Ecologically characteristic taxa of the smaller watershed streams included Corydalus cornutus, Isonychia, Psephenus herricki and Stenonema mediopunctatum (Table M-1). In the streams with larger watersheds, Chimarra obscura, Helichus and Wormaldia were characteristically dominant in addition to those mentioned above.

There was no distinctive trend in taxonomic richness when associated with stream watershed size; however, the greatest number of taxa were collected from the largest watershed stream and the lowest numbers were identified from streams with watersheds under 50 mi^2. The standing crop did increase as watershed size increased, but there was no recognizable shift among functional feeding groups as a function of watershed size.

Seasonally, there was no change in dominants on the ordinal level. However, Plecoptera replaced Trichoptera as a sub-dominant group in the small watershed streams. Coleoptera was a sub-dominant in only two samples. Other groups which appeared as sub-dominant in at least one sample included Diptera, Gastropoda, Isopoda and Odonata. Seasonal variation among the mayfly community and the variation of springtime sub-dominant groups resulted in seasonally different ecologically characteristic taxa. Characteristic springtime taxa include Amphinemuria delosa, Corydalus cornutus, Eurylophella spp., Psephenus herricki, Prosimulin mixtum, Rhithogena and Strophoteryx.

Taxonomic diversity in the smaller watershed streams reflected significant increases from summer to spring while the largest streams of this ecoregion exhibited significant decreases. Springtime sampling was not adversely affected by water levels as in other ecoregions. The trend of decreasing seasonal taxonomic variety as stream watershed size increases may be a response of the benthic community to the reduced seasonal variation in water quality combined with the reduction in the riffle/pool ratio.

This same trend was reflected in the standing crop of macroinvertebrates in Ouachita Mountains streams. The smaller streams exhibited increased numbers in the spring while the larger streams indicated reduced numbers when compared to the summer samples. Seasonal differences were also exhibited by functional feeding groups of all benthic communities. From summer to spring there was a decrease in the number of collectors and an increase in the number of scrapers and predators.

Ozark Highlands Ecoregion

The ecologically dominant order of the Ozark Highlands Ecoregion was Ephemeroptera. Trichoptera, Coleoptera and Gastropoda were distant sub-dominants (Figure M-5). Mayflies were dominant or co-dominant in all of the samples. Only six orders were found to be dominant or sub-dominant in at least one sample. Only the Ouachita Mountains Ecoregion was more restricted. Characteristic taxa include Cheumatopsyche, Corydalus cornutus, Dubiraphia vittata, Isonychia, Helicopsyche borealis, Psephenus herricki and Viviparus (Table M-1).

There was an increase of taxonomic multiplicity as watershed size increased. Twenty-three (23) taxa were identified from the smallest watershed and 85 taxa from the largest watersheds. There was also an increase in the total number of organisms from the smallest to largest watershed. The smaller watersheds were dominated by Gastropoda while Ephemeroptera and Trichoptera dominated the larger watersheds. This was reflected in the percentage composition of functional groups. The Ozark Highlands Ecoregion had the greatest percentage of scrapers and the smallest component of collectors of any other ecoregion. However, this trend was not sustained in the largest watershed of the ecoregion where collectors dominated.

Significant seasonal variation was exhibited in all sizes of watersheds, and there was a shift in dominant groups in all watersheds. In the spring samples, mayflies dominated and stoneflies replaced caddisflies and beetles as sub-dominants. As in the summer, only six orders were considered as dominant or sub-dominant during the spring. This further indicates an overall restricted benthic assemblage. There was a shift in characteristic taxa to Ephemerrid-type mayflies and stoneflies (i.e., Ephemerella spp., Eurylophella spp., Acroneuria, Amphinemuria and Phasganophora) from summer to spring. There was also an increase in the taxonomic multiplicity from summer to spring (average increase of 15 taxa per site) and all locations except the Kings River demonstrated an increase in taxonomic diversity. There was no established trend of increasing numerical standing crop from summer to spring. This, coupled with the taxonomic increases, resulted in higher calculated diversities during spring surveys.

Boston Mountains Ecoregion

The ecologically co-dominant orders of this ecoregion were Trichoptera and Ephemeroptera (Figure M-6). Sub-dominant orders were Odonata and Coleoptera. The caddisfly-mayfly combination ranked as the first and second dominant groups in all but one of the samples. This lack of variability among broad ecological groups indicates that these benthic assemblages could be vulnerable to slight habitat disruptions or alterations. The restricted diversification also indicates the harshness of the Boston Mountains Ecoregion. It is

Figure M-5. The Distribution of the Major Taxonomic Groups in the Summer Benthic Community of the Ozark Highlands Ecoregion

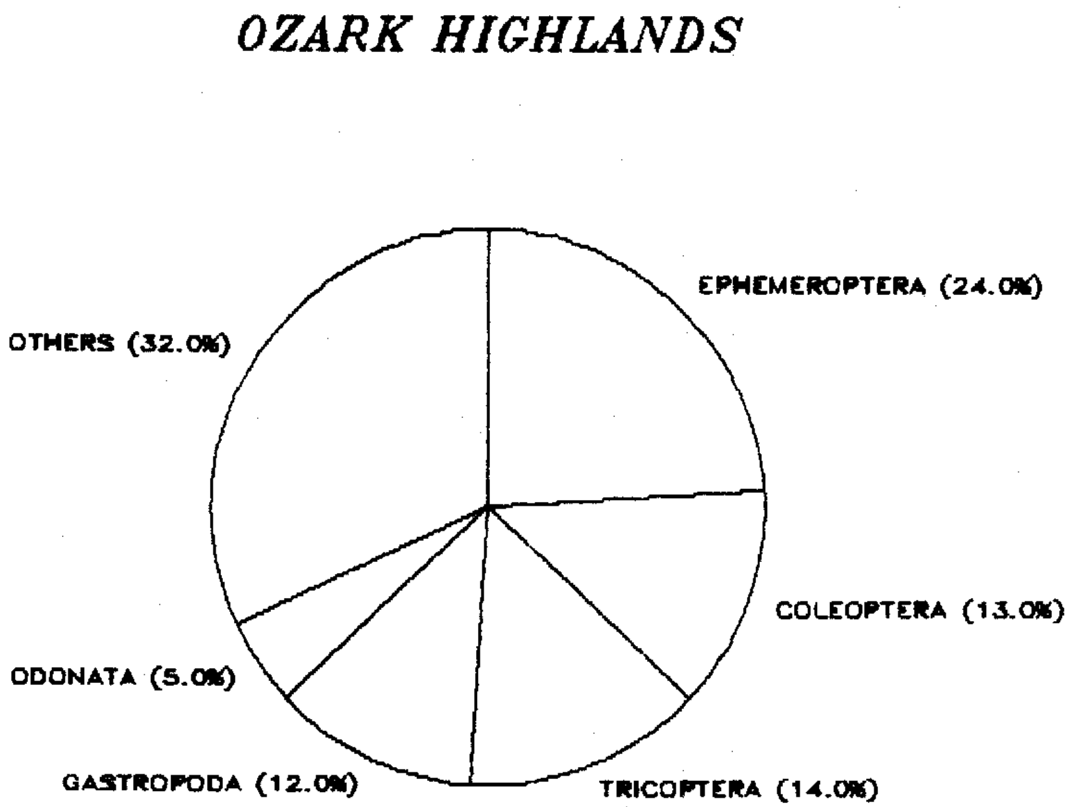
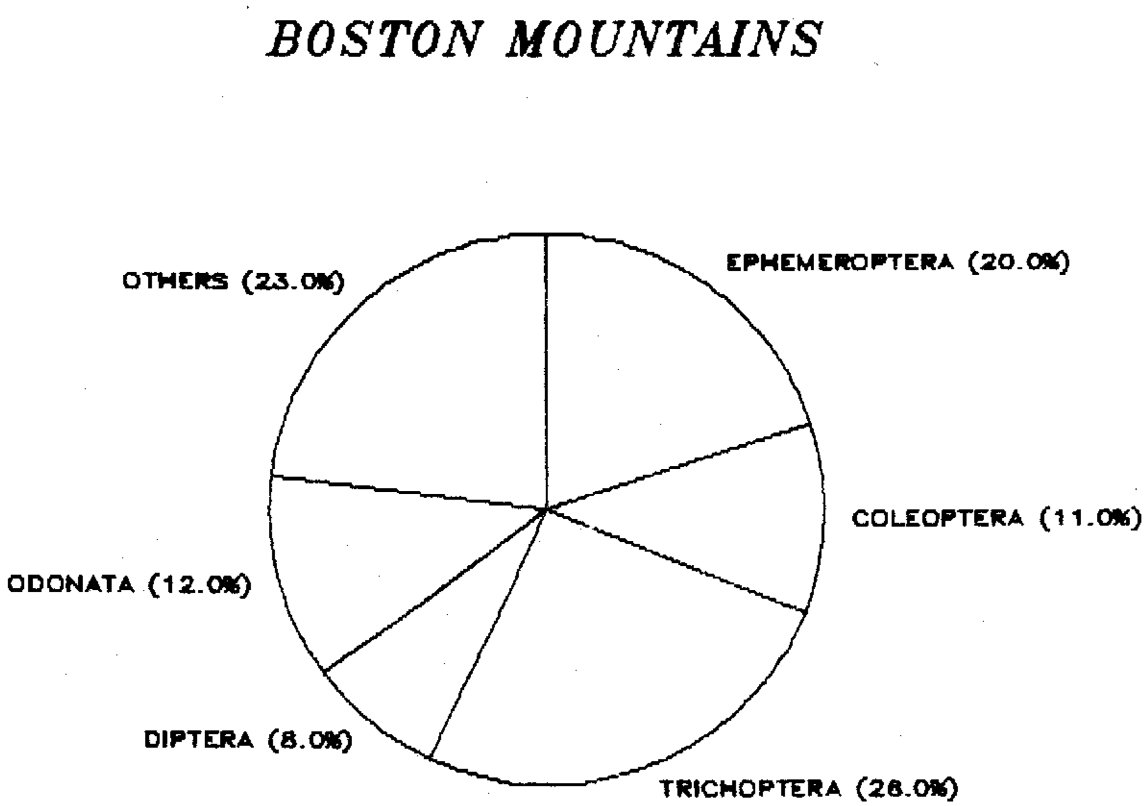


Figure M-6. The Distribution of the Major Taxonomic Groups in the Summer Benthic Community of the Boston Mountains Ecoregion



characterized as having high gradients and a lack of instream cover. A typical community would contain Chimarra obscura, Corydalus cornutus, Helichus, Ischnura, Isonychia, Stenonema terminatum and Tricorythodes as a major portion of the assemblage (Table M-1).

Taxonomic multiplicity appeared to increase with an increase in watershed size except in Illinois Bayou and Mulberry River. Despite Archey Creek having a relatively small watershed, it produced a significantly greater taxonomic diversity. Archey Creek had a slightly greater gradient than Illinois Bayou; however, macroinvertebrate habitat was almost twice as great in Archey Creek as in Illinois Bayou. The large variety of microhabitats at the Archey Creek location when compared to Illinois Bayou caused the greater diversity of taxa. The reduced taxa identified from the Mulberry River study site reflected the reduced riffle-to-pool ratio. Long, deep pools dominated this section of the river and served to reduce microhabitat diversity. Despite the lower number of taxa in the Illinois Bayou and Mulberry River, the calculated diversity indices at these sites were well above the ecoregion average.

There was also an increase in the diversity indices from the smallest Boston Mountains streams to the larger streams. These low diversities reflect conditions of zero summer flow in the small, high gradient streams. This reduces the summer benthic population to those that can subsist by inhabiting pools or migrating to subsurface inter-rubble flows. In addition, reduced instream cover eliminates habitat for many taxa which utilize wood or plant material as its inhabited base.

There was no definite change in taxonomic diversity or numerical standing crop from summer to spring in the Boston Mountains reference streams. There was also no significant change in spring diversity indices when compared to summer values. Mayflies increased their dominant status in the spring and only five orders were sub-dominants. Plecoptera replaced several taxonomic groups of the summer sample as a sub-dominant. The benthic population did exhibit some seasonal variation. This was largely reflected within major taxonomic groups instead of between groups. A typical benthic community of the spring would include Hetaerina, Isoperla, Perlesta, Psephenus herricki, Stenonema terminatum, Rhithrogena and Wormaldia. The spring benthic populations of the Boston Mountains were more restricted than in any other ecoregion.

Comparison of Ecoregions

The summer benthic communities of the Delta Ecoregion had the second lowest average number of taxa per sample and the second lowest diversity index of all ecoregions. The benthic community was composed primarily of collectors and had the smallest percentage of predatory insects (14%). The Delta was the only ecoregion in which Decapoda was the dominant order. The major contributing factors to the composition of the benthic communities were the mud/silt substrate and the extensive shoreline vegetation.

The summer benthic assemblages of the Gulf Coastal Ecoregion were the second most diverse, averaging 59.4 taxa per sample. This ecoregion also supported the second largest average standing crop of 815.7 organisms per sample. These two factors resulted in the highest diversity index of all ecoregions (4.67). The dominant order of the Gulf Coastal Ecoregion was Coleoptera, which comprised more than one-fifth of all organisms collected. The Coleopteran dominance influenced the percent composition of the functional feeding groups. Predators comprised 40% of the summer benthic assemblage from the Gulf Coastal sites. This was twice as many as any other ecoregion. The benthic community of the streams which were springwater influenced exhibited major taxonomic differences when compared to the typical streams of the ecoregion. The differences were primarily at the genus/species taxonomic levels.

The summer benthic communities of the Arkansas River Valley Ecoregion had the lowest average number of taxa per sample and the lowest standing crop of any ecoregion. However, ten orders were found to be sub-dominant in at least one sample, making this ecoregion the most diverse on a broad scale. This ecoregion was the only one in which Diptera were found to be a co-dominant constituent of the benthic community.

The Ouachita Mountains Ecoregion summer benthic community had the greatest number of taxa per sample of any ecoregion. This resulted in the second highest diversity index. The high benthic diversity is a result of exceptional water quality and a large variety of microhabitats. However, Ephemeroptera comprised 34% of the benthic samples. This may indicate a reduced ability of these streams to buffer themselves against disturbances in these streams or their watersheds.

The summer benthic communities of the Ozark Highlands had the greatest standing crop of any ecoregion, but the second lowest diversity index. The increased productivity of the Ozark Highland streams reflects the increased nutrient availability as a result of land use patterns within the watersheds. The functional feeding groups were dominated by collectors but scrapers comprised greater than 25% of the total organisms collected. This was 2.5 times more than in any other ecoregion. Several factors encouraged the presence of large populations of scrapers such as snails in some areas of this ecoregion. The major factor may have been elevated nutrient levels which caused abundant periphyton growth on which scrapers feed. This trend was not as prevalent in the larger Ozark Highland streams.

The Boston Mountains Ecoregion summer benthic communities exhibited the lowest diversity of any ecoregion and the second lowest numerical standing crop. Despite the high quality environment characterized by only limited disturbances within its watersheds, the benthic communities exhibited an innate sensitivity which could be adversely affected by even slight perturbations. Only five orders were collected in numbers to be considered dominant or sub-dominant. Two orders, Ephemeroptera and Trichoptera, comprised about one-half of all organisms collected.

Fish Populations of Ecoregion Reference Streams

Results of all fish sampling within each ecoregion are discussed separately. A concluding section compares the fisheries among the six ecoregions.

Delta Ecoregion

Fish populations in all Delta Ecoregion reference streams were sampled with rotenone. The list of species collected at each sample site and the relative abundance of each species is shown in Table F-1. The two larger watershed sites produced substantially fewer fish species than the small watershed sites (Figure F-1). This may have resulted from decreased sampling efficiency caused by the atypically high flow in these streams during the summer sample period. However, this may also have been caused by the nonpoint source runoff from agriculture activities in the watershed. There are few, if any, watersheds of larger size in the Delta region which are not impacted by agricultural activity. Some tributaries in the upper part of the larger watershed reference streams have been channelized to expedite drainage and certain water quality parameters, particularly turbidity, reflect contributions from such activities. Only one sensitive fish species was collected in this ecoregion.

Distribution of fishes among the common fish families (Figure F-2) shows Centrarchidae to be notably dominant; it is followed by Cyprinidae. This relationship is relatively consistent among the smaller watershed sites; however, in the largest watershed (Bayou DeView), Cyprinidae is about twice as abundant and Centrarchidae is only one-half as abundant as in the other sites. Also, Ictaluridae is twice as abundant in the Bayou DeView sample when compared to the others. These distinctive differences may have been caused by the higher turbidity found at the Bayou DeView sample site which is an indication of agricultural activities within the watershed. The distinctively higher proportion of Cyprinidae is the result of a large population of emerald shiner and bullhead minnow, both of which are very adaptable to turbid waters. Similarly, the high proportion of Ictaluridae is due to an abundant population of channel catfish and a relatively large population of flathead catfish. These two species also adapt

TABLE F-1. FISHES OF DELTA ECOREGION REFERENCE STREAMS

FISH SPECIES		BOAT G	SECOND	VILGE CR.	BY DeVIEW	SUM
(Gambusia affinis)	Mosquitofish	12.0	10.5	12.0	9.0	43.5
(Aphredoderus sayanus)	Pirate perch	10.0	12.0	12.0	8.0	42.0
(Lepomis macrochirus)	Bluegill	6.5	12.0	8.0	7.5	34.0
(Fundulus olivaceus)	Blackspotted topminnow	8.5	9.0	10.5	1.0	29.0
(Lepomis punctatus)	Spotted sunfish	7.5	9.0	6.0	4.0	26.5
(Lepomis megalotis)	Longear	6.0	10.5	8.0	1.0	25.5
(Lepomis gulosus)	Warmouth	9.0	9.0	5.5		23.5
(Micropterus salmoides)	Largemouth bass	6.5	12.0	2.0	2.0	22.5
(Ictalurus natalis)	Yellow bullhead	8.5	9.0	1.0	3.0	21.5
(Etheostoma chlorosomum)	Bluntnose darter	2.0	12.0	7.5		21.5
(Pomoxis nigromaculatus)	Black crappie	1.0	9.0	3.0	7.5	20.5
(Notropis emiliae)	Pugnose minnow		7.5	5.5	6.0	19.0
(Etheostoma asprigene)	Mud darter		9.0		9.0	18.0
(Elassoma zonatum)	Banded pygmy sunfish	12.0	2.0	4.0		18.0
(Notropis atherinoides)	Emerald shiner		7.5		10.0	17.5
(Etheostoma gracile)	Slough darter	9.0	2.0	5.0		16.0
(Lepisosteus oculatus)	Spotted gar	2.5	7.0	6.0		15.5
(Notemigonus crysoleucas)	Golden shiner	12.0	1.0	2.0		15.0
(Lepomis cyanellus)	Green sunfish	6.0	4.0	5.0		15.0
(Etheostoma proeliare)	Cypress darter	6.0	9.0			15.0
(Ictalurus punctatus)	Channel catfish		2.5		12.0	14.5
(Aplodinotus grunniens)	Freshwater drum		4.5	2.0	8.0	14.5
(Notropis fumeus)	Ribbon shiner	1.0	8.0	5.0		14.0
(Noturus gyrinus)	Tadpole madtom	6.0	6.0	1.0		13.0
(Pimephales vigilax)	Bullhead minnow				12.0	12.0
(Esox americanus)	Grass pickerel	9.0		2.0		11.0
(Amia calva)	Bowfin	10.0	S	1.0	S	11.0
(Fundulus notatus)	Blackstripe topminnow		9.0		1.0	10.0
(Notropis venustus)	Blacktail shiner		2.0		7.5	9.5
(Erimyzon sucetta)	Lake chubsucker	9.5				9.5
(Notropis texanus)	Weed shiner	6.0		3.0		9.0
(Dorosoma cepedianum)	Gizzard shad		3.0	4.0	2.0	9.0
(Centrarchus macropterus)	Flier	9.0				9.0
(Pylodictis olivaris)	Flathead catfish				8.0	8.0
(Ictiobus niger)	Black buffalo		2.0		6.0	8.0
(Hybognathus hayi)	Cypress minnow	5.5	1.0			6.5
*(Percina maculata)	Blackside darter				6.0	6.0
(Minytrema melanops)	Spotted sucker	1.5		2.0	2.0	5.5
(Micropterus punctulatus)	Spotted bass		1.0		3.5	4.5
(Cyprinus carpio)	Carp	S	1.5	S	3.0	4.5
(Lepomis symmetricus)	Bantam sunfish	1.5	1.0			2.5
(Hybognathus nuchalus)	Silvery minnow	1.5		1.0		2.5
(Ictiobus bubalus)	Smallmouth buffalo		2.0	S	S	2.0
(Pomoxis annularis)	White crappie	S	1.5			1.5
(Lepomis microlophus)	Redear	S	1.5			1.5
(Notropis maculatus)	Taillight shiner	1.0				1.0
(Labidesthes sicculus)	Brook silversides	1.0				1.0
(Ictalurus melas)	Black bullhead	1.0				1.0
(Lepisosteus platostomus)	Shortnose gar	S				0.0
(Ictiobus cyprinellus)	Bigmouth buffalo	S				0.0
(Esox niger)	Chain pickerel	S				0.0
	NUMBER OF SPECIES=	37	36	28	26	51.0

* - SENSITIVE SPECIES

S - SPRING COLLECTION ONLY

FIGURE F-1. NUMBER OF FISH SPECIES COLLECTED FROM DELTA ECOREGION REFERENCE STREAMS

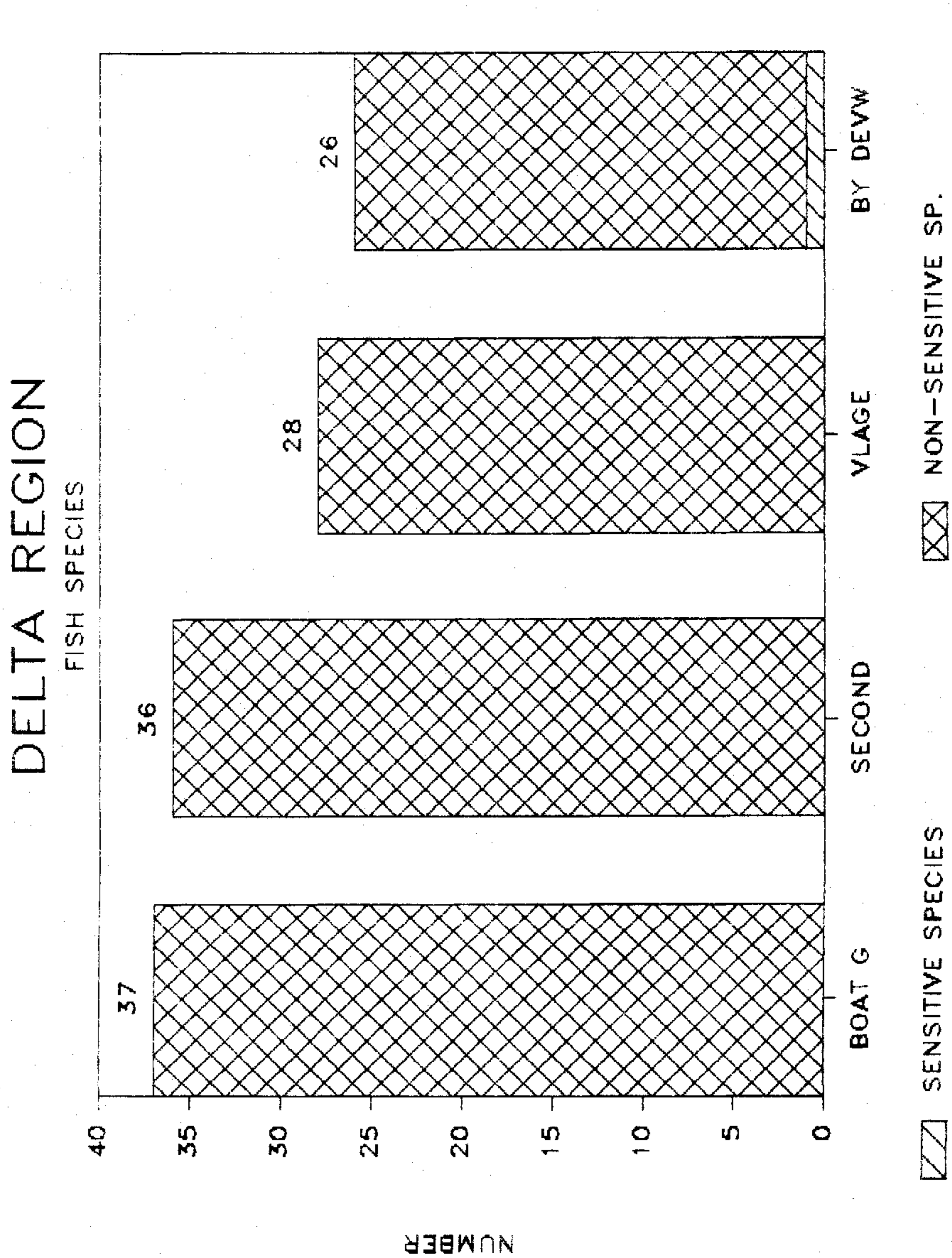


FIGURE F-2. ABUNDANCE OF KEY FISH FAMILIES

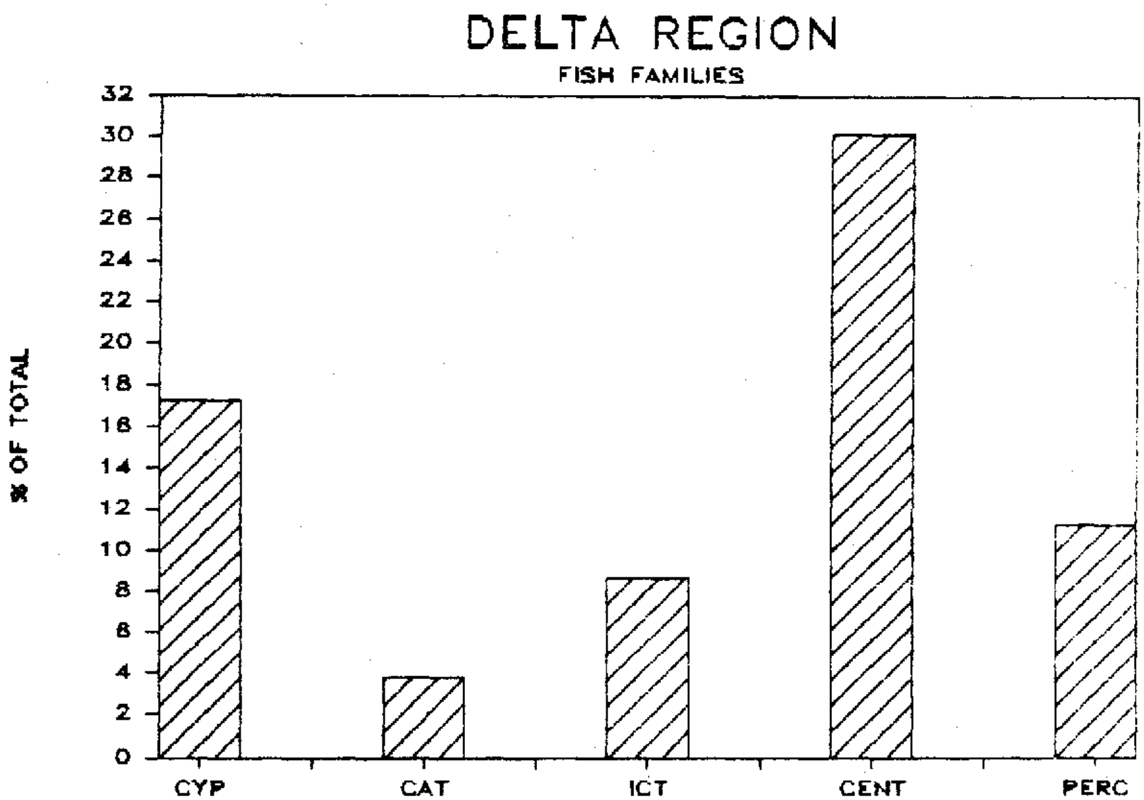
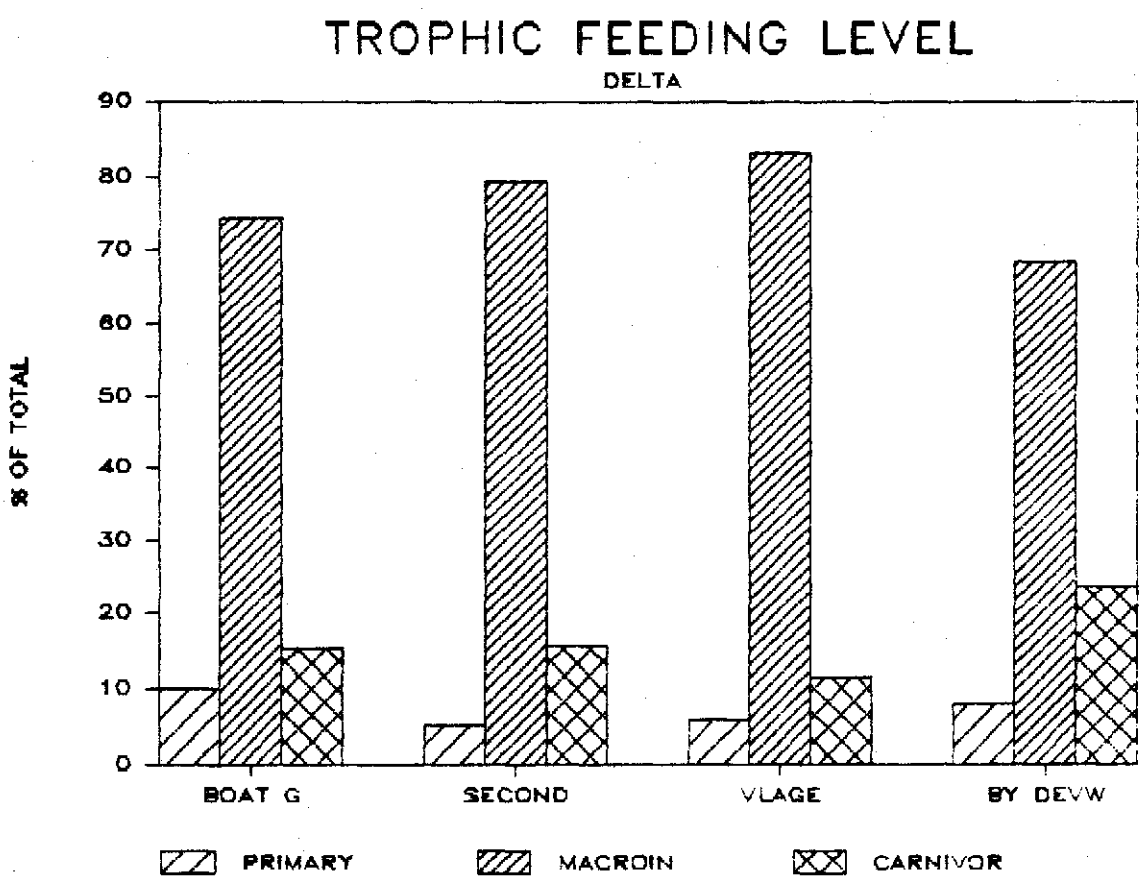


FIGURE F-3. DISTRIBUTION OF FISHES AMONG TROPHIC FEEDING LEVELS



well to turbid environments. The reduction of the Centrarchidae in the Bayou DeView site is, in part, caused by the low population of longear, which is one of the species of Centrarchidae that has a low tolerance to turbidity.

The trophic feeding levels of all sites are dominated by macroinvertebrate feeders, but this ecoregion has the highest proportion of carnivores of all ecoregions. The consistency of the trophic feeding levels among all Delta Ecoregion sites is apparent, but the Bayou DeView site has the highest proportion of carnivores due to its population of adult channel catfish and flathead catfish (Figure F-3).

Springtime sampling of these reference streams with trammel nets was very effective. In Boat Gunwale Slash, six additional species were collected during this period. These were primarily adult fishes such as carp, buffalo, gar and chain pickerel that had moved into this small stream for spawning during the high springtime flows. Large numbers of spawning buffalo and carp were also taken in Village Creek and Bayou DeView.

A single list of key and indicator species that adequately characterizes the Delta Ecoregion is difficult due to extensive and variable modifications of most streams within the region. The modifications are primarily related to agricultural needs and generally comprise some form of stream channelization to expedite drainage. Table F-2 lists the dominant key and indicator species for both unaltered and channel-altered streams within the ecoregion. Comparative fish population sampling in altered streams in the Delta has been done in association with use attainability studies. This information was utilized in developing these lists for channel-altered streams. The fishes in the channel-altered streams are generally tolerant of moderate to high turbidity levels from silt/clay particles and do not depend on an abundance of instream structures for cover or feeding areas.

Table F-2. Dominant Key Species and Indicator Species of Unaltered and Physically Altered Streams within the Delta Ecoregion

Unaltered Streams	Channel-Altered Streams
Key Species	
Ribbon shiner	Blacktail shiner
Smallmouth buffalo	Drum
Yellow bullhead	Carp
Bluegill	Channel catfish
Bluntnose darter	Green sunfish
Largemouth bass	Spotted gar
Indicator Species	
Pugnose minnow	Mosquitofish
Mosquitofish	Gizzard shad
Pirate perch	
Tadpole madtom	

Gulf Coastal Ecoregion

The relative abundance value of all species collected in this ecoregion, by sample site, is given in Table F-3. A total of 66 species, including 12 sensitive species, were collected. This represents the second highest species richness of the six ecoregions. With the exception of East Fork Tulip Creek and Cypress Creek, there is a general progression of increased species richness as watershed sizes increase (Figure F-4). A notably larger number of total and sensitive species occur in the relatively small watershed sites on East Fork Tulip and Cypress Creeks. These streams have substantial springwater influenced flows and higher water quality than typical Gulf Coastal Ecoregion reference streams. The most diverse fish population of all reference streams sampled is found in Moro Creek. This stream has a 7_{Q-10} flow of zero and probably has zero flow during the critical season of each year. However, the size of the watershed above the sample station is the largest of all sites sampled within this ecoregion.

Fish populations within the Gulf Coastal Ecoregion are characteristically dominated by Centrarchids (Figure F-5). Percidae is the next dominant fish family. This is influenced by the relatively large number of Percid species in the two springwater-influenced streams and in the Moro Creek sample. Cyprinidae is the third dominant family.

As in all ecoregions, macroinvertebrate feeding fishes distinctly dominate these populations (Figure F-6). Primary feeders make up a very small part of the populations and no primary feeders were found in Whitewater Creek or Freeo Bayou. A relatively large part of the fish populations in the springwater-influenced streams and in the three largest watersheds is composed of carnivorous fishes.

Springtime sampling in these reference streams was severely hampered by very high flows during one spring and very low flows during another spring. All successful springtime sampling was done with trammel nets; however, only one additional species was collected from Cypress Creek, Big Creek, Whitewater Creek and Moro Creek.

Because of the two substantially different types of streams within this ecoregion, two lists of dominant key species and indicator species are given in Table F-4. The springwater-influenced streams have a significantly different fishery from the typical Gulf Coastal streams. These differences are primarily a result of the critical season flow difference, although dissolved oxygen and other water quality differences are also apparent. The springwater-influenced streams can be further differentiated by their greater abundance of sensitive species, a higher percentage of Ictaluridae, which are primarily madtoms, and a slightly lower composition of Centrarchids, which are normally dominated by longear instead of bluegill and warmouth as in the typical Gulf Coastal streams.

TABLE F-3. FISHES OF GULF COASTAL ECOREGION REFERENCE STREAMS

FISH SPECIES		TULIP	CYPRS	W.WTR	BIG	DERSX	FREEO	HDGNS	L'AGL	MORO	SUM
(Aphredoderus sayanus)	Pirate perch	9.0	10.5	10.0	12.0	9.0	12.0	12.0	9.0	10.5	94.0
(Lepomis gulosus)	Warmouth	6.5	9.0	12.0	7.0	12.0	7.0	10.0	10.5	10.0	84.0
(Lepomis megalotis)	Longear	12.0	12.0	9.0	5.5	10.5	10.0	6.0	6.0	6.5	77.5
(Fundulus olivaceus)	Blackspotted topminnow	7.5	9.0	7.5	6.0	9.0	10.5	11.0	9.0	8.0	77.5
(Centrarchus macropterus)	Flier	4.5	9.0	12.0	10.0	12.0	6.0	8.0	10.5	5.0	77.0
(Esox americanus)	Grass pickerel	9.0	9.0	9.0	9.0	9.0	9.0	3.0	12.0	7.0	76.0
(Minytrema melanops)	Spotted sucker	2.0	7.0	9.0	1.0	11.0	3.0	12.0	12.0	12.0	69.0
(Ictalurus natalis)	Yellow bullhead	6.0	12.0	1.0	2.0	12.0	6.0	8.0	12.0	9.0	68.0
(Gambusia affinis)	Mosquitofish	4.5	4.5	9.0	9.0	6.5	7.5	9.0	9.0	7.5	66.5
(Etheostoma gracile)	Slough darter	7.5	4.5	9.0	9.0	10.0	2.0	12.0	7.0	4.0	65.0
(Notropis umbratilis)	Redfin shiner	12.0	12.0	6.0	6.0	9.0	10.5	6.5		2.0	64.0
(Lepomis macrochirus)	Bluegill	4.5		4.0	5.5	7.5	3.0	9.0	12.0	9.0	54.5
(Lepomis cyanellus)	Green sunfish	6.5	9.0	6.0	6.5	5.0	4.0	4.0	6.0	4.0	51.0
(Etheostoma whipplei)	Redfin darter	6.0	9.0	4.0	2.0	6.0	7.0	3.0	6.0	7.5	50.5
(Elassoma zonatum)	Banded pygmy sunfish	9.0	6.0	9.0	9.0	4.0	4.0	2.0	1.0	4.0	48.0
*(Etheostoma collettei)	Creole darter	9.0	7.5	1.0	S	1.0	9.0	2.0	7.0	11.0	47.5
(Lepomis punctatus)	Spotted sunfish	5.0	6.0	5.0		5.0	9.0	3.0	9.0	4.5	46.5
*(Percina maculata)	Blackside darter	6.0	6.0		7.0	5.5	8.0	5.5		5.0	43.0
(Etheostoma chlorosomum)	Bluntnose darter		1.0	1.0	2.0	6.0	6.0	12.0	4.5	9.0	41.5
(Micropterus salmoides)	Largemouth bass	7.5	2.0	1.0		4.0	2.0	9.0	7.5	7.0	40.0
*(Percina sciera)	Dusky darter	6.5	8.0		1.0	4.0	7.0		1.0	9.0	36.5
(Fundulus notatus)	Blackstripe topminnow	9.0	7.5	4.0				4.0	6.0	6.0	36.5
(Amia calva)	Bowfin	3.0	7.0	3.0		6.0	1.0	7.0	2.5	6.5	36.0
(Esox niger)	Chain pickerel		10.5	S		4.0		4.5	10.0	6.0	35.0
(Notropis chrysocephalus)	Striped shiner	9.0	7.5		6.0	2.0	1.0	4.0		5.0	34.5
(Notropis emiliae)	Pugnose minnow	6.0	6.0		1.0	3.0	2.0	6.0	2.0	7.0	33.0
(Hybognathus nuchalus)	Silvery minnow	1.5			2.0	7.0		12.0		9.0	31.5
(Erimyzon oblongus)	Creek chubsucker	2.0		6.0	8.0	5.0	5.0	1.0	2.0	2.5	31.5
*(Moxostoma poecilurum)	Blacktail redhorse	12.0	7.5			7.0	2.0	S		2.0	30.5
(Hybognathus hayi)	Cypress minnow					6.0		9.0	4.0	9.0	28.0
(Notropis fumeus)	Ribbon shiner					6.0		2.0	6.0	12.0	26.0
(Noturus nocturnus)	Freckled madtom	10.5	12.0							3.0	25.5
(Etheostoma proeliare)	Cypress darter		1.0	9.0			6.0		4.5	4.0	24.5
(Noturus gyrinus)	Tadpole madtom		6.0			4.0	9.0	2.0	1.0	2.0	24.0
(Notemigonus crysoleucas)	Golden shiner		1.0		9.0	8.0			2.0	4.0	24.0
(Notropis texanus)	Weed shiner					4.0			2.0	12.0	18.0
(Micropterus punctulatus)	Spotted bass	6.0	7.5					2.0			15.5
(Moxostoma erythrurum)	Golden redhorse	6.5	6.0							1.0	13.5
(Pomoxis nigromaculatus)	Black crappie		1.0			1.0		2.0	2.0	7.0	13.0
*(Ammocrypta vivax)	Scaly sand darter	9.0	1.0							2.0	12.0
(Noturus miurus)	Brindled madtom	10.5									10.5
(Percina caprodes)	Logperch							1.0		9.0	10.0
(Labidesthes sicculus)	Brook silversides		1.5			2.0	1.0		1.0	4.0	9.5
(Notropis atherinoides)	Emerald shiner						4.5		4.0		8.5
(Pimephales notatus)	Bluntnose minnow	7.5									7.5
(Aplodinotus grunniens)	Freshwater drum									5.0	5.0
(Pimephales vigilax)	Bullhead minnow									4.0	4.0
(Ichthyomyzon gagei)	Southern brook lamprey	3.0	1.0								4.0
(Campostoma anomalum)	Stoneroller	1.0	3.0								4.0
(Lepomis symmetricus)	Bantam sunfish			3.0							3.0
(Lepomis hybrid)	Hybrid sunfish					1.0	1.0	1.0			3.0
(Anguilla rostrata)	American eel		3.0								3.0
*(Percina ouachitae)	Saddleback darter									2.5	2.5
*(Etheostoma stigmaeum)	Speckled darter	1.5	1.0								2.5
*(Etheostoma parvipinne)	Goldstripe darter		1.0				1.0				2.0
(Percina shumardi)	River darter									2.0	2.0
(Cyprinus carpio)	Carp									2.0	2.0
*(Notropis amnis)	Pallid shiner									1.0	1.0
*(Hypentelium nigricans)	Northern hogsucker		1.0								1.0
*(Fundulus catenatus)	Northern studfish		1.0								1.0
*(Ammocrypta asprella)	Crystal darter									1.0	1.0
(Notropis venustus)	Blacktail shiner									1.0	1.0
(Lepomis microlophus)	Redear							1.0			1.0
(Lepisosteus oculatus)	Spotted gar							1.0			1.0
(Pomoxis annularis)	White crappie									S	0.0
(Ichthyomyzon castaneus)	Chestnut lamprey		S								0.0
	NUMBER OF SPECIES=	36	43	25	24	36	32	37	33	50	66.0

* - SENSITIVE SPECIES
S - SPRING COLLECTION ONLY

FIGURE F-4. NUMBER OF FISH SPECIES COLLECTED FROM
GULF COASTAL ECOREGION REFERENCE STREAMS

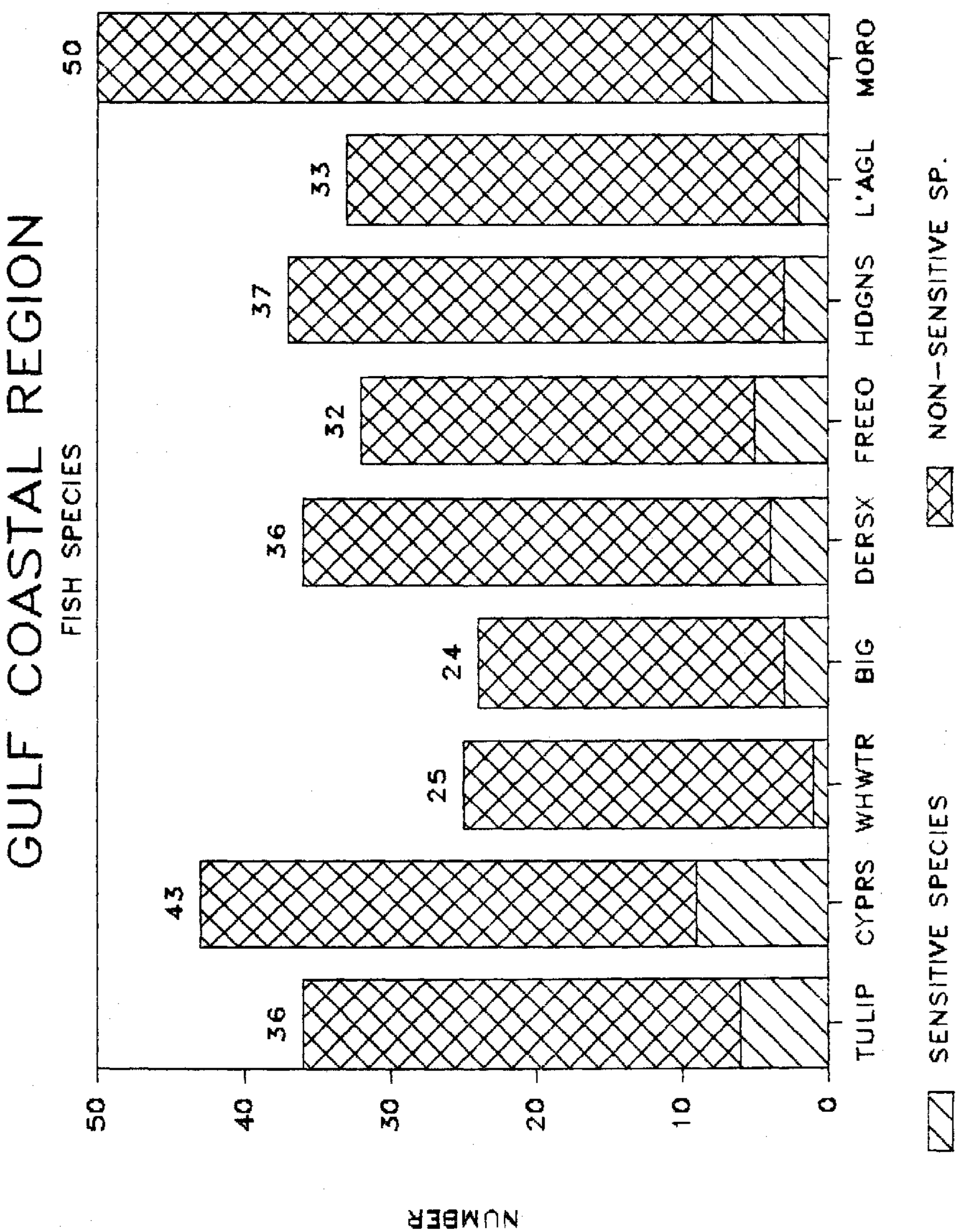


FIGURE F-5. ABUNDANCE OF KEY FISH FAMILIES

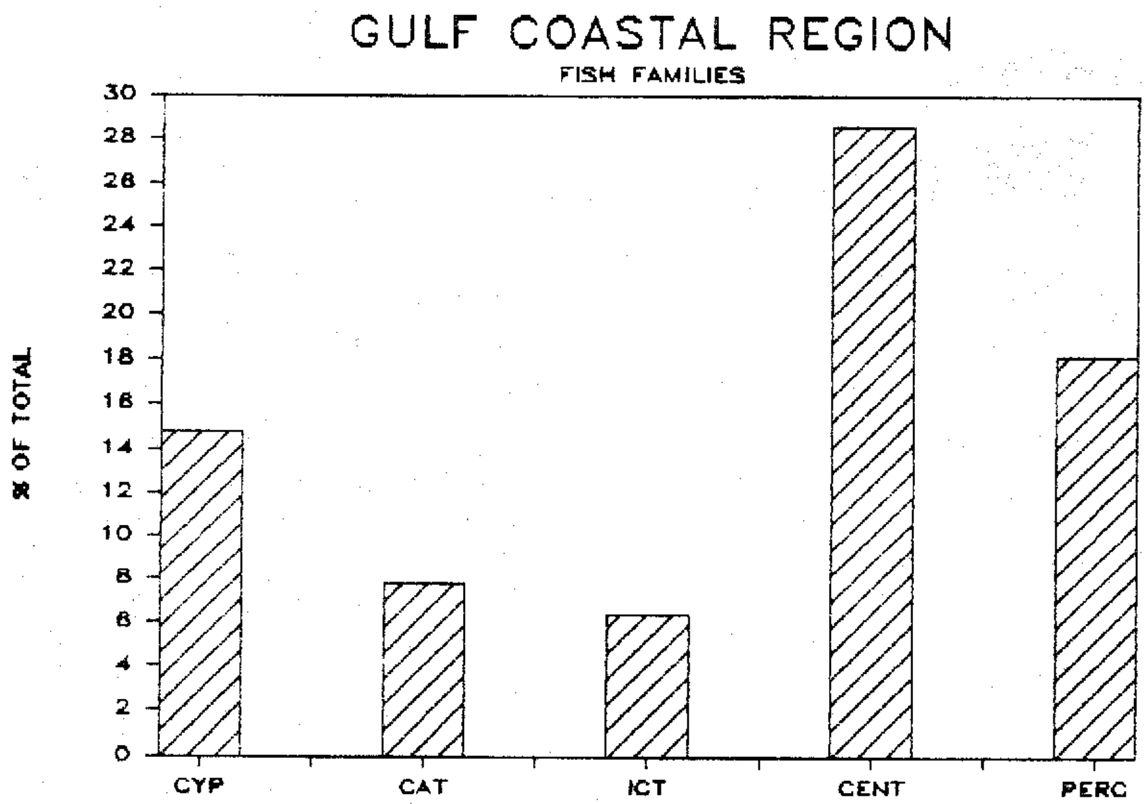


FIGURE F-6. DISTRIBUTION OF FISHES AMONG TROPHIC FEEDING LEVELS

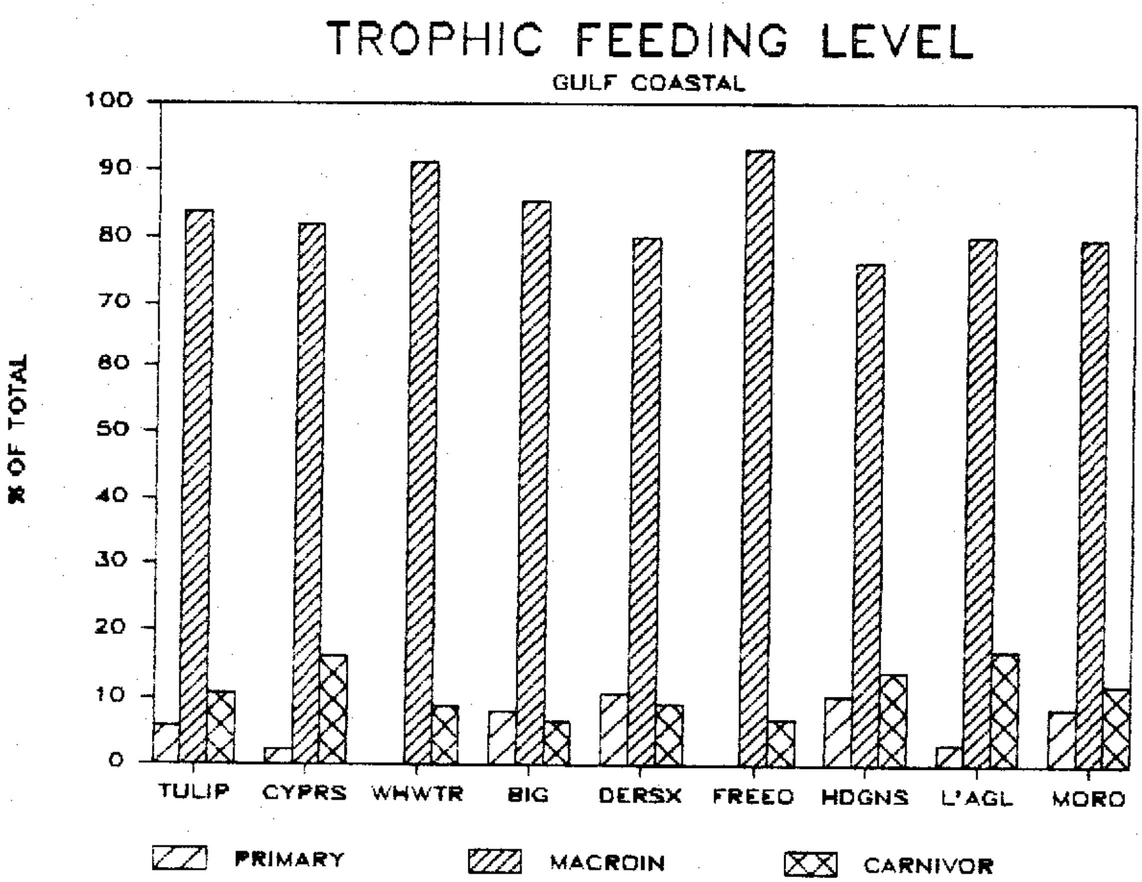


Table F-4. Dominant Key Species and Indicator Species of the Gulf Coastal Ecoregion Fish Populations

Typical Streams	Springwater Influenced
Key Species	
Redfin shiner	Redfin shiner
Spotted sucker	Blacktail redhorse
Yellow bullhead	Freckled madtom
Flier	Longear
Slough darter	Creole darter
Grass pickerel	Grass pickerel
Indicator Species	
Pirate perch	Pirate perch
Warmouth	Golden redhorse
Spotted sunfish	Spotted bass
Dusky darter	Scaly sand darter
Creek chubsucker	Striped shiner
Banded pygmy sunfish	Banded pygmy sunfish

Arkansas River Valley Ecoregion

Rotenone was used to sample the fish population at all sites within the Arkansas River Valley Ecoregion during the summer period. The 75 species collected from this ecoregion are listed in Table F-5 with their relative abundance value at each site.

The average number of species collected per site was 36 and the range was 27 to 44. The species richness of all samples was very similar, although the Dutch Creek site had a distinctly greater number of species (Figure F-7). Arkansas River Valley Ecoregion produced the largest number of species of all regions as it exhibits characteristics and subsequently fish populations reflecting both upland and lowland features. Sensitive species made up a relatively small part of these populations. Throughout this region, these species comprised less than 15% of the total population relative abundance. Centrarchidae was the dominant fish family at these sample sites, but it was closely followed by Cyprinidae. Percidae was noticeably sub-dominant to the dominant families and Ictaluridae was nearly as abundant as the darters (Figure F-8). This was due primarily to an abundance of several species of madtoms within these samples. Many samples had two or more species of madtoms that were common to abundant. The yellow bullhead was also numerous in most samples.

The trophic feeding level of the fishes was significantly dominated by macroinvertebrate feeders. Carnivores and primary feeders made up nearly equal parts of the remainder of the population (Figure F-9).

TABLE F-5. FISHES OF ARKANSAS RIVER VALLEY REFERENCE STREAMS

FISH	SPECIES	MILL CR.	N.FK.CAD	TEN MI.	DUTCH	PET JEAN	CADRON	SUM
(Lepomis megalotis)	Longear	10.5	10.5	12.0	12.0	12.0	6.0	63.0
(Pimephales notatus)	Bluntnose minnow	12.0	9.0	12.0	12.0	12.0	4.0	61.0
(Etheostoma whipplei)	Redfin darter	12.0	12.0	9.0	12.0	12.0		57.0
(Fundulus olivaceus)	Blackspotted topminnow	9.0	12.0	9.0	9.0	9.0	7.5	55.5
(Lepomis cyanellus)	Green sunfish	12.0	10.5	7.5	10.5	9.0	2.0	51.5
(Micropterus punctulatus)	Spotted bass	9.0	7.5	7.5	8.0	9.0	8.0	49.0
(Ictalurus natalis)	Yellow bullhead	10.5	12.0	12.0	12.0	2.0		48.5
(Lepomis macrochirus)	Bluegill	9.0	6.0	7.5	7.5	6.0	12.0	48.0
*(Noturus exilis)	Slender madtom	9.0	12.0	9.0	5.5	12.0		47.5
(Labidesthes sicculus)	Brook silversides	9.0	4.5	9.0	9.0	9.0	6.0	46.5
(Campostoma anomalum)	Stoneroller	S	12.0	6.0	10.5	9.0		37.5
(Notropis umbratilis)	Redfin shiner	9.0	9.0	6.0	4.0	6.0	2.0	36.0
(Moxostoma erythrurum)	Golden redhorse	10.5	9.0	2.0	2.0	9.0	1.0	33.5
*(Notropis boops)	Bigeye shiner	9.0	9.0	9.0	6.0			33.0
(Erimyzon oblongus)	Creek chubsucker	5.0	12.0	9.0	2.0			28.0
(Esox americanus)	Grass pickerel	9.0	7.5		10.0	1.0		27.5
(Etheostoma spectabile)	Orangethroat darter		9.0		10.5	7.5		27.0
(Minytrema melanops)	Spotted sucker	9.0	7.5	2.0	2.0	2.0	4.0	26.5
(Dorosoma cepedianum)	Gizzard shad	10.5				4.0	12.0	26.5
(Notropis emiliae)	Pugnose minnow	S		1.0	9.0	6.0	9.0	25.0
(Noturus gyrinus)	Tadpole madtom			7.5	9.0		7.5	24.0
(Micropterus salmoides)	Largemouth bass	1.5	7.5	8.0	1.0	2.0	4.0	24.0
(Aphredoderus sayanus)	Pirate perch	1.5	4.0	9.0	6.0		2.0	22.5
(Noturus miurus)	Brindled madtom				9.0	12.0		21.0
(Notropis fumeus)	Ribbon shiner				9.0	7.5	4.5	21.0
(Fundulus notatus)	Blackstripe topminnow			9.0	12.0			21.0
(Aplodinotus grunniens)	Freshwater drum	3.0				6.0	12.0	21.0
(Lepomis gulosus)	Warmouth	4.0		4.0	5.0	1.0	6.0	20.0
(Pimephales vigilax)	Bullhead minnow	S				7.5	12.0	19.5
(Percina caprodes)	Logperch	4.0	1.0		7.0	7.0		19.0
*(Notropis whipplei)	Steelcolor shiner		1.0		8.5	4.5	4.0	18.0
(Ictalurus punctatus)	Channel catfish				4.0	4.0	9.0	17.0
(Noturus nocturnus)	Freckled madtom				7.5	9.0		16.5
*(Percina sciera)	Dusky darter				6.0	6.0	4.0	16.0
(Lepomis humilis)	Orangespotted sunfish					9.0	6.0	15.0
(Lepomis punctatus)	Spotted sunfish	1.0	6.0		6.0		1.0	14.0
*(Etheostoma stigmaeum)	Speckled darter				6.0	7.5		13.5
(Gambusia affinis)	Mosquitofish					9.0	4.0	13.0
(Notropis volucellus)	Mimic shiner						12.0	12.0
(Etheostoma gracile)	Slough darter				9.0		1.0	10.0
*(Percina copelandi)	Channel darter					7.5	2.0	9.5
*(Etheostoma punctulatum)	Stippled darter			9.0				9.0
(Notropis atherinoides)	Emerald shiner						9.0	9.0
*(Etheostoma caeruleum)	Rainbow darter			7.5				7.5
(Notropis chrysocephalus)	Striped shiner			7.5				7.5
(Etheostoma proeliare)	Cypress darter			7.5				7.5
*(Etheostoma flabellare)	Fantail darter		7.0					7.0
(Notropis venustus)	Blacktail shiner					1.0	6.0	7.0
*(Percina maculata)	Blackside darter	3.0	1.5	1.0	1.0			6.5
*(Etheostoma blennioides)	Greenside darter			6.0				6.0
(Etheostoma chlorosomum)	Bluntnose darter			6.0				6.0
(Pomoxis annularis)	White crappie				1.0		4.5	5.5
(Ictiobus bubalus)	Smallmouth buffalo					4.0	1.0	5.0
(Lepomis microlophus)	Redear	4.0						4.0
(Elassoma zonatum)	Banded pygmy sunfish						4.0	4.0
(Amia calva)	Bowfin	3.0					1.0	4.0
(Notemigonus crysoleucas)	Golden shiner		1.0	1.5	1.0			3.5
*(Hypentelium nigricans)	Northern hogsucker	1.0	1.0	1.0				3.0
(Pylodictis olivaris)	Flathead catfish					2.0	1.0	3.0
(Morone chrysops)	White bass					2.0	1.0	3.0
(Lepomis hybrid)	Hybrid sunfish			1.0	2.0			3.0
(Etheostoma asprigene)	Mud darter						3.0	3.0
(Lepisosteus oculatus)	Spotted gar				1.5	1.0		2.5
(Carpiodes carpio)	River carpsucker				S		2.5	2.5
(Ictalurus melas)	Black bullhead	S		2.0				2.0
(Esox niger)	Chain pickerel	1.0		1.0				2.0
(Pomoxis nigromaculatus)	Black crappie	1.5						1.5
*(Semotilus atromaculatus)	Creek chub			1.0				1.0
*(Etheostoma histrio)	Harlequin darter					1.0		1.0
(Ichthyomyzon sp.)	Lamprey larvae				1.0			1.0
*(Pimephales tenellus)	Slim minnow				S			0.0
*(Moxostoma carinatum)	River Redhorse					S		0.0
(Moxostoma macrolepidotum)	Shorthead redhorse				S			0.0
(Lepisosteus osseus)	Longnose gar					S		0.0
(Cyprinus carpio)	Carp				S			0.0
	NUMBER OF SPECIES=	33	27	35	44	41	38	75.0

* - SENSITIVE SPECIES
S - SPRING COLLECTION ONLY

FIGURE F-7. NUMBER OF FISH SPECIES COLLECTED FROM
ARKANSAS RIVER VALLEY REFERENCE STREAMS

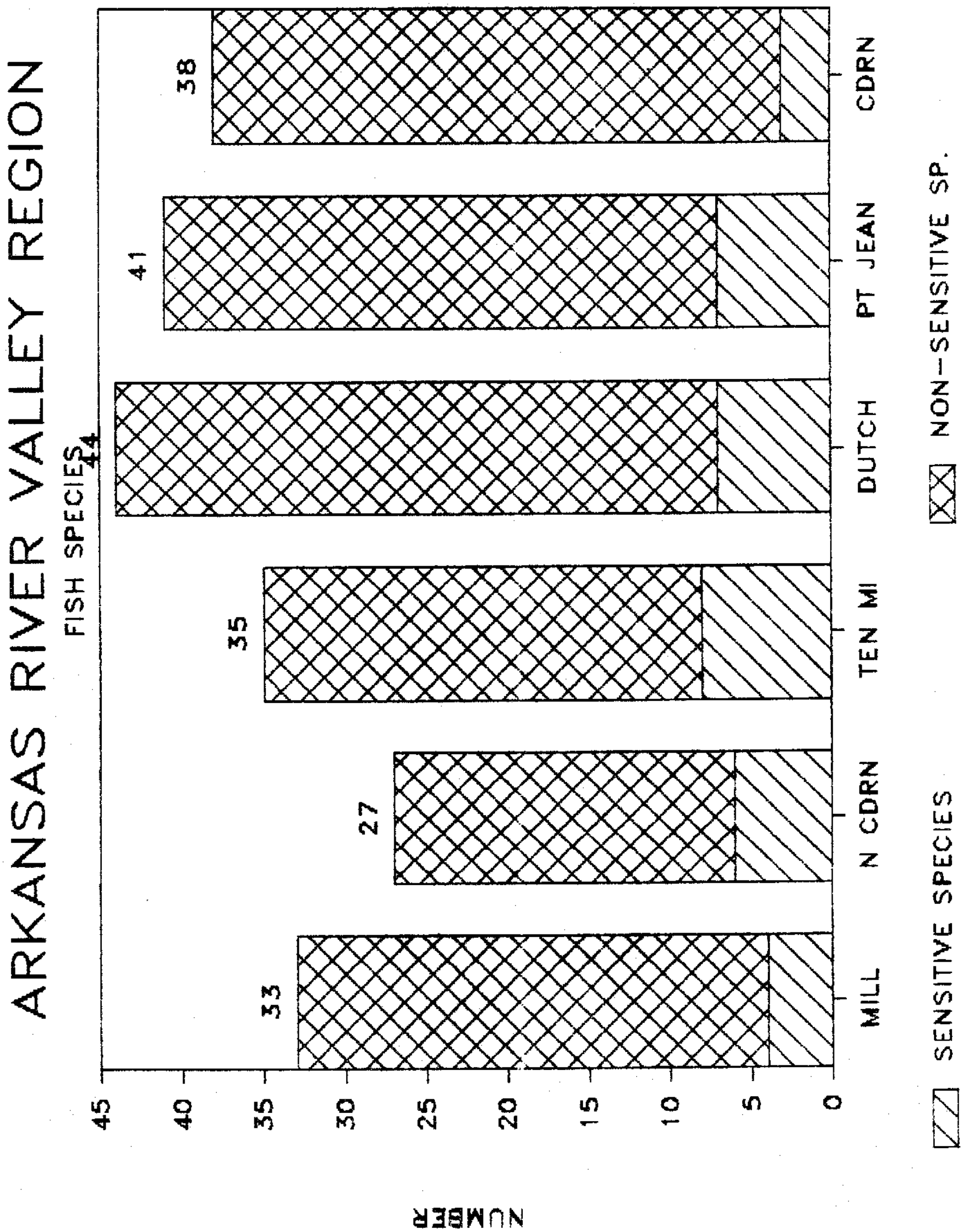


FIGURE F-8. ABUNDANCE OF KEY FISH FAMILIES

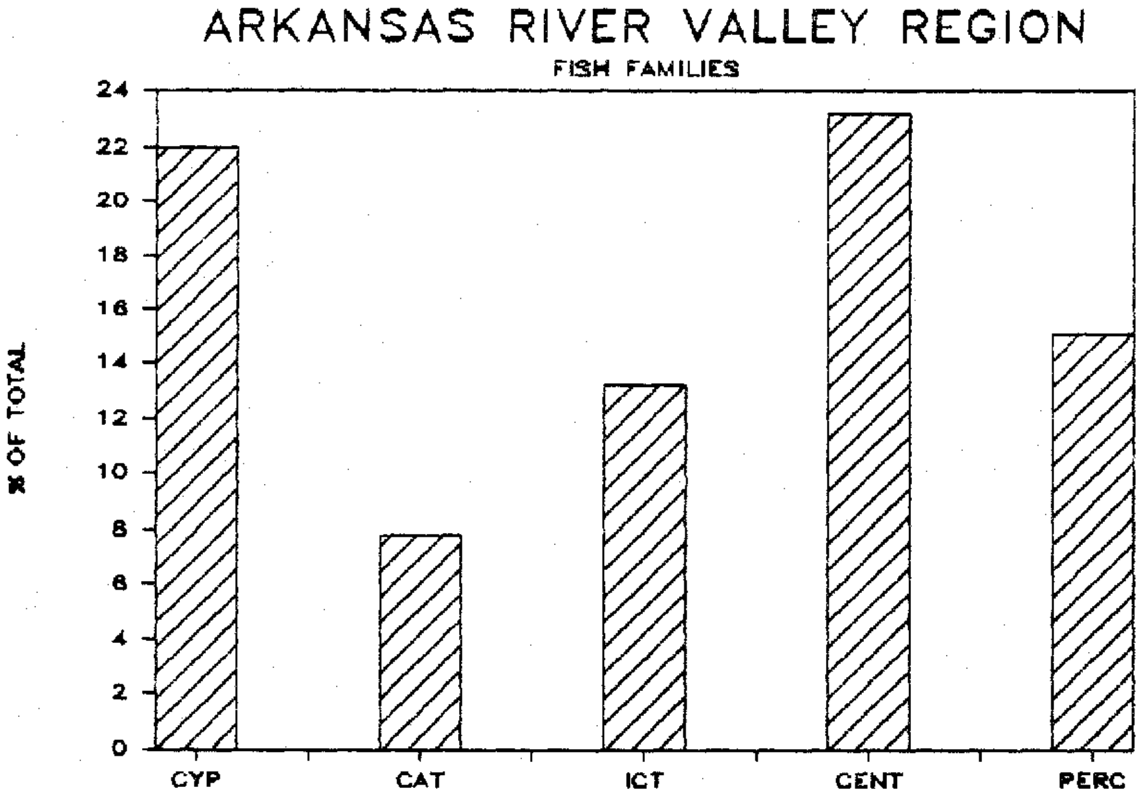
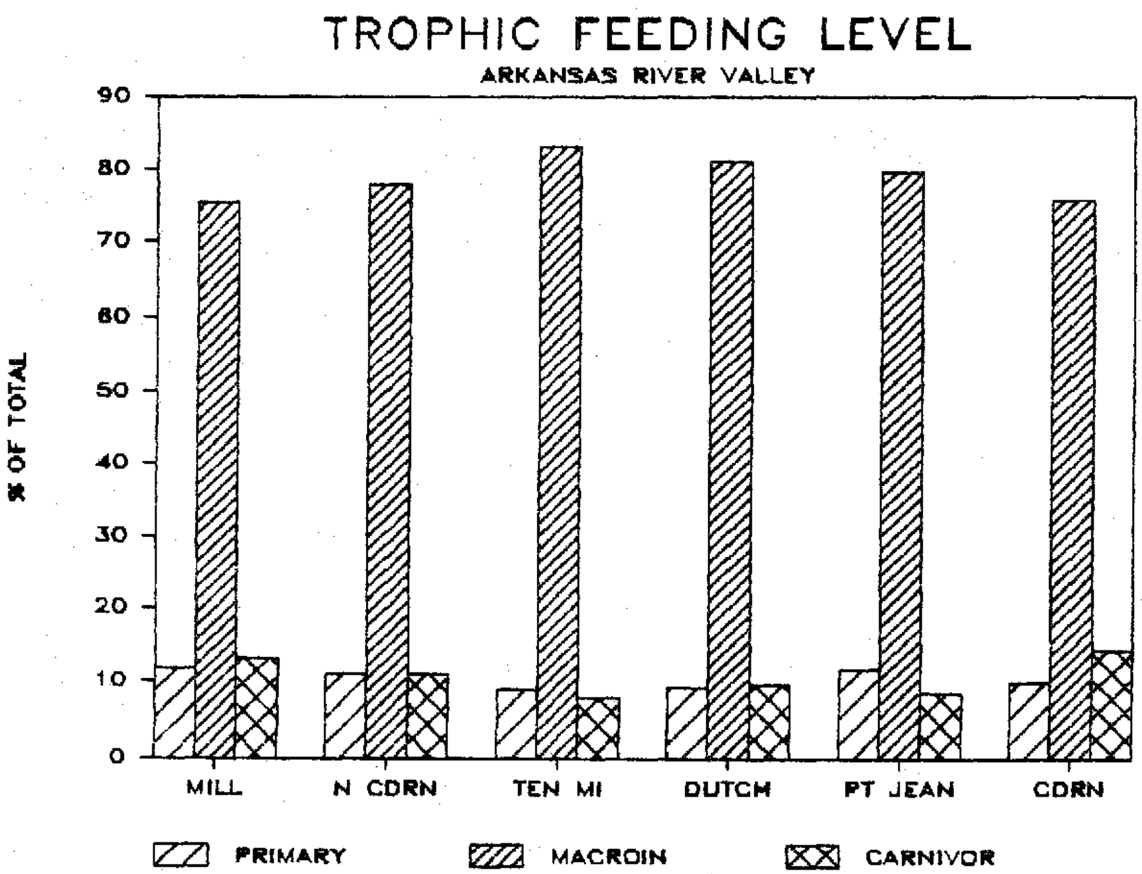


FIGURE F-9. DISTRIBUTION OF FISHES AMONG TROPHIC FEEDING LEVELS



Overnight trammel netting was done at each site to capture fishes during the spring sampling. This was supplemented by electrofishing collections on Mill Creek, Ten Mile Creek and Dutch Creek. Three additional species were collected during spring sampling in both Mill Creek and Dutch Creek. Two species were added to the species list of the Petit Jean River from the spring sampling.

Dominant key species within specific groups of Arkansas River Valley fishes are listed in Table F-6. Additionally, sub-dominant but indicator species of the region are also listed. The fish populations within this ecoregion are unique but are highly variable as are the streams of the region, many of which have upland-influenced segments and lowland-influenced segments. The region may be called "transitional" since it separates two very similar ecoregions (Boston Mountains and Ouachita Mountains); however, there is little similarity among the fishes of the Arkansas River Valley and its northern and southern boundary ecoregions.

The fishery of this ecoregion is characterized by its key and indicator species, the Centrarchidae-Cyprinidae-dominated populations, substantial numbers of Ictalurids and its moderately low composition of sensitive species.

Table F-6. Dominant Key Species and Indicator Species of Arkansas River Valley Ecoregion Fish Populations

Key Species	Indicator Species
Bluntnose minnow	Orangespotted sunfish
Golden redhorse	Blackside darter
Yellow bullhead	
Longear	
Redfin darter	
Spotted bass	

Ouachita Mountains Ecoregion

The fish population was sampled during the summer period with electorfishing gear in all reference streams within the Ouachita Mountains Ecoregion. Table F-7 lists all species collected and their relative abundance at each sample site. A total of 61 species, including 23 sensitive species, were collected. There was a general trend of increased species richness in the larger watershed sites and in those streams with lower stream gradients. However, the very high gradient in the large watershed of the Cossatot River site resulted in the lowest species richness of all Ouachita Mountains reference streams. Also, the relatively low gradient in the small watershed of the South Fork Ouachita River resulted in a relatively large number of species (Figure F-10).

The dominant fish family in reference streams of this ecoregion is Cyprinidae followed by Centrarchidae with Percidae a noticeable sub-dominant. Ictaluridae has the lowest abundance of the five major fish families (Figure F-11).

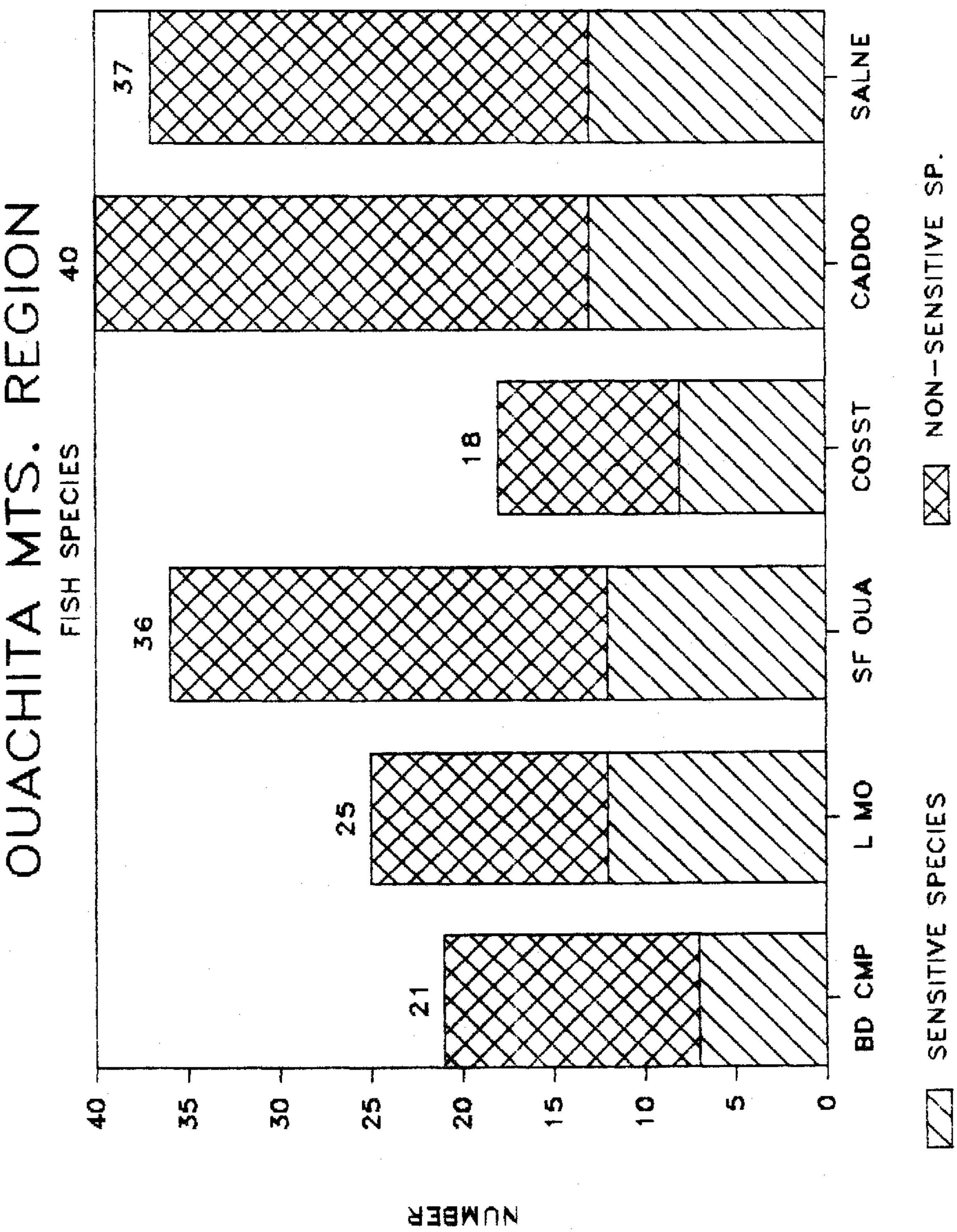
TABLE F-7. FISHES OF OUACHITA MOUNTAINS REFERENCE STREAMS

FISH SPECIES		BRD.CAMP	L.MO.	S.FK.OUA	COSSAT.	CADDO	SALINE	SUM
(Campostoma anomalum)	Stoneroller	12.0	12.0	12.0	12.0	12.0	12.0	72.0
(Lepomis megalotis)	Longear	10.5	12.0	12.0	12.0	12.0	9.5	68.0
*(Notropis boops)	Bigeye shiner	9.5	12.0	12.0	7.0	12.0	10.0	62.5
*(Etheostoma radiosum)	Orangebelly darter	12.0	12.0	12.0	12.0	12.0		60.0
*(Etheostoma blennioides)	Greenside darter	6.5	12.0	10.5		10.5	11.0	50.5
*(Micropterus dolomieui)	Smallmouth bass	4.0	9.5	10.5	8.0	6.0	7.0	45.0
(Noturus nocturnus)	Freckled madtom	9.0	2.0	9.0		10.5	12.0	42.5
(Lepomis cyanellus)	Green sunfish	9.0	6.0	9.0	6.0	9.0	2.0	41.0
(Notropis chrysocephalus)	Striped shiner	7.0	9.0	12.0		6.0	6.0	40.0
*(Fundulus catenatus)	Northern studfish	6.5	6.0	9.0	8.0	9.0		38.5
*(Hypentelium nigricans)	Northern hogsucker	7.0	9.0	9.0		5.0	6.5	36.5
(Pimephales notatus)	Bluntnose minnow	S	12.0	10.5		7.5	6.0	36.0
(Moxostoma erythrurum)	Golden redhorse	S		9.0	7.0	7.0	7.5	30.5
*(Etheostoma zonale)	Banded darter		1.0	7.5		9.0	12.0	29.5
(Percina caprodes)	Logperch		6.0	10.5	S	11.0	1.0	28.5
(Micropterus punctulatus)	Spotted bass			10.5		9.0	9.0	28.5
(Fundulus olivaceus)	Blackspotted topminnow	1.0	6.0	7.5	6.0	6.0	2.0	28.5
*(Moxostoma duquesnei)	Black redhorse		S	8.5	7.0	4.0	7.5	27.0
*(Ambloplites ariommus)	Shadow bass		7.5	8.0	2.0	4.5	5.0	27.0
*(Hybopsis x-punctata)	Gravel Chub					10.5	12.0	22.5
(Lepomis macrochirus)	Bluegill	4.0	1.0	6.0		7.0	2.0	20.0
*(Notropis whipplei)	Steelcolor shiner			7.5	1.0	6.0	4.0	18.5
(Ictalurus natalis)	Yellow bullhead	2.0	6.0	5.5	2.0			15.5
(Micropterus salmoides)	Largemouth bass		1.0	6.5	1.0	6.0		14.5
(Etheostoma whipplei)	Redfin darter						12.0	12.0
(Labidesthes sicculus)	Brook silversides	1.0	7.5			1.0	2.0	11.5
*(Nocomis asper)	Redspot chub			9.0				9.0
(Minytrema melanops)	Spotted sucker			6.0		3.0		9.0
(Lepomis microlophus)	Redear			6.0		2.0	1.0	9.0
*(Notropis snelsoni)	Ouachita Mt. shiner				8.5			8.5
(Esox americanus)	Grass pickerel			6.0			2.0	8.0
(Notropis umbratilis)	Redfin shiner		6.0	S			1.0	7.0
(Dorosoma cepedianum)	Gizzard shad					2.0	4.5	6.5
*(Noturus eleutherus)	Mountain madtom					6.0		6.0
*(Etheostoma collettei)	Creole darter						5.0	5.0
(Notropis atherinoides)	Emerald shiner			5.0				5.0
(Lepomis gulosus)	Warmouth			S		4.0	1.0	5.0
(Fundulus notatus)	Blackstripe topminnow					4.5	S	4.5
*(Noturus taylori)	Caddo madtom			1.0		2.0		3.0
(Ichthyomyzon sp.)	Lamprey larvae			2.0		1.0		3.0
(Lepomis hybrid)	Hybrid sunfish	1.5				1.0		2.5
*(Pimephales tenellus)	Slim minnow	2.0						2.0
(Pylodictis olivaris)	Flathead catfish				2.0			2.0
(Noturus miurus)	Brindled madtom						2.0	2.0
(Notropis fumeus)	Ribbon shiner		1.0			1.0		2.0
(Erimyzon oblongus)	Creek chubsucker	1.0		S		1.0		2.0
*(Semotilus atromaculatus)	Creek chub		1.0					1.0
*(Percina copelandi)	Channel darter						1.0	1.0
*(Etheostoma histrio)	Harlequin darter						1.0	1.0
(Lepomis punctatus)	Spotted sunfish						1.0	1.0
(Ichthyomyzon castaneus)	Chestnut lamprey						1.0	1.0
(Etheostoma chlorosomum)	Bluntnose darter			1.0				1.0
(Aphredoderus sayanus)	Pirate perch			S		1.0		1.0
*(Salmo gairdneri)	Rainbow trout		S					0.0
*(Noturus lachneri)	Ouachita madtom						S	0.0
*(Moxostoma carinatum)	River Redhorse					S	S	0.0
(Pomoxis nigromaculatus)	Black crappie					S		0.0
(Lepisosteus osseus)	Longnose gar				S	S		0.0
(Ictalurus punctatus)	Channel catfish					S	S	0.0
(Ictalurus melas)	Black bullhead	S						0.0
(Ichthyomyzon gagei)	Southern brook lamprey			S				0.0
	NUMBER OF SPECIES=	21	25	36	18	40	37	61.0

* - SENSITIVE SPECIES

S - SPRING COLLECTION ONLY

FIGURE F-10. NUMBER OF FISH SPECIES COLLECTED FROM OUACHITA MOUNTAINS REFERENCE STREAMS



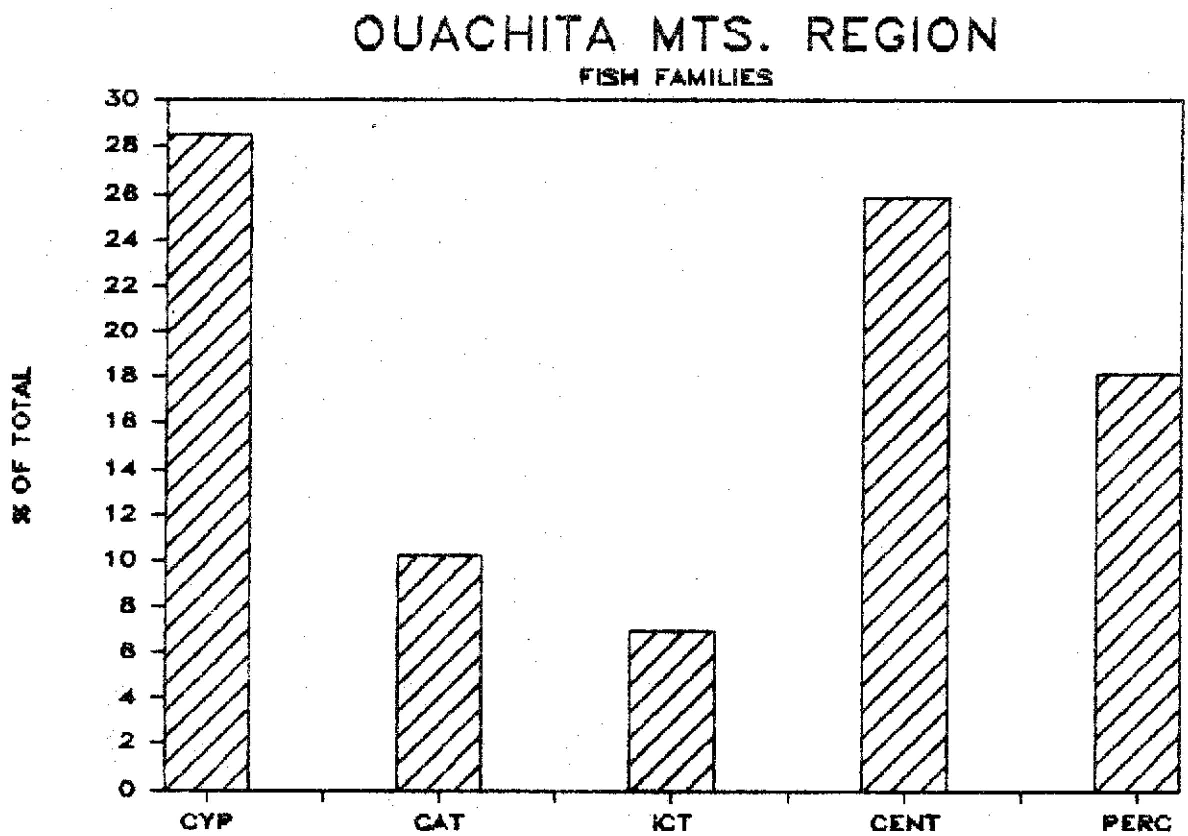
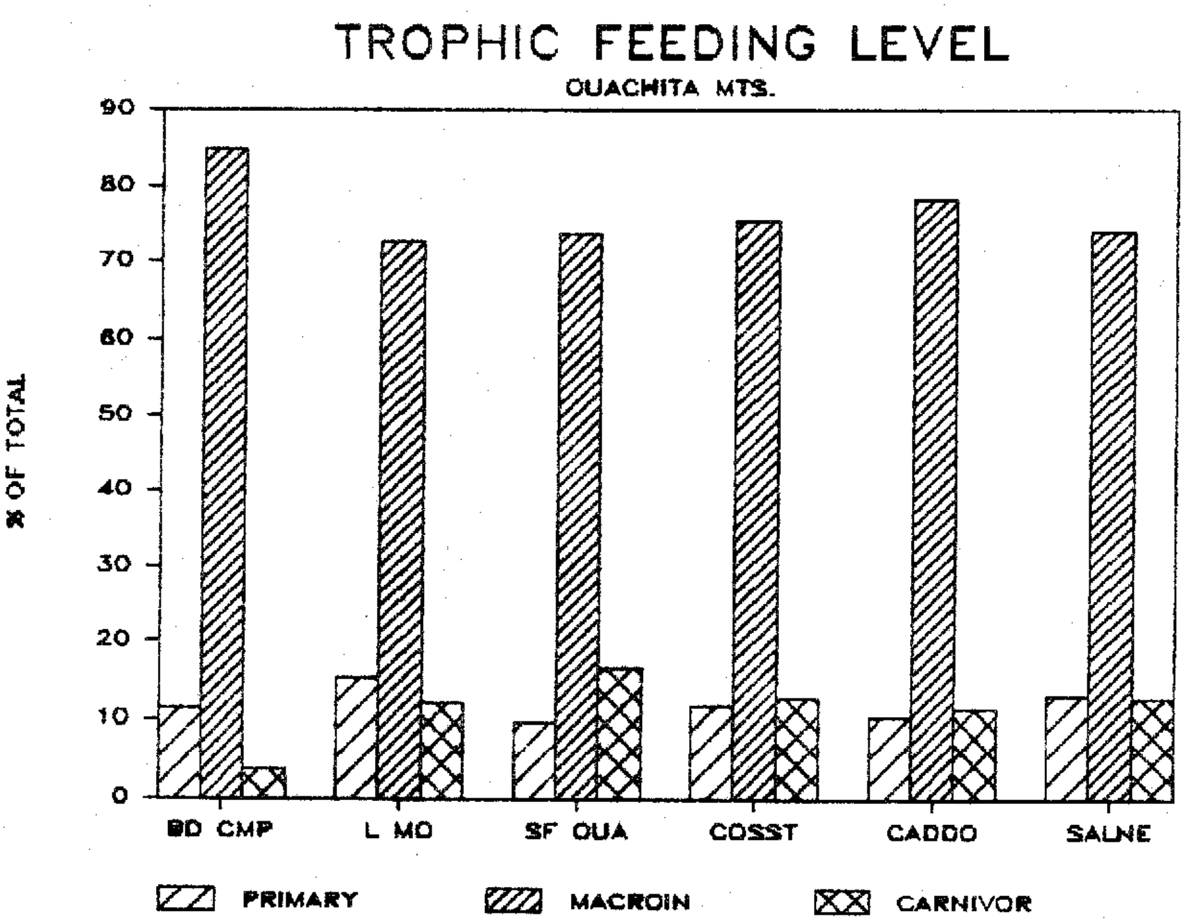


FIGURE F-12. DISTRIBUTION OF FISHES AMONG TROPHIC FEEDING LEVELS



Macroinvertebrate feeding fishes dominate the trophic structure of Ouachita Mountains Ecoregion fish populations. Primary feeders and carnivores make up nearly equal segments of the combined samples of the region (Figure F-12). Variation of the trophic structure among the sites is not evident, except the abundance of carnivores is significantly lower in the smallest reference stream which has very small and shallow pools and limited habitat for the larger predators.

Springtime sampling of these reference streams included a combination of overnight trammel netting and electrofishing of the riffles and shallow shoreline at all sites. The exceptions were Board Camp Creek, which was electrofished only, and the Cossatot River, which was netted only. The number of additional species taken during the spring sampling includes five from the South Fork of the Ouachita River, four each from Saline River and Caddo River, three from Board Camp Creek, two from the Little Missouri River and one from the Cossatot River.

The key species which are dominant within the major families or groups of fishes are listed in Table F-8. Also listed are species which are usually sub-dominant, but which are indicators of Ouachita Mountains Ecoregion fish populations. Some of the indicator species may be found in other ecoregions and not all waters of an ecoregion contain the indicator species. As an example, the gravel chub is found primarily within the Ouachita River drainage of the region and may not occur in the Little River drainage of the western Ouachita Mountains Ecoregion. It also seems to avoid the very small streams.

The Cyprinidae and Centrarchidae-dominated fish population and the relatively low component of Percidae is characteristic of the Ouachita Mountains Ecoregion fisheries. The sub-dominance of Percidae is probably related to the relatively low diversity of Percid species and the normally strong dominance of the orangebelly darter in most populations. The Saline River drainage seems to be an exception to this as the orangebelly darter is absent from this drainage and the greatest number of Percid species were found in the Saline River site. The list of key and indicator species and the nearly 50% composition of sensitive species within the populations further characterizes the fishery of this ecoregion.

Table F-8. Dominant Key and Indicator Species of the Ouachita Mountains Ecoregion Fish Populations

Key Species	Indicator Species
Bigeye shiner	Shadow bass
Northern hogsucker	Gravel chub
Freckled madtom	Northern studfish
Longear	Striped shiner
Orangebelly darter	
Smallmouth bass	

Ozark Highlands Ecoregion

Table F-9 lists all 60 species collected within the Ozark Highlands Ecoregion and gives the relative abundance value for each species at each site where it was collected. The range of species collected per sample site was 16 to 39 with a distinct trend of the largest number of species in the largest watershed (Figure F-13). Conversely, there appears to be an inverse relationship between the number of species and the stream gradient. Sensitive species made up more than 65% of the population in all samples and a total of 33 sensitive species were taken in this region. The sensitive species are designated in Table F-9.

Among the five key families of fish within the state, Cyprinidae comprise the greatest percentage of the relative abundance value of the combined samples from the Ozark Highlands. This dominance is more pronounced in the smaller watersheds and the minnows are sub-dominant in the largest watershed. Centrarchidae and Percidae are normally second and third sub-dominant and are followed by Catostomidae and Ictaluridae (Figure F-14).

Macroinvertebrate feeding fishes dominate the population by comprising almost 71% of the population relative abundance. Primary feeding fishes make up over 13.5% of the population and carnivores are over 15.5%. There is no apparent trend among the sites in variation of the trophic structure, except for slightly higher abundances of primary feeding species within the two smallest watershed streams (Figure F-15).

Spring sampling included electrofishing in the South Fork of Spavinaw, Flint Creek and Yocum Creek while Long Creek, War Eagle Creek and the Kings River received limited electrofishing and overnight trammel netting. Relative abundance values were not assigned to the springtime collection data. Two additional species were collected from the South Fork of Spavinaw, Yocum Creek and Long Creek; however, trammel nets in the deeper pools of War Eagle Creek and the Kings River produced an additional six and four species, respectively. These species are those which typically move considerable distances during the spring of the year, particularly when searching for spawning areas. The latter two sites are also upstream from major reservoirs from which many of the species may have migrated.

The key species which dominate specific groups of fishes and which, as a group, characterize the Ozark Highlands Ecoregion are listed in Table F-10. Often, the sub-dominant but distinctive indicator species of most Ozark Highlands fish populations are also listed in this table. The "rock" basses include the Ozark bass within the White River drainage, the shadow bass in the eastern part of the Ozark Highlands, and remnants or intergrades of the introduced rock bass in the Grand-Neosho drainage of extreme northwest Arkansas. The rainbow and orangethroat darters are syntopic in some waters within the region but the orangethroat darter prefers the

TABLE F-9. FISHES OF OZARK HIGHLANDS REFERENCE STREAMS

FISH	SPECIES	SPAW.CR.	FLINT CR	YOCUM CR	LONG CR	WAR EGLE	KINGS	SUM
*(Notropis pilsbryi)	Duskystripe shiner	12.0	12.0	12.0	12.0	12.0	10.5	70.5
(Campostoma anomalum)	Stoneroller	10.5	12.0	12.0	12.0	12.0	12.0	70.5
*(Hypentelium nigricans)	Northern hogsucker	2.0	9.0	12.0	12.0	10.5	9.0	54.5
*(Cottus carolinae)	Banded sculpin	12.0	10.5	12.0	9.0	7.5		51.0
*(Etheostoma caeruleum)	Rainbow darter			10.5	12.0	12.0	12.0	46.5
(Lepomis megalotis)	Longear		9.0	8.0	9.0	10.5	9.0	45.5
*(Noturus exilis)	Slender madtom	12.0	10.5	9.0	6.0	3.0		40.5
*(Ambloplites constellatus)	Ozark bass			12.0	9.5	9.0	9.0	39.5
*(Micropterus dolomieui)	Smallmouth bass	2.0	10.5	8.5	4.0	1.0	10.5	36.5
(Notropis nubilus)	Ozark minnow		6.0	1.0	10.5	12.0	7.0	36.5
(Micropterus punctulatus)	Spotted bass				12.0	12.0	12.0	36.0
*(Noturus albater)	Ozark madtom			4.0	12.0	9.0	8.0	33.0
*(Etheostoma juliae)	Yoke darter				12.0	12.0	9.0	33.0
(Lepomis cyanellus)	Green sunfish	1.5	7.5	6.0	4.0	5.0	7.0	31.0
*(Moxostoma duquesnei)	Black redhorse				10.5	8.0	12.0	30.5
(Percina caprodes)	Logperch			1.0	12.0	2.0	12.0	27.0
(Etheostoma spectabile)	Orangethroat darter	9.0	12.0	6.0	S			27.0
*(Etheostoma zonale)	Banded darter				9.0	4.5	12.0	25.5
*(Notropis rubellus)	Rosyface shiner	S	1.5		6.0	9.0	7.5	24.0
*(Etheostoma flabellare)	Fantail darter	12.0		12.0				24.0
*(Etheostoma blennioides)	Greenside darter			S	9.0	6.0	9.0	24.0
*(Phoxinus erythrogaster)	Southern redbelly dace	12.0	9.0	S				21.0
*(Nocomis asper)	Redspot chub	9.0	12.0					21.0
*(Ambloplites rupestris)	Rock bass	9.0	12.0					21.0
*(Nocomis biguttatus)	Hornyhead chub			10.5	9.0			19.5
(Lepomis macrochirus)	Bluegill		1.0	6.0	3.0	2.0	6.5	18.5
(Moxostoma erythrurum)	Golden redhorse				1.0	8.0	8.0	17.0
*(Semotilus atromaculatus)	Creek chub	10.5	6.0					16.5
(Fundulus olivaceus)	Blackspotted topminnow		6.0	4.0		4.0	1.0	15.0
*(Moxostoma carinatum)	River Redhorse				4.0	1.0	9.0	14.0
*(Hybopsis dissimilis)	Streamline chub				6.0		8.0	14.0
*(Fundulus catenatus)	Northern studfish		4.5	8.0	1.0			13.5
(Notropis chrysocephalus)	Striped shiner				6.0	5.5	2.0	13.5
*(Notropis boops)	Bigeye shiner				4.5	4.0	4.0	12.5
(Ictalurus punctatus)	Channel catfish				4.5	S	8.0	12.5
*(Etheostoma euzonum)	Arkansas saddled darter						12.0	12.0
(Gambusia affinis)	Mosquitofish		10.5					10.5
(Pimephales notatus)	Bluntnose minnow				7.5	1.0	1.0	9.5
*(Etheostoma punctulatum)	Stippled darter	S	9.0					9.0
*(Notropis galacturus)	Whitetail shiner				6.0	1.0	1.0	8.0
(Dorosoma cepedianum)	Gizzard shad				1.5		6.0	7.5
(Micropterus salmoides)	Largemouth bass			1.0	1.0	1.0	4.0	7.0
*(Notropis whipplei)	Steelcolor shiner					4.0	1.0	5.0
(Pylodictis olivaris)	Flathead catfish					S	4.0	4.0
(Cyprinus carpio)	Carp				1.0	S	2.0	3.0
*(Notropis greenei)	Wedgespot shiner						2.0	2.0
*(Hybopsis amblops)	Bigeye chub						2.0	2.0
*(Etheostoma stigmaeum)	Speckled darter					2.0		2.0
(Labidesthes sicculus)	Brook silversides				1.0	1.0		2.0
*(Noturus flavater)	Checkered madtom					1.0		1.0
*(Notropis telescopus)	Telescope shiner					1.0		1.0
(Lepomis hybrid)	Hybrid sunfish	1.0						1.0
(Catostomus commersoni)	White sucker		1.0					1.0
*(Stizostedion vitreum)	Walleye						S	0.0
(Lepisosteus osseus)	Longnose gar					S		0.0
(Lepisosteus oculatus)	Spotted gar						S	0.0
(Ictalurus natalis)	Yellow bullhead				S			0.0
(Ictalurus melas)	Black bullhead						S	0.0
(Carpiodes velifer)	Highfin carpsucker					S	S	0.0
(Carpiodes cyprinus)	Quillback carpsucker					S		0.0
	NUMBER OF SPECIES=	16	21	22	36	39	39	60.0

* - SENSITIVE SPECIES
S - SPRING COLLECTION ONLY

FIGURE F-13. NUMBER OF FISH SPECIES COLLECTED FROM
OZARK HIGHLANDS REFERENCE STREAMS

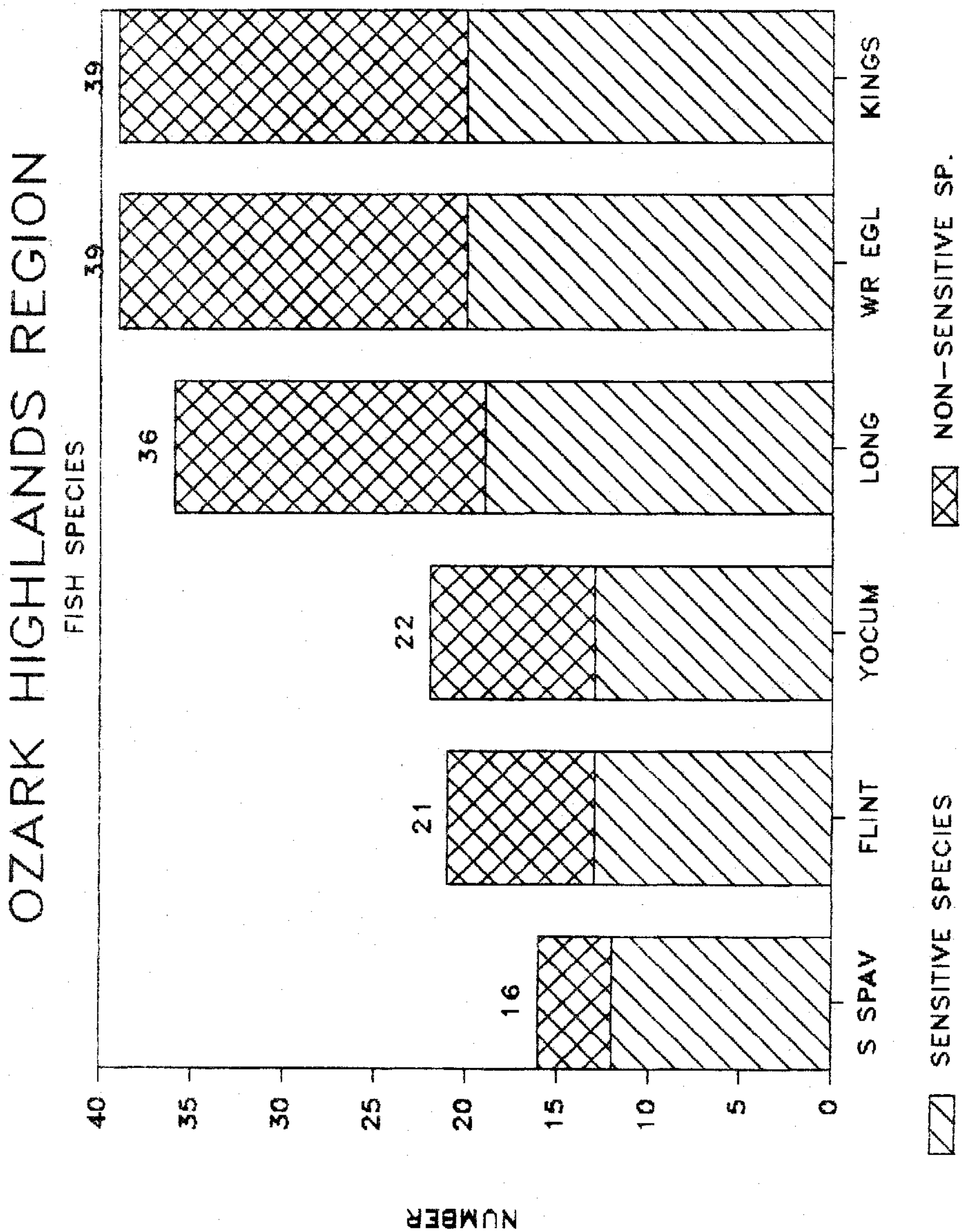


FIGURE F-14. ABUNDANCE OF KEY FISH FAMILIES

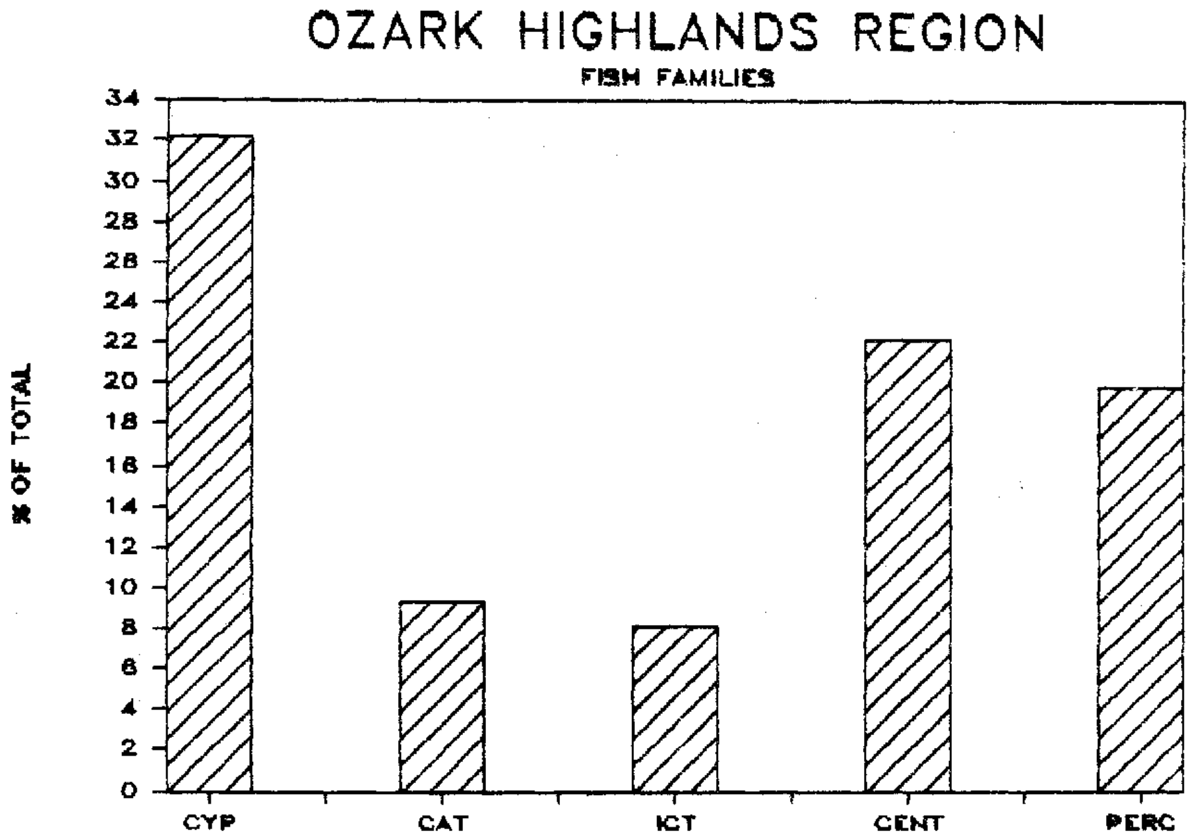
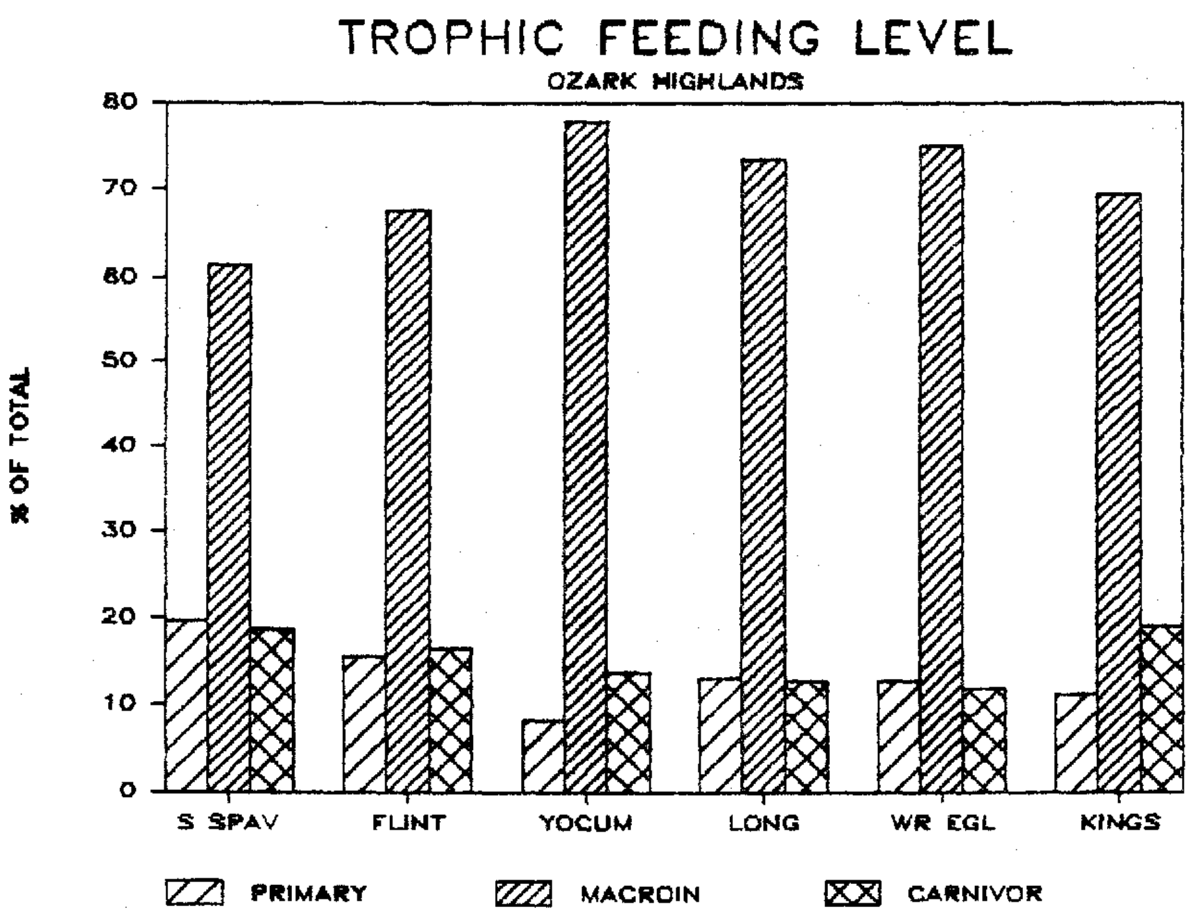


FIGURE F-15. DISTRIBUTION OF FISHES AMONG TROPHIC FEEDING LEVELS



smaller headwaters streams and the rainbow darter dominates in the larger streams. The rainbow darter is not found in the Grand-Neosho drainage of northwest Arkansas; here a different subspecies of the orangethroat darter usually dominates.

The list of key and indicator species, the abundance of sensitive species within the population and the large diversity of Cyprinidae distinguishes the Ozark Highlands fishery from the other ecoregions.

Table F-10. Dominant Key Species and Indicator Species of Ozark Highlands Ecoregion Fish Populations

Key Species	**Indicator Species**
Duskystripe shiner	Banded sculpin
Northern hogsucker	Ozark madtom
Slender madtom	Southern redbelly dace
"Rock" basses	Whitetail shiner
Rainbow-orangethroat darters	Ozark minnow
Smallmouth bass	

Boston Mountains Ecoregion

Rotenone was used to sample the fish population in the Boston Mountains Ecoregion during the summer period at three sites and electrofishing was used at three sites. The 60 species collected from the reference streams are listed in Table F-11 with their relative abundance per sample site. A slightly greater number of species is present in the large watersheds; however, this relationship is not distinctive. The two sites with the smallest number of species have significantly higher stream gradients but the Archey Creek sample is noticeably the most species rich population (Figure F-16). A total of 27 sensitive fish species were collected from this region and these species make up about 50% of the population abundance.

The dominant fish family from all samples within the region is Percidae although Cyprinidae dominate two of the samples. Centrarchidae is slightly sub-dominant to the perches and minnows in the combined samples. Catostomidae and Ictaluridae are distinctly sub-dominant to the previous three families (Figure F-17).

The distribution of the three basic trophic levels of fishes is generally uniform among the samples within this region. Carnivores at 13.8% are slightly more abundant than primary feeders at 10.5% and, as in all of the regions, macroinvertebrate feeders dominate at 75.7% of the population (Figure F-18).

Both electrofishing and trammel netting were used to collect fishes during the spring period at all sites, except only netting was used at Archey Creek. Electrofishing produced four additional species from Hurricane Creek and one from Mulberry River. Netting produced two additional species from Archey Creek and from Illinois Bayou, three from Lee Creek and four from Mulberry River. The netted species were the larger,

TABLE F-11. FISHES OF BOSTON MOUNTAINS ECOREGION REFERENCE STREAMS

FISH	SPECIES	INDIAN	HURR	ARCHEY	ILL. BY.	LEE CR.	MULBRY	SUM
(Campostoma anomalum)	Stoneroller	12.0	12.0	9.0	12.0	12.0	12.0	69.0
*(Notropis boops)	Bigeye shiner	12.0	12.0	9.0	10.5	12.0	12.0	67.5
(Lepomis megalotis)	Longear	11.0	12.0	10.5	12.0	10.0	12.0	67.5
*(Noturus exilis)	Slender madtom	10.5	10.5	12.0	10.5	10.5	12.0	66.0
*(Etheostoma blennioides)	Greenside darter	10.5	12.0	12.0	9.0	7.5	9.0	60.0
(Lepomis cyanellus)	Green sunfish	8.0	10.5	10.0	12.0	6.0	10.5	57.0
*(Micropterus dolomieui)	Smallmouth bass	9.0	9.0	8.5	11.5	10.5	4.0	52.5
(Micropterus punctulatus)	Spotted bass	7.0	6.5	9.0	10.5	9.5	9.0	51.5
*(Etheostoma zonale)	Banded darter	7.5	10.5	7.5	9.0	6.0	9.0	49.5
*(Moxostoma duquesnei)	Black redhorse	11.0	9.0	10.0	10.5	7.5		48.0
(Pimephales notatus)	Bluntnose minnow	9.0	1.0	10.5	9.0	5.0	9.0	43.5
(Labidesthes sicculus)	Brook silversides	12.0	6.0	9.0	10.5	4.0	2.0	43.5
(Fundulus olivaceus)	Blackspotted topminnow	10.5	8.0	9.0	6.0	4.0	5.0	42.5
*(Hypentelium nigricans)	Northern hogsucker	9.0	6.0	6.5	7.5	4.0	8.5	41.5
*(Notropis greenei)	Wedgespot shiner		6.0	9.0	9.0	7.5	9.0	40.5
(Etheostoma spectabile)	Orangethroat darter	12.0	10.5		12.0	1.0	S	35.5
*(Etheostoma flabellare)	Fantail darter	4.5	6.0			12.0	12.0	34.5
(Etheostoma whipplei)	Redfin darter	12.0		6.0	12.0	2.0	2.0	34.0
*(Notropis whipplei)	Steelcolor shiner	2.5	1.5	7.0	9.0	6.0	7.5	33.5
(Moxostoma erythrurum)	Golden redhorse	9.0	4.5	6.0	1.0	9.0	3.0	32.5
*(Percina nasuta)	Longnose darter			6.5	7.5	5.0	6.0	25.0
*(Etheostoma punctulatum)	Stippled darter	4.5		3.0	12.0	4.0		23.5
(Percina caprodes)	Logperch	1.5		9.5		4.0	7.5	22.5
(Ictalurus punctatus)	Channel catfish	9.0	3.0	1.0		S	7.0	20.0
*(Ambloplites ariommus)	Shadow bass		1.0	10.5	6.0			17.5
(Micropterus salmoides)	Largemouth bass				2.5	6.0	6.0	14.5
(Lepomis macrochirus)	Bluegill	1.0		3.5	2.0	5.0	2.0	13.5
*(Notropis pilsbryi)	Duskystripe shiner					12.0		12.0
*(Etheostoma caeruleum)	Rainbow darter			12.0				12.0
*(Noturus albater)	Ozark madtom			9.0				9.0
*(Hybopsis dissimilis)	Streamline chub			9.0				9.0
*(Etheostoma moorei)	Yellowcheek darter			9.0				9.0
(Notropis nubilus)	Ozark minnow					9.0		9.0
*(Etheostoma stigmaeum)	Speckled darter			7.5		1.0		8.5
(Ictalurus natalis)	Yellow bullhead		S	2.0	6.5			8.5
*(Etheostoma euzonum)	Arkansas saddled darter			8.0				8.0
(Pylodictis olivaris)	Flathead catfish			6.0	1.0		1.0	8.0
*(Pimephales tenellus)	Slim minnow			6.0				6.0
*(Percina maculata)	Blackside darter	1.0	S			2.5	2.0	5.5
(Esox americanus)	Grass pickerel	1.0			4.5			5.5
(Cyprinus carpio)	Carp	1.5				2.0	2.0	5.5
(Aplodinotus grunniens)	Freshwater drum	2.0		2.0			1.0	5.0
*(Fundulus catenatus)	Northern studfish					4.0		4.0
(Fundulus notatus)	Blackstripe topminnow			2.0		1.0		3.0
(Lepomis gulosus)	Warmouth			1.0			1.0	2.0
*(Semotilus atromaculatus)	Creek chub			1.0				1.0
*(Percina copelandi)	Channel darter						1.0	1.0
(Noturus miurus)	Brindled madtom			1.0				1.0
(Morone chrysops)	White bass			1.0				1.0
(Lepomis hybrid)	Hybrid sunfish				1.0			1.0
(Lepomis humilis)	Orangespotted sunfish					1.0		1.0
(Lepisosteus osseus)	Longnose gar					1.0	S	1.0
(Ichthyomyzon sp.)	Lamprey larvae		S	1.0				1.0
(Dorosoma cepedianum)	Gizzard shad			1.0	S			1.0
*(Stizostedion vitreum)	Walleye			S				0.0
*(Moxostoma carinatum)	River Redhorse				S	S	S	0.0
(Notropis emiliae)	Pugnose minnow		S					0.0
(Lepisosteus oculatus)	Spotted gar			S		S		0.0
(Ictiobus bubalus)	Smallmouth buffalo						S	0.0
(Carpiodes carpio)	River carpsucker						S	0.0
	NUMBER OF SPECIES=	27	25	43	30	37	34	60.0

* - SENSITIVE SPECIES

S - SPRING COLLECTIION ONLY

FIGURE F-16. NUMBER OF FISH SPECIES COLLECTED FROM BOSTON MOUNTAINS ECOREGION REFERENCE STREAMS

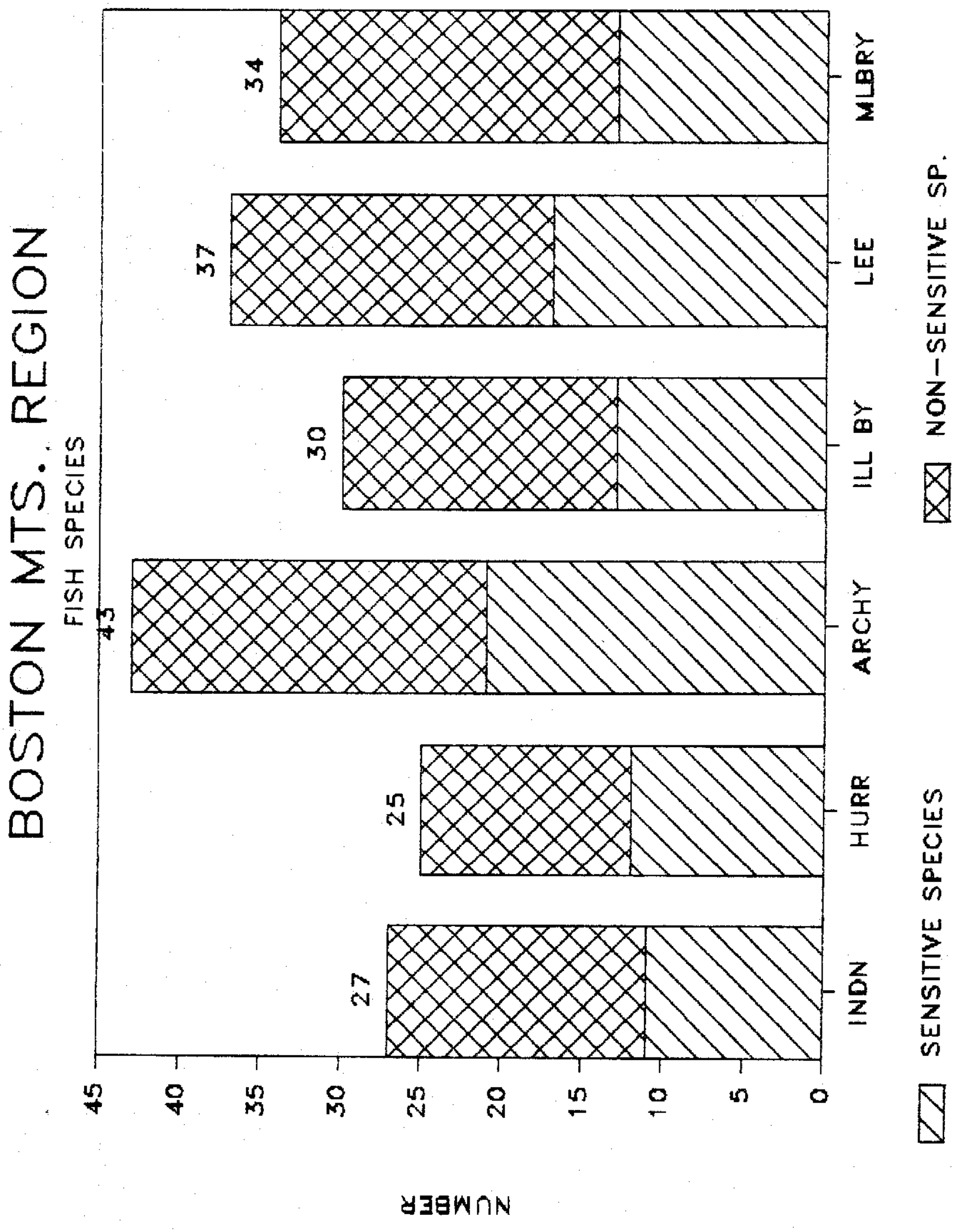


FIGURE F-17. ABUNDANCE OF KEY FISH FAMILIES

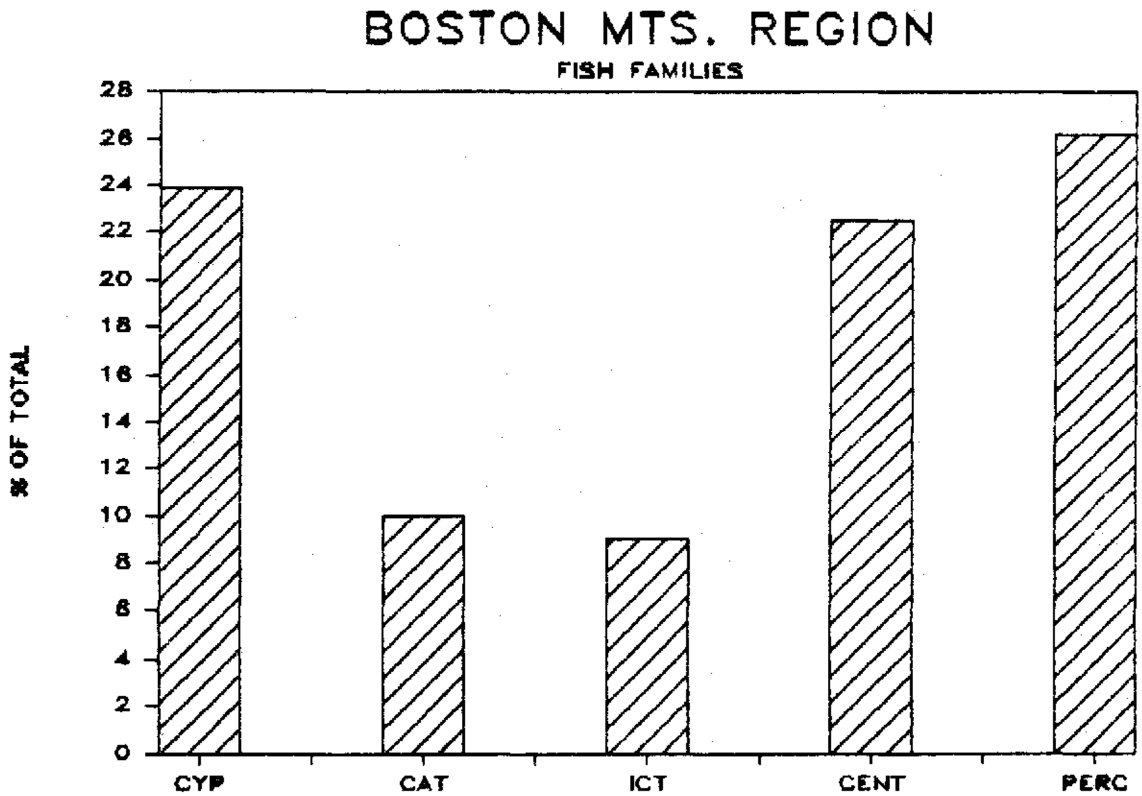
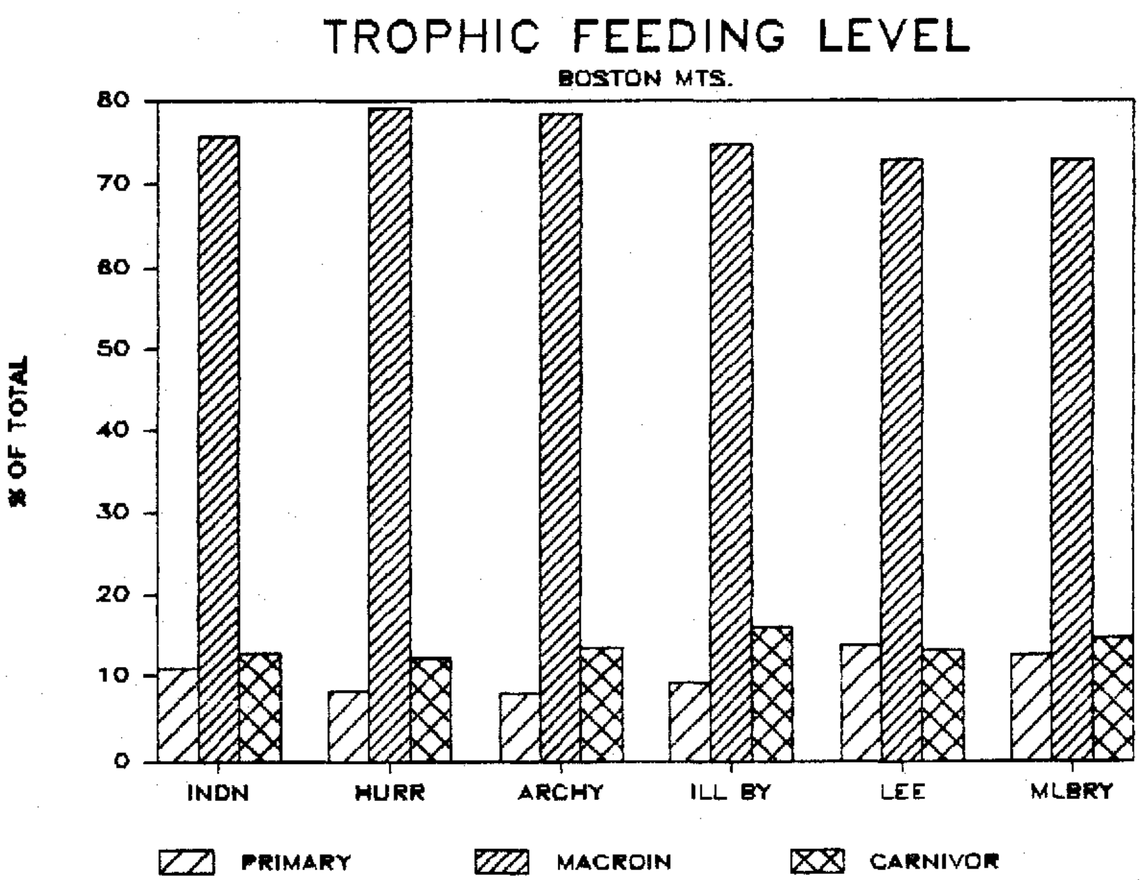


FIGURE F-18. DISTRIBUTION OF FISHES AMONG TROPHIC FEEDING LEVELS



more transient fishes such as river redhorse, gar, buffalo and river carpsucker.

Table F-12 lists the key species that are dominant within particular species groups. These and the indicator species, although not unique to the Boston Mountains region, characterize the fish population of typical Boston Mountains Ecoregion streams. While a similarity exists between the Boston Mountains and Ozark Highlands fisheries, a much greater similarity exists between the Boston Mountains and Ouachita Mountains fisheries.

In addition to its key and indicator species, Boston Mountains Ecoregion fisheries have a high abundance of Percidae followed closely by Cyprinidae and Centrarchidae and about one-half of the population abundance is composed of sensitive species.

Table F-12. Dominant Key Species and Indicator Species of Boston Mountains Ecoregion Fish Populations

Key Species	**Indicator Species**
Bigeye shiner	Shadow bass
Black redhorse	Wedgespot shiner
Slender madtom	Longnose darter
Longear	Fantail darter
Greenside darter	
Smallmouth bass	

Comparison of Ecoregions

The fish populations of the ecoregion reference streams are notably different and these population assemblages can be used to characterize each ecoregion. The basic population differences can be demonstrated by comparing the ten most abundant species within each ecoregion. The similarity index of Odum was modified to use relative abundance values as follows:

$$SI = \frac{C}{A + B + D} \times 100$$

SI = similarity index (range from 0 to 100; 100 = identical populations)
A = total relative abundance value of sample A
B = total relative abundance value of sample B
C = sum of relative abundance values of species common to both samples
D = sum of difference in relative abundance values of species common to both samples

Table F-13 compares all possible combinations among the six ecoregions using the ten most abundant species of each

TABLE F-13. SIMILARITY INDEX COMPARISON OF TEN MOST ABUNDANT SPECIES FROM ALL ECOREGIONS

	ECOREGIONS				
	BOSTON MTNS.	OZARK HIGHLAND	AR RIVER VALLEY	DELTA	GULF COASTAL PLAINS
OUACHITA MTNS.	62	32	21	11	11
BOSTON MTNS.		39	40	10	10
OZARK HIGHLAND			19	9	9
AR RIVER VALLEY				36	29
DELTA					58

region and the modified similarity index. The Boston Mountains and Ouachita Mountains fishes are most similar and the Gulf Coastal and Delta also show some relative similarity. The Ozark Highlands versus the Delta and the Ozark Highlands versus the Gulf Coastal show the least similarity. These comparisons show that there is substantially more dissimilarity than similarity among the ecoregion fisheries. This substantiates the distinctiveness of these ecoregions as demonstrated by the fish populations of the reference streams.

Many of the fish population differences can be explained by a comparison of the fish habitat among the ecoregions. Figure F-19 shows the percent of the stream width of the ecoregion reference streams which contain instream cover such as brush, logs, debris, undercut banks, aquatic vegetation and low overhanging vegetation. Also shown is the composition of substrate types which provide substantial fish cover. A factor relative to the value which each substrate type provides as fish cover was multiplied by the proportion of each substrate type for all streams. These factors are as follows: mud/silt, sand and bedrock = 0; gravel = 0.5; rubble, boulders and large boulders = 1. The Delta and Gulf Coastal Ecoregions are dominated by fish habitat from brush, logs, debris and other similar types of instream cover. Conversely, the Ozark Highlands, Ouachita Mountains and Boston Mountains Ecoregions are dominated by substrate that provides desirable fish cover. The Arkansas River Valley contains substantial amounts of both types of fish habitat and is extremely variable between the different streams.

The greatest species richness is found in the Arkansas River Valley Ecoregion and the Delta has the lowest total number of species from all reference streams (Figure F-20). Although the average number of species per sample is similar among the regions, the species collected are distinctly different. Fish species sensitive to environmental disturbances make up about 50% or more of the total population relative abundance in the Ozark Highlands, Boston Mountains and Ouachita Mountains Ecoregions. Less than 15% of the Arkansas River Valley and Gulf Coastal fishes are sensitive species and less than 1% of the Delta fishes are considered sensitive species (Figure F-21).

Distribution of the major fish families of the ecoregions is shown in Figure F-22. Centrarchidae clearly dominate the Delta and Gulf Coastal Ecoregions and Cyprinidae dominate the Ozark Highlands and Ouachita Mountains. The Arkansas River Valley is almost equally dominated by Centrarchidae and Cyprinidae while the Boston Mountains are slightly dominated by Percidae, followed closely by Cyprinidae and Centrarchidae.

The trophic levels are substantially dominated by macroinvertebrate feeding fishes in all ecoregions. The Delta and Ozark Highlands Ecoregions have slightly higher

FIGURE F-19. COMPARISON OF FISH HABITAT TYPES AMONG ALL ECOREGIONS

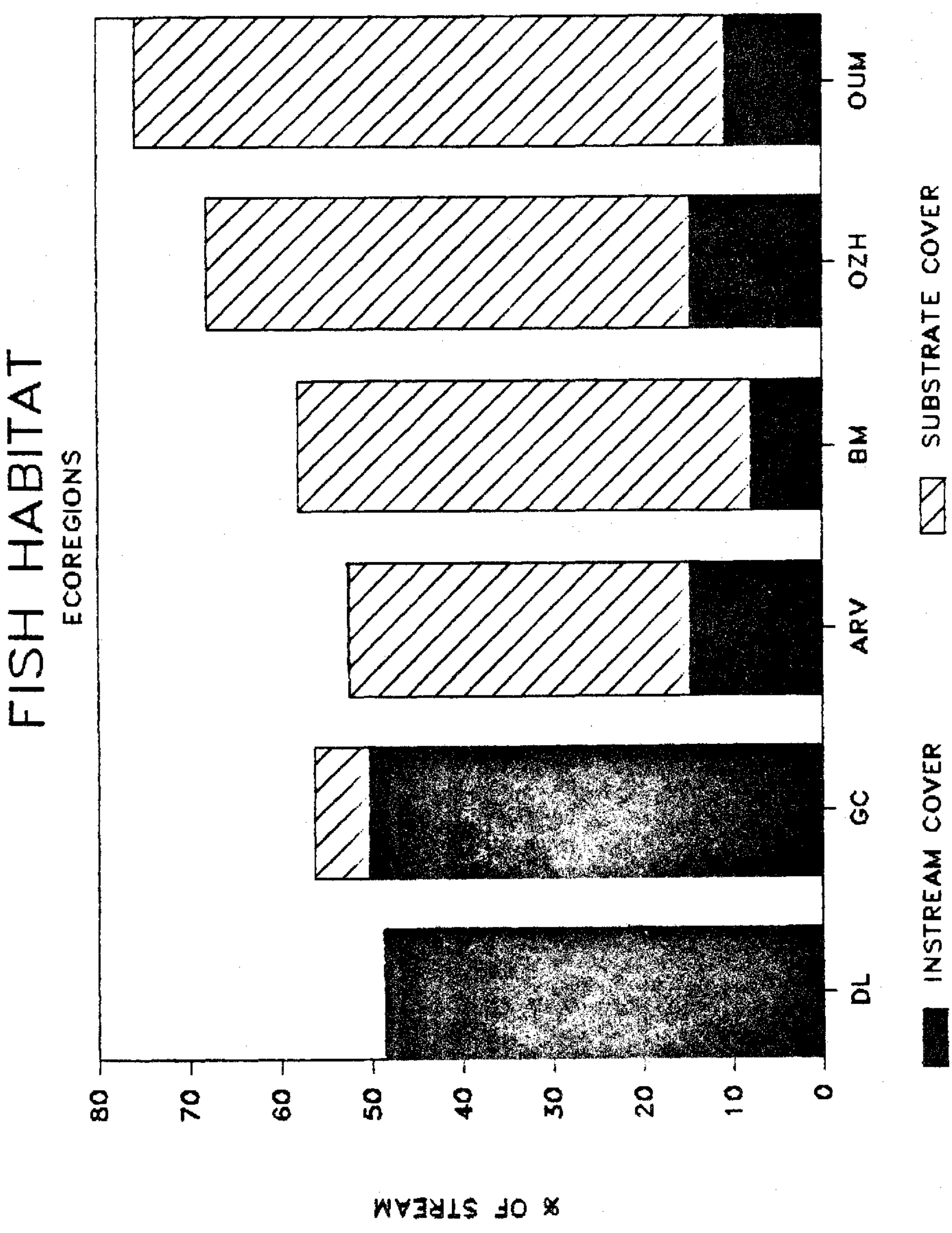


FIGURE F-20. AVERAGE AND TOTAL NUMBER FISH SPECIES
COLLECTED FROM ECOREGION REFERENCE STREAMS

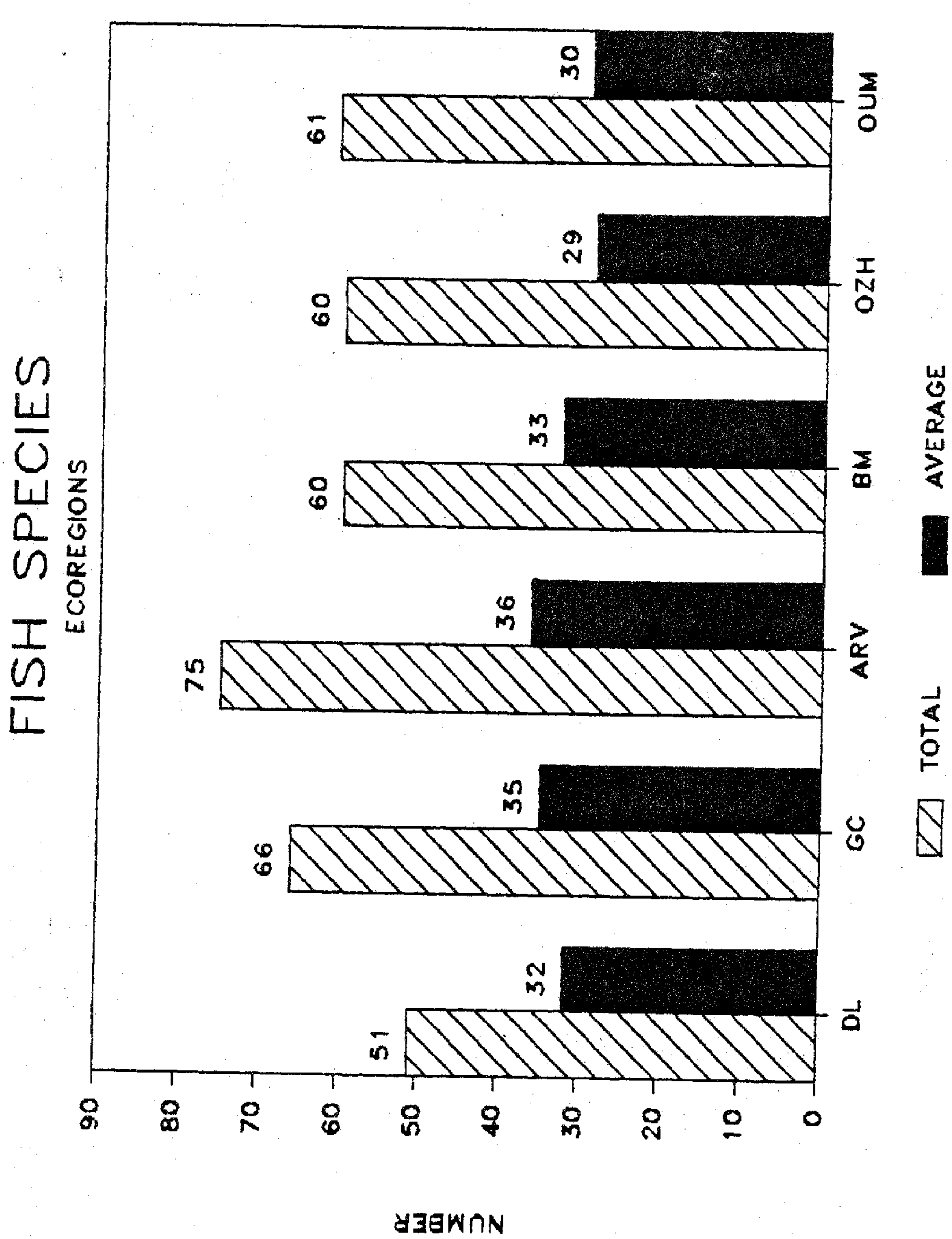


FIGURE F-21. COMPOSITION OF SENSITIVE FISH SPECIES WITHIN ALL ECOREGIONS

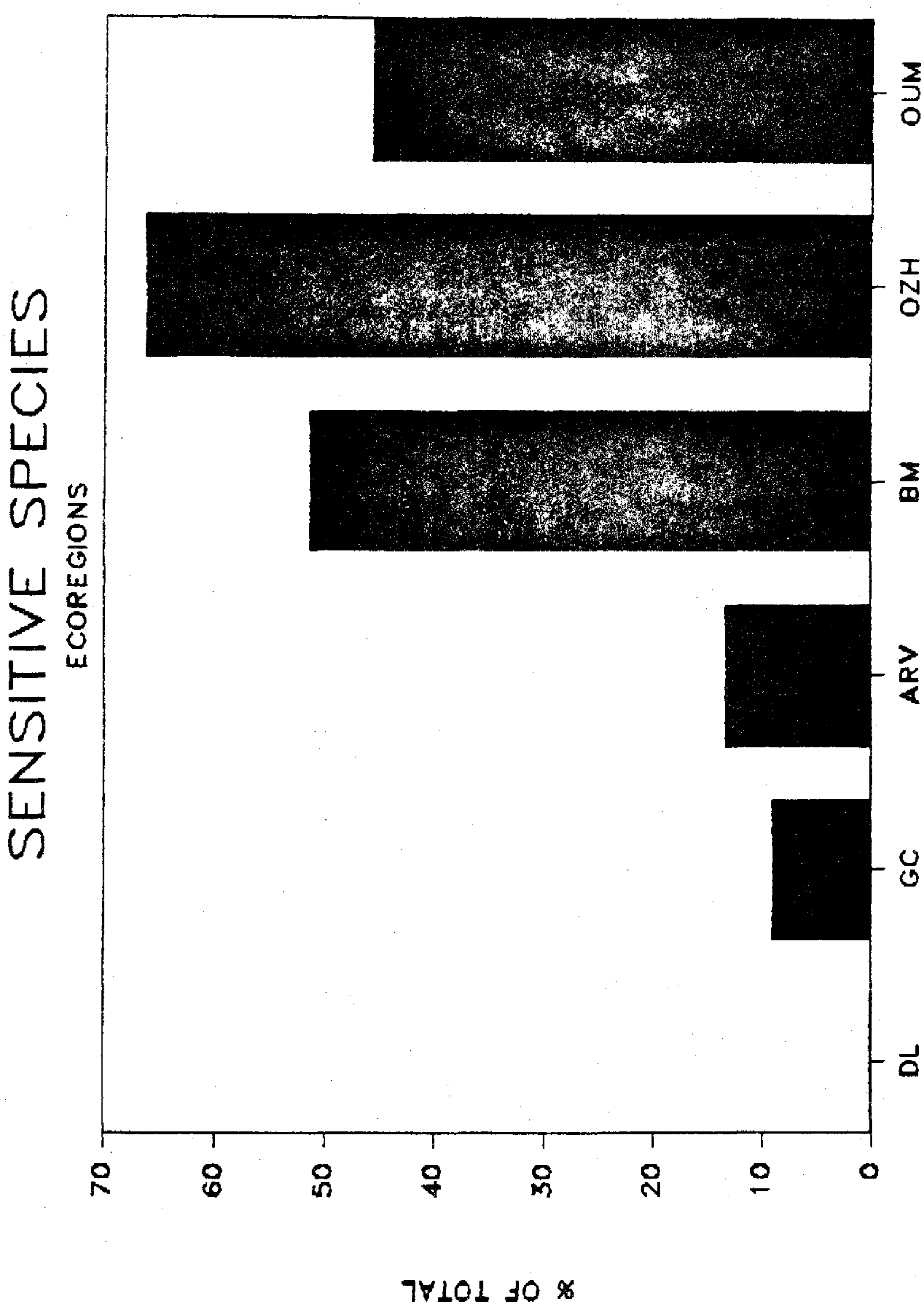
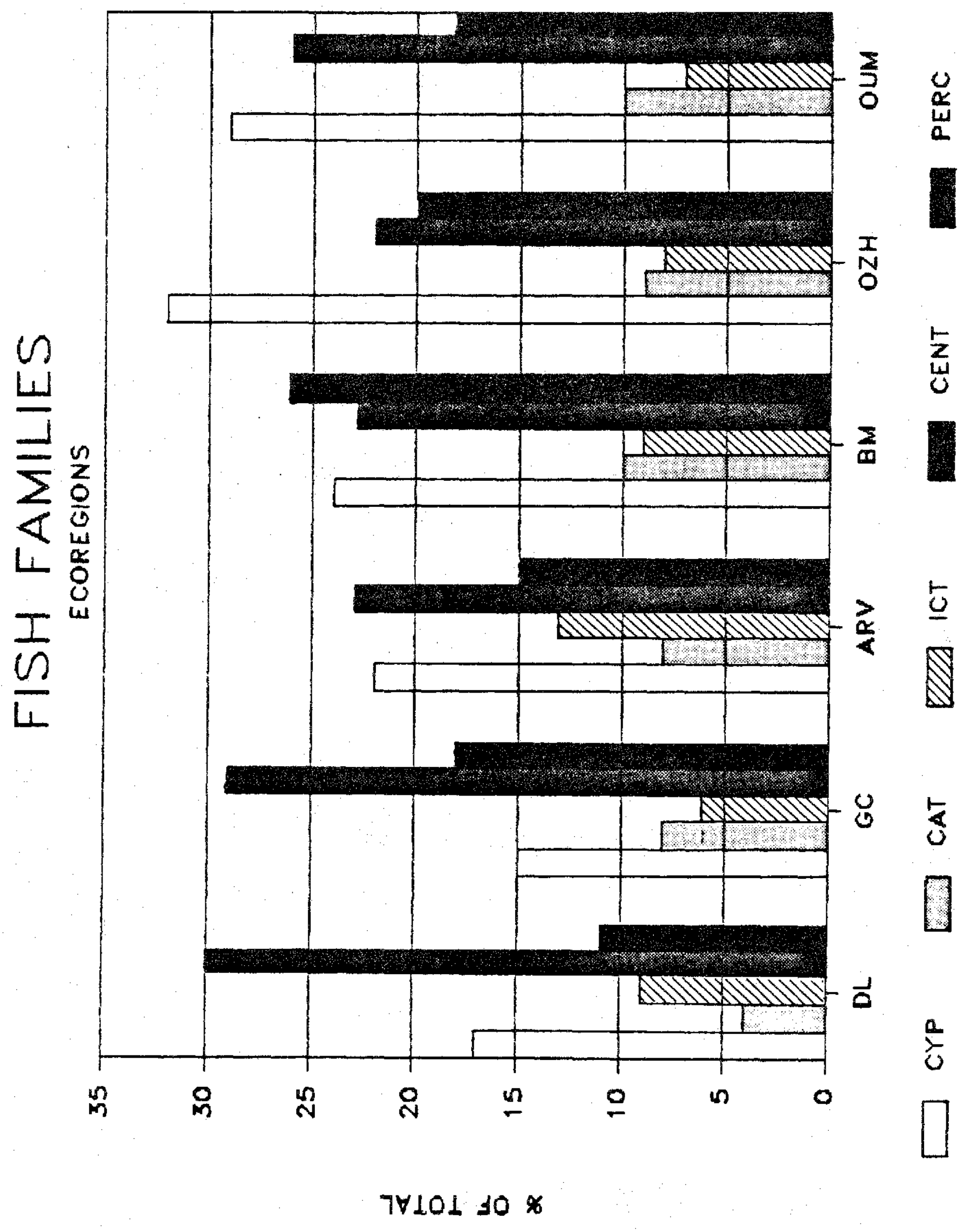


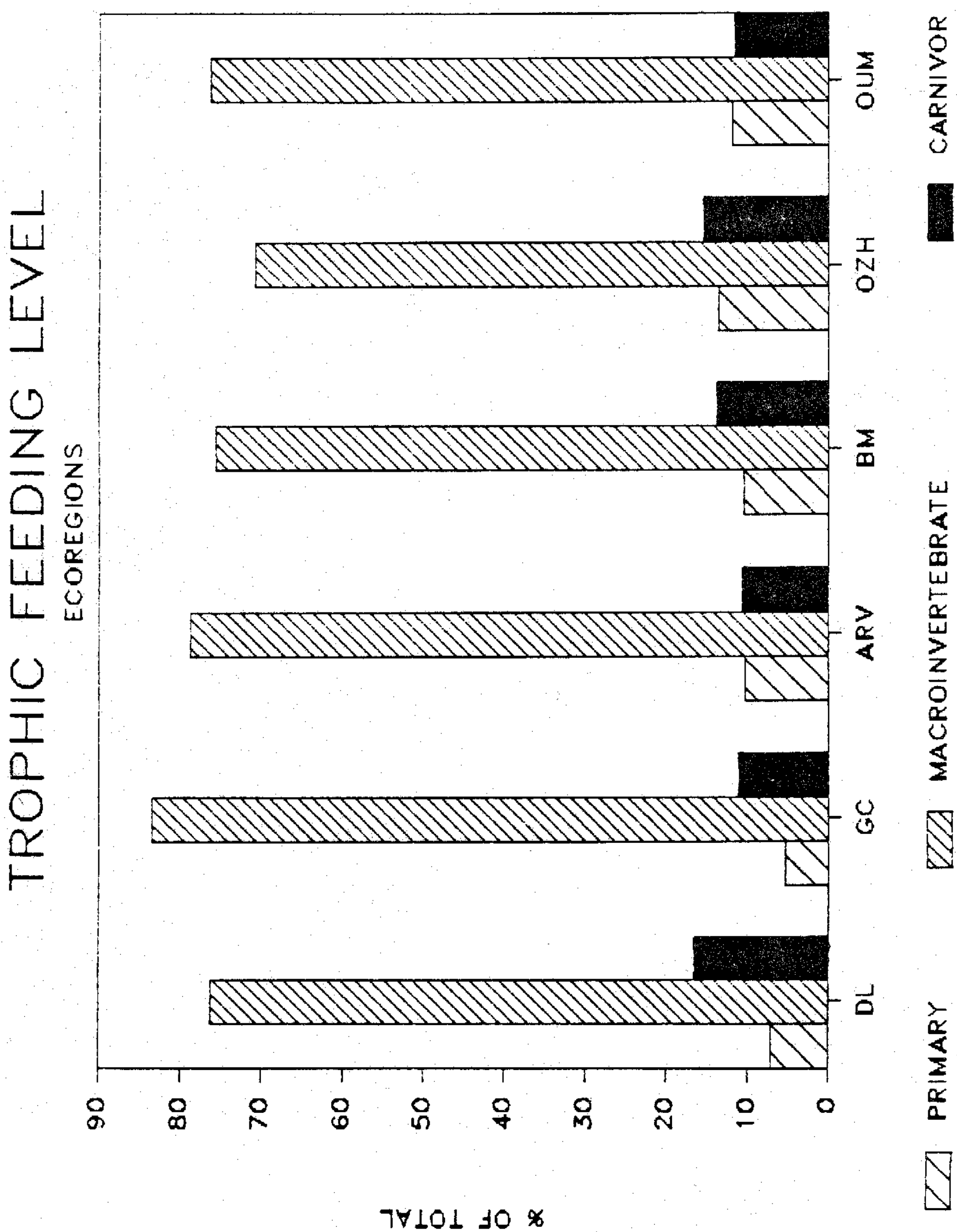
FIGURE F-22. DISTRIBUTION OF MAJOR FISH FAMILIES WITHIN ALL ECOREGIONS



proportion of carnivorous fishes. The composition of primary feeding fishes is lowest in the Gulf Coastal Ecoregion and highest in the Ozark Highlands (Figure F-23).

Fish population compositions from the least-disturbed reference streams within the ecoregions are distinctive and can serve as a means of characterizing each ecoregion. The key parameters found to characterize the fish populations of each ecoregion include: (1) distribution of the major fish families of the population; (2) identification and proportion of sensitive fish species; (3) comparison of dominant key species and the presence of indicator species.

FIGURE F-23. DISTRIBUTION OF TROPHIC FEEDING LEVELS OF FISHES FROM ALL ECOREGIONS



Summary of Findings

1. The least-disturbed reference streams selected within each of the six ecoregions of the state contain physical, chemical and biological features which are characteristically similar within the ecoregions and distinctively dissimilar among the ecoregions.

2. Substantial differences were found in the flow regime of the ecoregion streams during the low-flow period. The Boston Mountains, Arkansas River Valley and typical Gulf Coastal streams had little, if any, surface flow during the dry seasons even in streams with relatively large watersheds. Dry season flows were maintained by springwater in most Ouachita Mountains and Ozark Highlands streams and in a few Gulf Coastal streams. Delta Ecoregion stream flows were often supplemented by drainage of irrigation waters.

3. The surface geology and stream gradient are the major factors in determining the physical characteristics of the streams in each ecoregion.

4. Groundwater influences, particularly from continuously flowing springs, substantially affected the flow regime of certain Gulf Coastal, Ouachita Mountains and Ozark Highlands streams. This also influenced water quality and the dissolved oxygen concentrations in some of these streams.

5. Stream canopy was found to be a significant influence on stream water temperatures. Canopy was affected by land uses in some ecoregions and by the scouring action of springtime flows in high gradient streams of other regions.

6. Impacts of the watershed geology and certain land uses are identifiable in the water quality of some least-disturbed reference streams.

7. The mineral content of streams within most ecoregions is very low except for the Ozark Highlands streams which drain large areas of limestone and dolomite, streams draining isolated areas of limestone outcroppings in the Ouachita Mountains and streams along the fall line between the southern boundary of the Ouachita Mountains and the Gulf Coastal Plains.

8. Agricultural activities in the Delta Ecoregion result in increased turbidity, total suspended solids, BOD, and phosphorus in the surface waters of this region, and confined animal production activities produce elevated values of nitrite-nitrate nitrogen in Ozark Highland Ecoregion streams.

9. Maximum summer water temperatures are lowest in the Ozark Highlands and the Gulf Coastal Ecoregion streams. Water temperatures in the Boston Mountains Ecoregion are surprisingly warm due to the "pooled" stream condition and limited stream canopy. Delta Ecoregion streams potentially have the warmest water temperatures, but high summertime stream flows and irrigation water inflows resulted in relatively low values during the sample period.

10. The smaller streams in the the lowland ecoregions (Delta, Gulf Coastal and Arkansas River Valley) revealed minimum summertime dissolved oxygen values substantially below the current water quality standard of 5 mg/l. Some of the upland ecoregion streams have minimum dissolved oxygen values above the standard for those waters.

11. Dissolved oxygen saturation values are notably different among the ecoregions. Values are around 80% to supersaturated in the upland areas during both summer and spring. The lowland regions have summer saturation values around 50-60% or lower, and springtime values are normally somewhat higher.

12. The D.O. values, particularly during the spring period, show a strong positive correlation to stream flows.

13. Based on the results from the dissolved oxygen values obtained, seasonal D.O. criteria which will be protective of the biotic integrity of streams in each ecoregion have been developed.

14. For the Delta Ecoregion, the following dissolved oxygen limitations are expected to protect the aquatic community.

    a. <u>Summer critical conditions</u> - Watersheds larger than 100 mi² should maintain a dissolved oxygen concentration of 5 mg/l. Streams with a drainage area of 100 mi² or less should maintain a dissolved oxygen concentration of 3 mg/l. When the water temperature exceeds 22°C, the dissolved oxygen concentration may be lowered 1 mg/l below the applicable standard due to diurnal fluctuation. This decrease shall not persist longer than 8 hours during any 24-hour period.

b. Spring conditions - Sensitive life stages of aquatic organisms should be protected in all streams with an absolute minimum dissolved oxygen concentration of 5 mg/l.

15. The following dissolved oxygen requirements will protect the integrity of the biological community attainable within streams of the Gulf Coastal Plains Ecoregion.

For typical Gulf Coastal streams:

a. Summer critical condition - All streams with watersheds greater than 500 mi^2 should maintain a dissolved oxygen concentration of no less than 5 mg/l. In streams with watersheds of 500 mi^2 or less, the minimum dissolved oxygen concentration should be 3 mg/l. When the water temperature exceeds 22°C, the dissolved oxygen concentration may be lowered 1 mg/l below the applicable standard due to diurnal fluctuation. This decrease shall not persist longer than 8 hours during any 24-hour period.

b. Spring conditions - To totally protect sensitive life stages of aquatic organisms, an absolute minimum dissolved oxygen concentration of 6.5 mg/l is necessary.

For springwater-influenced Gulf Coastal streams:

a. Summer critical season - All streams should have a minimum dissolved oxygen concentration of 6 mg/l. When water temperature exceeds 22°C, the dissolved oxygen concentration may be lowered 1 mg/l below the applicable standard due to diurnal fluctuation. This decrease may not persist longer than 8 hours during any 24-hour period.

b. Spring conditions - To totally protect sensitive life stages of aquatic organisms, an absolute minimum dissolved oxygen concentration of 6.5 mg/l is necessary.

16. The following dissolved oxygen requirements are expected to protect the integrity of the biological community attainable within the Arkansas River Valley Ecoregion.

a. Summer critical condition - Streams with a drainage area greater than 400 mi^2 should have a minimum dissolved oxygen concentration of 5 mg/l. Streams with watersheds from 150-400 mi^2 should have a 4 mg/l minimum dissolved oxygen concentration, and streams with a drainage area of less than 150 mi^2 should have a minimum dissolved oxygen concentration of 3 mg/l. When the water temperature exceeds 22°C, the dissolved oxygen concentration may be lowered 1 mg/l below the applicable standard due to diurnal fluctuation. This decrease shall not persist longer than 8 hours during any 24-hour period.

b. Spring conditions - Sensitive life stages of aquatic organisms will be totally protected in all stream sizes with an absolute minimum dissolved oxygen concentration of 6.5 mg/l.

17. The following dissolved oxygen requirements will protect the integrity of the biological community attainable within the Ouachita Mountains Ecoregion.

a. Summer critical conditions - Streams with watersheds of all sizes in this ecoregion should have a minimum dissolved oxygen concentration of 6 mg/l. When the water temperature exceeds 22°C, the dissolved oxygen concentration may be lowered 1 mg/l below the applicable standard due to diurnal fluctuation. This decrease shall not persist longer than 8 hours during any 24-hour period.

b. Spring conditions - Sensitive life stages of aquatic organisms should be protected in all streams with an absolute minimum dissolved oxygen concentration of 6.5 mg/l.

18. Based on data from the reference streams within the Ozark Highlands Ecoregion, the following requirements will protect the integrity of the attainable aquatic communities.

a. Summer critical conditions - Streams with a drainage area greater than 100 mi^2 should have a minimum dissolved oxygen concentration of 6 mg/l. Streams with a drainage area of 100 mi^2 or less should have a minimum dissolved oxygen concentration of 5 mg/l. When the water temperature exceeds 22°C, the dissolved oxygen concentration may be lowered 1 mg/l below the applicable standard due to diurnal fluctuation. This decrease shall not persist longer than 8 hours during any 24-hour period.

b. Spring conditions - Sensitive life stages of aquatic organisms should be protected in all streams with an absolute minimum dissolved oxygen concentration of 6.5 mg/l.

19. The following dissolved oxygen requirements will protect the integrity of the biological community attainable within the Boston Mountains Ecoregion.

    a. Summer critical conditions - All streams within this ecoregion should have a minimum dissolved oxygen concentration of 6 mg/l. When the water temperature exceeds 22°C, the dissolved oxygen concentration may be lowered 1 mg/l below the applicable standard due to diurnal fluctuation. This decrease shall not persist longer than 8 hours during any 24-hour period.

    b. Spring conditions - Sensitive life stages of aquatic organisms should be protected in all watersheds with an absolute minimum dissolved oxygen concentration of 6.5 mg/l.

20. Various taxa groupings of macroinvertebrates are characteristic of the ecoregion streams; however, the high mobility of many macroinvertebrates results in considerable overlap of taxa among streams of certain ecoregions.

21. All ecoregions demonstrated substantial variation between spring and summer macroinvertebrate populations; however, the summer conditions facilitate increased sampling efficiency and provide a better characterization of the communities.

22. Because of their dependence on attachment or cover-providing structures, macroinvertebrate diversity is strongly correlated with physical habitat variability.

23. The diversity index of all macroinvertebrate populations sampled was high because of the least-disturbed nature of the sample streams; however, the lowest diversities were found in the Boston Mountains and the Delta Ecoregions because of their more homogeneous, although different, habitat. The greatest diversity was found in the Gulf Coastal Ecoregion.

24. Functional feeding assemblages of macroinvertebrates also characterize the ecoregion benthic communities. Although collectors dominate in streams of all ecoregions, they are most abundant in the Delta Ecoregion populations. The Gulf Coastal Ecoregion has the greatest number of predators and scrapers are most abundant in Ozark Highland communities.

25. Fish populations within the six ecoregions are distinctive and characteristic of the least-disturbed streams. These populations are identifiable by a list of key and indicator species.

26. The greatest similarity of fish populations exist between the Ouachita Mountains and Boston Mountains Ecoregions; the Delta and Gulf Coastal Ecoregion fisheries are the next most similar.

27. The largest proportion of sensitive fishes exist in the upland ecoregions, particularly in the Ozark Highlands.

28. The largest number of fish species was collected from the Arkansas River Valley Ecoregion because of its wide range of stream habitat types. The Delta Ecoregion was lowest in species richness.

Glossary of Terms

1. **Amphipoda:** The order of crustaceans with a laterally compressed body. Commonly referred to as sideswimmers or water-scuds.

2. **Benthos:** Collectively, bottom-dwelling or substrate-oriented organisms.

3. **Carnivores:** Fishes which feed primarily on other fishes and large invertebrates such as crayfish.

4. **Catostomidae (CAT):** The family of fishes which includes the suckers, buffalo and redhorses.

5. **Centrarchidae (CENT):** The family of fishes known as sunfishes, which also includes the black basses and crappies.

6. **Coleoptera:** The order of insects commonly referred to as beetles.

7. **Collector:** One of the functional feeding groups of macroinvertebrates. They gather food either actively or passively generally by feeding of fine particulate organic matter suspended in the water column.

8. **Coarse Particulate Organic Matter:** Organic material utilized as a food source. Particles are larger than 1 mm in size.

9. **Cyprinidae (CYP):** The family of fishes which includes the minnows and carp.

10. **Decapoda:** The order of crustaceans including crayfishes and freshwater shrimp.

11. **Diptera:** The order of insects that undergo complete metamorphosis and have only one pair of wings as adults. Commonly referred to as flies.

12. **Diversity Index:** Refers to the Shannon-Wiener dominance diversity index which is a measure of the distribution of the taxa within the population. Values generally range from 0 to 5; 0 is the least diverse and 5 the most diverse.

13. **Ephemeroptera:** The order of insects which have wings held vertically over the back when at rest. The group is commonly referred to as mayflies.

14. **Fine Particulate Organic Matter:** Organic material utilized as a food source. Particle size ranges from 0.5 μm to <1 mm.

15. **Functional Feeding Group:** A general association of aquatic insects based on the feeding mechanism of the species.

16. **Gastropoda:** A class of mollusks with a univalve shell. Commonly referred to as and includes all freshwater snails.

17. **Ictaluridae (ICT):** The family of fishes which includes the catfishes and madtoms.

18. **Indicator Species:** Species of fish which may or may not be dominant within a species group and may not be limited to one area of the state, but which, because of their presence, are readily associated with a specific type of ecosystem.

19. **Isopoda:** An order of crustaceans whose bodies are dorso-ventrally compressed. These are commonly referred to as aquatic sowbugs.

20. **Key Species:** Fishes which are normally the dominant species within the important groups such as fish families or trophic feeding levels.

21. **Macroinvertebrate Feeders:** Fishes which feed primarily on macroinverbrates such as insects and other small invertebrates; the secondary or intermediate feeding level.

22. **Megaloptera:** The order of a small group of insects whose immature forms are commonly referred to as hellgrammites.

23. **Odonata:** The order of a large group of insects which are commonly referred to as dragonflies and damselflies.

24. **Percidae (PERC):** The family of fishes which includes the darters, walleye and sauger.

25. **Plecoptera:** The order of net-winged insects commonly referred to as stoneflies.

26. **Predator:** One of the functional feeding group designations. Includes those organisms which obtain food by killing and consuming living animals.

27. **Primary Feeders:** Fishes which feed on the primary or lowest production level in the aquatic ecosystem, e.g., phytoplankton, periphyton, detritus.

28. **Relative Abundance Value:** A numerical ranking of the abundance of a species based on their frequency of occurrence, knowledge of normal distributions of the species, gear selectivity, collecting limitations at sample sites and the distribution of different size or age groups of the species. **Maximum value is 12 and minimum is 1** (see Appendix C of Volume I: Data Compilation).

29. **Scraper:** One of the functional feeding groups of macroinvertebrates. This group's feeding method is dislodging attached algae or periphyton and associated material from mineral or organic surfaces.

30. **Sensitive Species:** A species of fish which is intolerant and may disappear or become substantially reduced in abundance due to slight to moderate perturbations within its habitat; a list developed by consensus of local ichthyologists.

31. **Shredder:** One of the functional feeding groups of macroinvertebrates. This group's feeding method is chewing mostly on living vascular plant tissue or coarse particulate organic matter.

32. **Syntopic:** Found within the same general area; often collected within the same sample; normally refers to two similar species which have overlapping habitat requirements.

33. **Trichoptera:** The order of insects having hairy wings and undergoing complete metamorphosis. Commonly referred to as caddisflies.

34. **Trophic Feeding Level:** Refers to the level of the food chain upon which a particular organism derives its primary energy supply; the primary food source.

Appendix A: Water Quality Data - Summer

STREAM	REG	SORT#	WTRSHD	FT/MI	CVR	SB TYPE	DATE	Q-CFS	T-CEL.	pH	TURB	TSS	TDS	BOD5	BOD20	T.PHOS	PO4-P	NO2+NO3-N	NH3-N	CL-	SO4	Fe	COND	ALK	HARD	Chl a
								SUMMER CHEMISTRY DATA								SUMMER CHEMISTRY DATA							SUMMER CHEMISTRY DATA			
*BOAT 6	BOAT 6	10	23	0.7	40.0	M/S	*8-2-83	2.9	26.5	6.5	6	3	93	2.4	7.3	0.20	0.22	0.05	0.30	5	3	1.32	110	44	51	
*SECOND	SECOND	11	60	0.8	43.0	M/S	*7-31-84	7.5	25.0	7.5	8	11	248	1.2	3.9	0.10	0.04	0.12	0.07	32	8	0.25	416	163	181	
*VILLAGE CR.	VLAGE	12	194	0.5	87.0	M/S	*7-30-85	133.5	25.0	7.5	30	33	104	1.2	4.2	0.16	0.09	0.12	0.09	9	11		203	117	109	8.9
*BA.DEVIEW	BY DEVW	13	460	0.6	24.0	M/S	*7-30-85	191.0	27.0	7.9	55	60	232	1.6	5.5	0.20	0.10	0.72	0.11	9	24		360	137	146	21.7
* AVERAGE		14	184	0.7	48.5	M/S	*	83.7	26.1	7.4	25	27	189	1.6	5.2	0.19	0.11	0.25	0.14	14	12	0.79	294	115	122	15.3
*E.FK.TULIP	TULIP	20	46	3.5	57.0	SND	*8-9-83	5.2	24.5	5.4	8	5	49	0.4	1.4	0.03	0.01	0.00	0.04	5	4	0.41	37	8	11	2.4
*CYPRESS	CYPRS	21	73	4.2	16.0	M\S	*8-9-83	10.0	25.0	6.1	21	7	45	0.7	2.1	0.05	0.02	0.14	0.07	5	1	0.94	24	5	10	3.0
*WHITEWATER	WHWTR	22	23	2.8	33.0	SND	*8-13-85	0.0	25.0	6.9	6	8	66	3.5	6.9	0.12	0.04	0.01	0.03	4	9	0.17	68	27	28	8.8
*BIG CREEK	BIG	23	59	2.7	29.0	SND	*8-6-85	0.0	24.2	6.6	26	13	62	2.6	5.1	0.07	0.03	0.02	0.03	3	15		59	16	24	9.6
*DERRIEUSSEAUX	DERSX	24	140	3.4	43.0	SND-SLT	*8-6-85	0.0	23.0	6.7	7	10	65	3.3	8.1	0.07	0.03	0.04	0.06	4	8		83		38	
*FREEO CREEK	FREEO	25	156	3.0	74.0	SND-GVL	*8-13-85	.0	25.0	7.0	12	10	69	2.2	5.6	0.10	0.06	0.07	0.07	5	8	0.12	65	27	26	1.0
*HUDGINS CREEK	HDGNS	26	187	1.4	59.0	M/S	*8-6-85	.0	25.0	6.9	9	10	81	2.9	6.8	0.10	0.04	0.03	0.02	5	10	0.20	101		40	6.1
*L'AIGLE CREEK	L'AGL	27	232	2.6	80.0	M/S-GVL	*8-13-85	0.0	27.0	6.8	9	18	64	4.0	8.7	0.13	0.06	0.01	0.03	6	9	0.08	57	15	22	12.3
*MORO BAYOU	MORO	28	451	1.6	61.0	SND-GVL	*8-13-85	0.0	26.0	6.7	8	7	62	1.7	4.2	0.11	0.07	0.05	0.09	5	8	0.07	60	20	23	5.7
*AVERAGE (EXCLUDES TLP&C		29	179	2.9	54.1	SND-M/S	*	.0	25.0	6.8	11	11	67	2.9	6.5	0.10	0.05	0.03	0.05	4	10	0.13	70	21	29	7.4
*MILL	MILL	30	17	13.5	3.0	BDR	*8-30-83	0.0	26.0	6.3	8	10	52	2.5	5.5	0.06	0.01	0.02	0.07	6	1	0.50	75	22	23	11.0
*N.FK CADRON	N CDRN	31	21	10.0	7.0	BDR-RBL	*8-30-83	0.1	26.0	6.2	4	3	38	1.2	3.5	0.06	0.01	0.07	0.06	4	1	1.05	42	11	17	1.0
*TEN MILE	TEN MI	32	49	8.1	17.0	BLD-RBL	*8-21-84	0.2	24.0	6.6	2	5	47	1.1	2.5	0.16	0.13	0.21	0.05	6	1	0.20		27	29	5.9
*DUTCH	DUTCH	33	110	3.0	46.0	GVL-M/S	*8-21-84	0.5	25.5	6.7	4	5	57	1.3	3.7	0.05	0.01	0.12	0.08	6	2	0.83		32	34	6.2
*PETIT JEAN	PT JEAN	34	241	3.9	9.0	RBL-GVL	*8-27-85	0.3	24.0	7.2	14	13	88	1.4	3.9	0.06	0.01	0.05	0.04	6	8		130	58	38	5.6
*CADRON CREEK	CDRN	35	300	0.6	6.0	M/S	*8-27-85	15.0	27.0	7.0	14	17	72	3.3	8.8	0.08	0.02	0.04	0.02	5	4		87	34	32	24.1
* AVERAGE		36	124	6.7	14.7		*	0.2	25.4	6.7	8	9	59	1.0	4.7	0.08	0.03	0.09	0.05	5	3	0.65	84	29	29	9.0
							*	AVG Q EXCLUDES CADRON CREEK																		
*INDIAN	INDN	40	47	32.0	0.0	BDR-RBL	*9-13-83	0.1	25.5	6.6	3	1	34	1.1	1.6	0.01	0.01	0.01	0.02	3	2	0.07	44	14	23	1.1
*HURRICANE	HURR	41	50	33.0	3.0	RBL-SND	*9-13-83	0.1	24.5	6.4	3	2	36	1.7	2.2	0.01	0.01	0.01	0.01	3	2	0.09	54	20	28	0.3
*ARCHEY	ARCHY	42	107	14.0	19.0	RBL-LBD	*8-14-84	0.6	27.5	7.0	3	2	31	1.1	3.0	0.03	0.01	0.03	0.01	4	2	0.19	47	18	19	1.6
*ILLINOIS B.	ILL BY	43	125	12.5	7.0	BDR-RBL	*8-14-84	1.0	26.0	6.8	2	2	35			0.03	0.02	0.05	0.02	4	3	0.11	47	17	19	2.1
*LEE CREEK	LEE	44	168	15.3	15.0	BDR-RBL	*9-3-85	3.5	26.0	7.4	2	1	85	1.2	2.1	0.02	0.01	0.03	0.01	12	6			42	45	0.5
*MULBERRY RIVER	MLBRY	45	373	13.7	3.0	BDR-RBL	*9-3-85	6.4	28.0	7.3	2	5	38	1.0	1.7	0.01	0.01	0.01	0.01	3	5			20	19	1.3
* AVERAGE		46	145	20.1	7.8	BDR-RBL	*	2.0	26.3	6.9	3	2	43	1.2	2.1	0.02	0.01	0.02	0.01	5	3	0.12	48	22	26	1.2
*S.FK.SPAV	S SPAV	50	18	25.5	33.0	GVL-RBL	*9-20-83	1.4	20.0		2	2	145	0.2	0.8	0.01	0.01	0.92	0.01	8	2	0.05	227		117	0.5
*FLINT	FLINT	51	19	19.6	28.0	GVL-RBL	*9-20-83	4.5	20.0	7.5	3	6	134	1.0	2.9	0.08	0.01	0.92	0.04	9	1	0.05	206		100	3.3
*YOCUM	YOCUM	52	55	18.0	5.0	GVL-RBL	*8-20-84	5.3	22.0		2	1	196	0.4	1.6	0.03	0.02	0.72	0.02	9	3	0.03		153	161	0.6
*LONG	LONG	53	104	7.0	12.0	GVL-SND	*8-20-84	9.5	22.0	7.1	4	7	190	0.4	1.9	0.03	0.01	1.03	0.04	11	5	0.09		145	154	1.0
*WAR EAGLE	WR EGL	54	263	4.0	8.0	GVL-RBL	*9-9-85	25.1	23.0	7.9	6	12	139	1.3	2.6	0.05	0.03	1.15	0.01	7	7			107	112	5.0
*KINGS RIVER	KINGS	55	526	4.6	2.0	GVL-BDR	*9-9-85	40.0	26.0	8.0	7	10	156	0.7	2.0	0.09	0.07	0.38	0.01	6	12			120	133	1.5
* AVERAGE		56	178	13.1	14.7	GVL-RBL	*	15.8	22.2	7.6	4	6	161	0.7	2.0	0.05	0.03	0.05	0.02	8	5	0.06	217	133	130	2.1
*BOARD CAMP	BD CMP	60	19	27.0	19.0	GVL-RBL	*8-7-84	2.7	24.0	6.6	4	2	39	0.7	1.9	0.01	0.01	0.10	0.01	5	7		40	12	35	1.1
*L.MO	L MO	61	30	29.0	6.0	RBL-GVL	*8-16-83	3.9	26.0	7.3	2	1	42	0.5	1.1	0.01	0.01	0.02	0.01	3	1	0.05	43	13	19	0.7
*S.F.OUA	SF OUA	62	46	7.0	20.0	GVL	*8-16-83	6.7	27.0	6.6	2	2	105	0.8	1.7	0.02	0.01	0.03	0.02	3	4	0.05	167	68	90	0.6
*COSSATOT	COSST	63	120	40.0	1.0	BDR-LBD	*8-7-84	17.4	26.0	7.2	2	1	42	0.5	1.9	0.01	0.01	0.02	0.01	5	9		55	21	33	0.4
*CADDO RIVER	CADDO	64	291	13.3	14.0	RBL-BDR	*8-20-85	134.0	27.0	7.6	4	5	74	0.6	1.5	0.04	0.03	0.01	0.02	3	8		104	45	49	1.7
*SALINE RIVER	SALNE	65	361	4.1	5.0	RBL-GVL	*8-20-85	53.0	25.5	7.7	3	3	73	0.5	1.3	0.03	0.03	0.05	0.04	3	6		103	47	45	
* AVERAGE		66	145	20.2	10.0	RBL-GVL	*	36.3	25.9	7.2	3	2	63	0.6	1.6	0.02	0.02	0.04	0.02	4	6	0.05	85	34	45	0.9
*DELTA	DL	70	104	0.7	48.5	M/S	*	83.7	26.1	7.4	25	27	189	1.6	5.2	0.19	0.11	0.25	0.14	14	12	0.79	294	115	122	15.3
GULF COASTAL	GC	80	179	2.5	54.1	SND-M/S	*	.0	25.0	6.8	11	11	67	2.9	6.5	0.10	0.05	0.03	0.05	4	10	0.13	70	21	29	7.4
*ARK RIVER VAL	ARV	90	124	6.7	14.7		* NOTE **	0.2	25.4	6.7	8	9	59	1.0	4.7	0.08	0.03	0.09	0.05	5	3	0.65	84	29	29	9.0
*BOSTON MTS	BM	100	145	20.1	7.8	BDR-RBL	*	2.0	26.3	6.9	3	2	43	1.2	2.1	0.02	0.01	0.02	0.01	5	3	0.12	48	22	26	1.2
*OZARK HIGHLD	OZH	110	178	13.1	14.7	GVL-RBL	*	15.8	22.2	7.6	4	6	161	0.7	2.0	0.05	0.03	0.05	0.02	8	5	0.06	217	133	130	2.1
*OUACHITA MTS	OUH	120	145	20.2	10.0	RBL-GVL	*	36.3	25.9	7.2	3	2	63	0.6	1.6	0.02	0.02	0.04	0.02	4	6	0.05	85	34	45	0.9

Appendix A (cont.): Water Quality Data - Spring

STREAM	DATE	Q-CFS	T-CEL.	pH	TURB	TSS	TDS	BOD5	BOD20	T.PHOS	PO4-P	NO2+NO3-N	NH3-N	CL-	SO4	Fe	COND	ALK	HARD	Chl a	FecColi
BOAT G	4-10-84	230	16.0	5.9	63	22	102	2.0	6.0	0.24	0.16	0.22	0.20	1	2	3.10	43	15	19	3.0	90
SECOND	4-2-85	165	13.0	7.0	218	139	303	3.5	9.4	0.26	0.24	0.24	0.27	6	13	4.48	94	30	42	4.5	680
VILLAGE CR.	4-8-86	35	19.0	7.3	102	73	180	5.0	12.2	0.41	0.20	0.12	0.13	6	10	2.70		51	50	18.5	1130
BA.DEVIEW	4-8-86	500	21.0	6.8	128	69	168	3.3	8.6	0.27	0.15	0.17	0.16	4	8	2.50		21	20	16.7	505
AVERAGE		233	17.3	6.8	128	76	188	3.5	9.1	0.30	0.19	0.19	0.19	4	8	3.20	69	29	33	10.7	601
E.FK.TULIP	4-5-84	56	12.0	5.8	20		52	1.4	2.3	0.04	0.02	0.03	0.06	3	5	0.48	35	5	14	0.3	30
CYPRESS	4-5-84	150	13.0	5.6	10		39	1.4	2.5	0.04	0.02	0.04	0.05	2	3	0.39	22	2	11	0.3	10
WHITEWATER	4-1-86	2	17.0	6.4	8	9	94	1.6	4.4		0.01	0.01	0.01	13	13	2.40	80	11	21	4.2	108
BIG CREEK	4-1-86	1	16.0	6.1	12	21	116	1.7	4.9	0.08	0.01	0.01	0.02	9	33	2.40	117	8	30	18.8	348
DERRIEUSSEAUX	3-27-85	200	15.0	5.8	26	19	69	1.2	3.2	0.05	0.04	0.06	0.03	4	12	0.72	44	5	13	0.6	80
FREEO CREEK	4-1-86	16	17.0	6.6	6	6	76	1.3	4.1		0.01	0.03	0.03	8	9	1.60	57	11	17	0.7	48
HUDGINS CREEK	3-27-85	300	15.0	6.2	24	19	88	0.9	2.5	0.05	0.04	0.13	0.05	5	25	0.74	79	5	19	0.7	16
L'AIGLE CREEK	3-25-86	189	13.5	6.6	22	15	72	1.3	3.2	0.07	0.02	0.07	0.10	6	10			8	16	1.6	100
MORO BAYOU	3-25-86	350	14.0	6.5	17	12	72	1.0	3.8	0.06	0.01	0.04	0.07	7	11			8	15	3.6	40
AVERAGE		151	15.4	6.3	16	9	67	1.4	3.7	0.06	0.02	0.05	0.04	7	16	1.57	75	8	19	4.3	106
MILL	5-1-84	10	16.0	6.5	5	4	38	0.7	1.9	0.01	0.01	0.40	0.05	4	2	0.18	34	8	11		10
N.FK CADRON	5-1-84	10	15.5	5.6	4	4	31	0.6	1.8	0.01	0.01	0.10	0.01	3	2	0.28	21	4	7	0.8	160
TEN MILE	4-16-85	105	15.0	6.9	5	4	38	0.7	2.3	0.08	0.04	0.25	0.06	4	3	0.35	40	9	12	1.9	233
DUTCH	4-16-85	70	16.0	6.6	10	8	51	0.7	2.4	0.05	0.01	0.51	0.04	5	5	1.08	53	13	25	1.1	132
PETIT JEAN	4-15-86	300	18.0	7.0	43	27	77	1.3	3.4	0.06	0.04	0.11	0.11	4	12	1.10	73	16	22	0.4	223
CADRON CREEK	4-16-86	500	18.0	6.8	10	18	38	0.1	2.1	0.04	0.02	0.44	0.08		3	0.50	34	6	11	1.1	200
AVERAGE		166	16.4	6.6	13	11	46	0.7	2.3	0.04	0.02	0.30	0.06	4	5	0.56	43	9	15	1.1	160
INDIAN	5-22-84	19	16.5	6.2	6	1	27	0.1	1.3	0.01	0.01	0.01	0.04	2	1	0.14	30	9	13		
HURRICANE	5-22-84	30	18.5	6.7	3	1	30	0.1	1.4	0.01	0.01	0.01	0.03	2	1	0.09	45	14	17		
ARCHEY	5-7-85	122	19.0	7.0	4	3	33	1.4	1.7	0.02	0.02	0.02	0.03	3	5	0.07		10	12	0.2	12
ILLINOIS B.	5-7-85	147	19.0	7.0	4	3	22	1.1	1.5	0.01	0.01	0.04	0.03	3	6	0.05		10	13	0.5	8
LEE CREEK	5-6-86	300	17.0	7.4	11	5	51	0.5	1.1	0.05	0.02	0.05	0.02	3	3	0.30	71	28	33	0.0	56
MULBERRY RIVER	5-6-86	300	18.5	7.1	7	3	27	0.6	1.2	0.05	0.01	0.05	0.01	3	3	0.20	33	12	13	0.3	8
AVERAGE		153	18.1	6.9	6	3	32	0.6	1.4	0.03	0.01	0.03	0.03	2	3	0.14	45	14	17	0.2	21
S.FK.SPAV	5-15-84	17	15.0	7.3	2	3	114	0.6	1.6	0.01	0.01	1.51	0.04	4	4	0.03	180	69	89	1.7	2500
FLINT	5-15-84	27	15.0	6.7	7	19	111	2.2	5.2	0.15	0.09	1.06	0.10	5	5	0.14	170	61	71	4.5	8800
YOCUM	5-1-85	162	17.0	7.9	8	9	175	1.0	2.2	0.07	0.03	1.52	0.01	8	10	0.15	272	118	135	2.0	2300
LONG	5-6-85	183	19.0	8.3	2	4	151	1.5	2.1	0.04	0.03	0.99	0.03	5	8	0.03		115	131		
WAR EAGLE	5-13-86	102	21.0	7.7	4	3	93	1.1	2.4	0.03	0.02	0.62	0.07	5	9	0.01	165	68	77	2.1	40
KINGS RIVER	5-13-86	252	21.0	7.9	3	4	111	1.1	2.4	0.02	0.02	0.19	0.08	3	8	0.01	207	97	107	6.4	28
AVERAGE		124	18.0	7.6	4	7	126	1.3	2.7	0.05	0.03	1.11	0.06	5	7	0.06	199	88	102	3.4	2735
BOARD CAMP	4-8-85	20	13.0	6.1	3	4	30	0.9	1.5	0.02	0.02	0.09	0.01	2	6	0.05	27	8	13	0.0	12
L.MO	4-17-84	26	13.0	6.6	2	1	35	0.3	0.9	0.02	0.01	0.01	0.01	5	2	0.03	25	7	9	0.3	4
S.F.OUA	4-17-84	34	13.0	7.6	2	2	91	0.4	0.9	0.03	0.01	0.07	0.01	5	6	0.03	149	61	69	0.4	24
COSSATOT	4-8-85	97	16.5	6.7	3	2	29	0.9	1.9	0.01	0.01	0.01	0.02	2	6	0.05	30	9	11	0.2	4
CADDO RIVER	4-30-86	500	20.0	7.4	6	1	23	0.7	1.6	0.03	0.03	0.07	0.01	3	6	0.02	73	28	33	2.7	44
SALINE RIVER	4-30-86	400	20.0	7.6	5	3	49	0.6	1.9	0.02	0.02	0.02	0.01	3	7	0.20	110	43	51	1.3	40
AVERAGE		179	15.9	7.0	4	2	43	0.6	1.5	0.02	0.02	0.05	0.01	3	6	0.06	69	26	31	0.8	21
DELTA		233	17.3	6.8	128	76	188	3.5	9.1	0.30	0.19	0.19	0.19	4	8	3.20	69	29	33	10.7	601
GULF COASTAL		151	15.4	6.3	16	9	67	1.4	3.7	0.06	0.02	0.05	0.04	7	16	1.57	75	8	19	4.3	106
ARK RIVER VAL		166	16.4	6.6	13	11	46	0.7	2.3	0.04	0.02	0.30	0.06	4	5	0.56	43	9	15	1.1	160
BOSTON MTS		153	18.1	6.9	6	3	32	0.6	1.4	0.03	0.01	0.03	0.03	2	3	0.14	45	14	17	0.2	21
OZARK HIGHLD		124	18.0	7.6	4	7	126	1.3	2.7	0.05	0.03	1.11	0.06	5	7	0.06	199	88	102	3.4	2735
OUACHITA MTS		179	15.9	7.0	4	2	43	0.6	1.5	0.02	0.02	0.05	0.01	3	6	0.06	69	26	31	0.8	21

Appendix B. Water Temperature Values for All Ecoregion Reference Streams

STREAM	REG	SUMMER DATE	MAX	MIN	MEAN	SPRING DATE	MAX	MIN	MEAN	CANOPY
BOAT G	BOAT G	8-2-83	27.5	24.5	26.2	4-10-84	18.9	15.0	16.7	94
SECOND	SECOND	7-31-84	28.0	22.3	25.0	4-2-85	17.5	12.0	14.3	55
VILLAGE CR.	VLAGE	7-30-85	28.5	24.8	27.4	4-8-86	20.0	14.0	17.4	85
BA.DEVIEW	BY DEVW	7-30-85	28.5	26.6	27.9	4-8-86	22.6	20.4	21.5	60
MAXIMUM			28.5	26.6	27.9		22.6	20.4	21.5	74 AVG
E.FK.TULIP	TULIP	8-9-83	26.0	23.9	25.1	4-5-84	14.0	11.2	13.0	95
CYPRESS	CYPRS	8-9-83	26.3	24.9	25.6	4-5-84	14.3	12.0	13.2	90
WHITEWATER	WHWTR	8-13-85	25.4		24.8	4-1-86	18.0	15.5	17.0	96
BIG CREEK	BIG	8-6-85	24.5	23.0	23.7	4-1-86	14.9	14.0	14.6	100
DERRIEUSSEAUX	DERSX	8-6-85	23.6	23.0	23.4	3-27-85	15.5	15.0	15.4	88
FREED CREEK	FREED	8-13-85	26.0		25.3	4-1-86	17.1	16.5	17.1	100
HUDGINS CREEK	HDGNS	8-6-85	25.9	24.0	25.1	3-27-85	15.9	14.5	15.3	66
L'AIGLE CREEK	L'AGL	8-13-85	28.0	25.6	26.7	3-25-86	13.8	13.0	13.8	47
MORO BAYOU	MORO	8-13-85	26.6	25.5	26.1	3-25-86	16.0	12.7	14.5	71
MAXIMUM			28.0	25.6	26.7		18.0	16.5	17.1	84 AVG
MILL	MILL	8-30-83	28.3	24.8	26.4	5-1-84	18.3	14.3	16.3	56
N.FK CADRON	N CDRN	8-30-83	26.5	23.0	24.7	5-1-84	18.0	14.5	16.1	33
TEN MILE	TEN MI	8-21-84	27.5	23.1	24.9	4-16-85	17.3	14.3	15.9	88
DUTCH	DUTCH	8-21-84	26.7	25.2	26.1	4-16-85	17.5	15.5	16.8	64
PETIT JEAN	PT JEAN	8-27-85	27.0	23.5	25.1	4-15-86	16.5	14.0	15.6	64
CADRON CREEK	CDRN	8-27-85	30.5	26.0	28.1	4-16-86	17.0	15.0	16.3	22
MAXIMUM			30.5	26.0	28.1		18.3	16.5	17.1	55 AVG
INDIAN	INDN	9-13-83	26.4	21.9	24.3	5-22-84	21.9	15.5	18.0	5
HURRICANE	HURR	9-13-83	25.4	21.6	23.4	5-22-84	21.8	17.1	19.5	59
ARCHEY	ARCHY	8-14-84	28.5	27.0	28.0	5-7-85	19.0	17.0	18.1	7
ILLINOIS B.	ILL BY	8-14-84	30.8	25.0	27.5	5-7-85	21.5	17.5	19.1	8
LEE CREEK	LEE	9-3-85	30.0	24.0	26.5	5-6-86	19.0	17.0	18.1	0
MULBERRY RIVER	MLBRY	9-3-85	29.0	26.5	27.6	5-6-86	18.2	17.1	17.7	15
MAXIMUM			30.8	27.0	28.0		21.9	17.5	19.5	16 AVG
S.FK.SPAV	S SPAV	9-20-83	21.3	15.4	18.2	5-15-84	19.0	14.3	16.0	19
FLINT	FLINT	9-20-83	22.9	13.5	17.4	5-15-84	22.2	13.3	16.6	11
YOCUM	YOCUM	8-28-84	26.5	21.7	24.0	5-1-85	18.2	15.0	16.3	21
LONG	LONG	8-28-84	28.5	22.0	25.3	5-6-85	18.5	15.2	16.6	36
WAR EAGLE	WR EGL	9-9-85	24.0	19.5	21.5	5-13-86	22.0	20.5	21.4	37
KINGS RIVER	KINGS	9-9-85	27.0	23.0	24.9	5-13-86	22.0	19.8	21.0	29
MAXIMUM			28.5	23.0	25.3		22.2	20.5	21.4	26 AVG
BOARD CAMP	BD CMP	8-7-84	27.5	23.5	24.9	4-8-85	16.0	10.0	12.7	72
L.MO	L MO	8-16-83	28.0	24.0	26.0	4-17-84	17.5	9.8	14.7	24
S.F.OUA	SF OUA	8-16-83	28.2	25.1	26.6	4-17-84	17.5	11.2	14.8	48
COSSATOT	COSST	8-7-84	30.5	25.3	27.9	4-8-85	16.3	12.0	14.1	0
CADDO RIVER	CADDO	8-20-85	28.0	25.0	26.5	4-30-86	20.5	19.3	19.9	26
SALINE RIVER	SALNE	8-20-85	28.0	25.0	26.2	4-30-86	20.2	19.3	19.8	11
MAXIMUM			30.5	25.3	27.9		20.5	19.3	19.9	30 AVG

Appendix B (cont.).

STREAM	REG		MAX	MIN	MEAN		MAX	MIN	MEAN	AVERAGE CANOPY
DELTA	DL		28.1	24.6	26.6		19.8	15.4	17.5	74
GULF COASTAL	GC	SUMMER	25.8	24.3	25.1	SPRING	15.5	13.8	14.9	84
ARK RIVER VAL	ARV	AVERAGES(	27.8	24.3	25.9	AVERAGES(	17.4	14.6	16.2	55
BOSTON MTS	BM		28.4	24.3	26.2		20.2	16.9	18.4	16
OZARK HIGHLD	OZH		25.0	19.2	21.9		20.3	16.4	18.0	26
OUACHITA MTS	OUM		28.4	24.7	26.4		18.0	13.6	16.0	30
DELTA	DL		28.5	26.6	27.9		22.6	20.4	21.5	
GULF COASTAL	GC	SUMMER	28.0	25.6	26.7	SPRING	18.0	16.5	17.1	
ARK RIVER VAL	ARV	MAXIMUMS(	30.5	26.0	28.1	MAXIMUMS(	18.3	15.5	16.8	
BOSTON MTS	BM		30.8	27.0	28.0		21.9	17.5	19.5	
OZARK HIGHLD	OZH		28.5	23.0	25.3		22.2	20.5	21.4	
OUACHITA MTS	OUM		30.5	25.3	27.9		20.5	19.3	19.9	