Microhabitat and Instream Flow Needs of the Topeka Shiner in the Rock River Watershed, MN

by

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INTRODUCTION

The Topeka shiner *(Notropis topeka)* is Minnesota's only federally endangered fish species, listed in 1999. A species of special concern in Minnesota, it has only been found in the Rock River Watershed. Reasons for its decline are not fully understood and basic understanding of habitat needs and life history have been lacking. This study was initiated to gain a better understanding of this species and factors affecting its status. Objectives of the study were to develop habitat suitability curves (HSC) and habitat versus discharge models for Topeka shiners in the Rock River Watershed. Results from this study will be incorporated into recommendations for streamflow and habitat protection for the Rock River Watershed.

The Minnesota Department of Natural Resources (MNDNR) Stream Habitat Program is developing recommendations for streamflow and habitat protection for each of Minnesota's 39 major watersheds. These recommendations are being developed using the Instream Flow Incremental Methodology (IFIM) (Bovee et al. 1998). The IFIM, developed by the U.S. Fish and Wildlife Service, is the most widely used method for addressing instream flow issues (Reiser et al. 1989). The Physical Habitat Simulation System (PHABSIM), a group of computer programs within the IFIM, combines hydraulic simulation procedures with species-specific habitat suitability criteria to predict changes in available physical habitat with changes in flow (Milhous et al. 1981; Milhous et al. 1989). Habitat suitability criteria describe the preference of an aquatic organism for the variables water depth, mean column water velocity, substrate, and cover. These flow-dependent physical habitat features play a vital role in governing the distribution and abundance of stream fishes and macroinvertebrates (Hynes 1970; Aadland 1993; Hart 1995). Because changes in flow translate into changes in these habitat features, streamflow regulation can adversely affect the structure, function, and composition of stream communities by altering the availability of various habitat types on both spatial and temporal scales (Cushman 1985; Bain et al. 1988; Sparks 1992).

Watershed Characteristics

The Rock River Watershed (Figure 1) is the only major watershed in Minnesota that is a part of the Missouri River Watershed. The source of the Rock River is in Pipestone County. The river starts out at an elevation of 1820 feet dropping 465 ft on its way to the Iowa border (Figure 2) and continues in Iowa until joining the Big Sioux River. This report only pertains to the Minnesota portion of the Rock River Watershed. The Rock River Watershed covers 1793 square miles in the southwest corner of Minnesota and includes all of Rock County and parts of Pipestone, Nobles, Jackson, Lincoln, and Murray counties. It includes the Rock River and its tributaries and parts of smaller rivers that originate in Minnesota and drain into the Rock River or the Big Sioux River in Iowa and South Dakota (Hydrologic Atlas of Minnesota 1959). The Rock River Watershed contains no natural lakes and has few trees, most found in occasional pockets along the riverbanks (Waters 1977). Many species of macroinvertebrates, reptiles, amphibians,

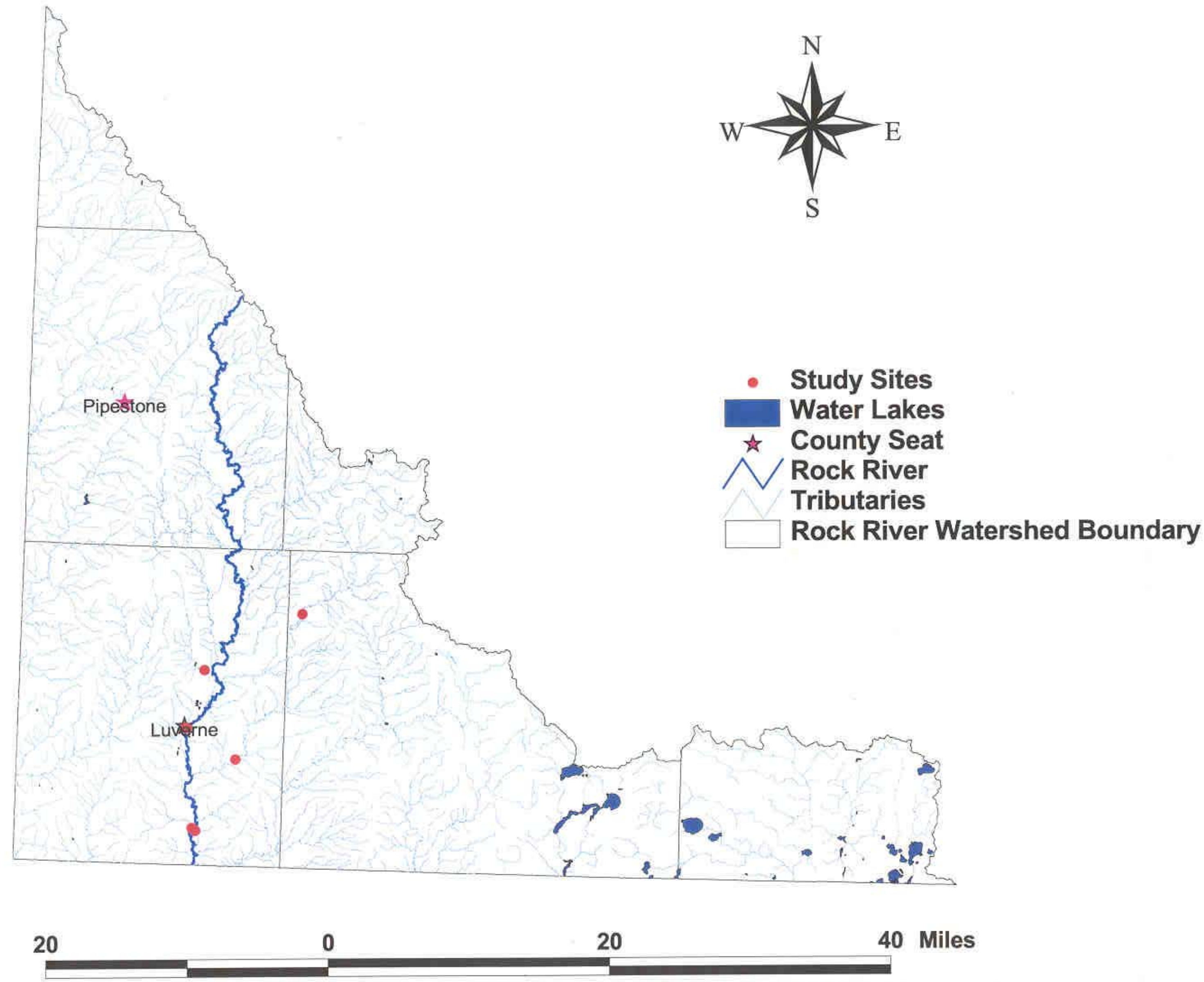


Figure 1: Map of the Rock River Watershed, showing study sites.

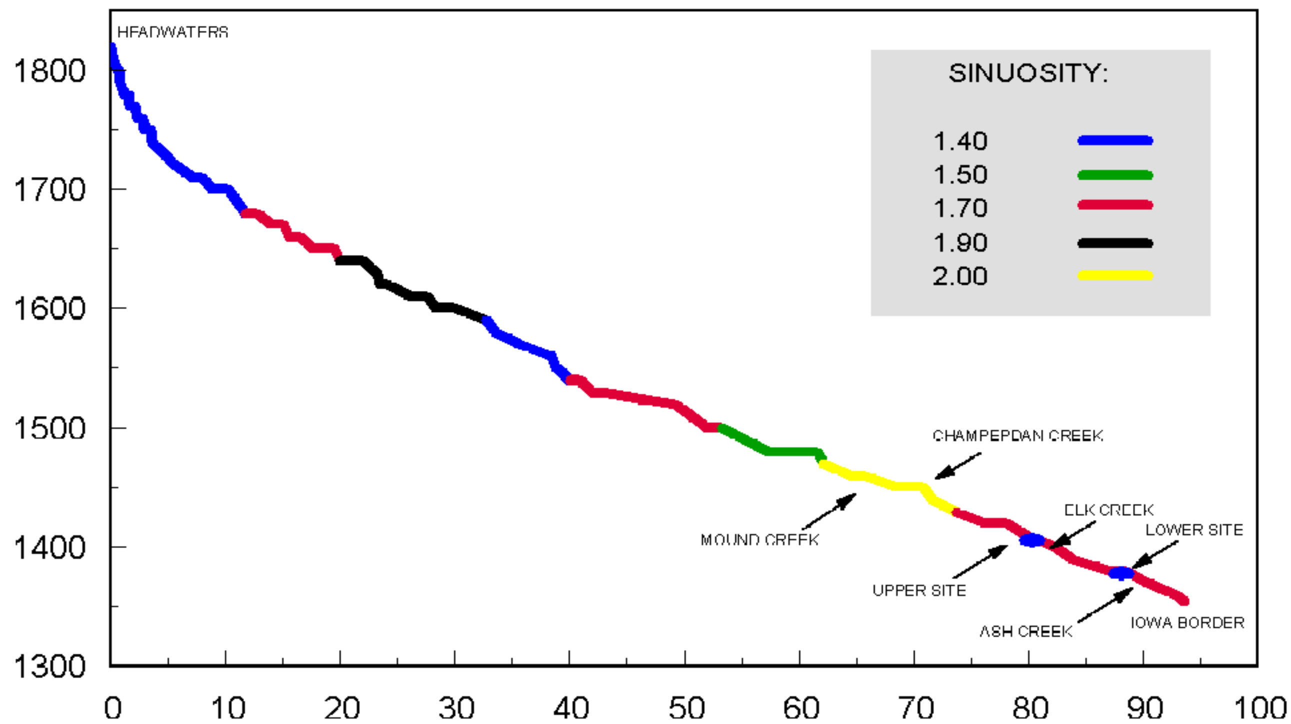


FIGURE 2. Elevation and sinuosity of the Rock River from its headwaters to the Iowa border.

birds, and mammals, and at least 45 species of fish (Table 1) and 11 species of mussels (Table 2) depend on the rivers in this watershed to meet requirements such as food, cover, and reproduction.

METHODS

Habitat Suitability Criteria

Two sites on the Rock River and one each on its tributaries Ash, Champepadan, Elk, and Mound creeks were sampled to collect fish habitat-use data and develop habitat suitability criteria for the Topeka shiner (Table 3). Fish were captured using a 6 x 25 ft. prepositioned area shocker, and microhabitat variables (depth, velocity, substrate, and cover) were measured according to methods described in Aadland 1993. Criteria describing the suitability of mean column velocity and depth were developed for Topeka shiner adults and spawners following the guidelines of Bovee et al. (1998) and substrate and cover as in Aadland et al. 1991.

Habitat Modeling

Hydraulic models were developed for the upper and lower Rock River study sites (Table 3). Data for model development were collected along 18 transects at the upper site and 14 at the lower site. Field data were collected such that any computer model or combination of models within PHABSIM could be used as needed. Models were developed separately for each site. Thirty flows were simulated at the upper site, ranging from 15 to 1150 cubic feet per second (cfs). Nineteen flows were simulated at the lower site, ranging from 5 to 250 cfs. Methods used to develop these models are described in Kuitunen et al. 1997.

Habitat guilds were modeled to examine the relation between discharge and the availability of habitat types in the Rock River Watershed (Figures 3 and 4). Habitat-preference guilds were identified by Aadland (1993) for warmwater and coolwater streams in Minnesota. Species and species-life stages were assigned to a habitat guild based on the habitat type in which their densities (individuals per area sampled) were highest. The habitat types were defined as: shallow pool (< 2 ft deep, < 1 ft/s velocity); medium pool (2-5 ft deep, < 1 ft/s velocity); deep pool (5 ft deep); raceway (2-5 ft deep, 1 ft/s velocity); slow riffle (< 2 ft deep, 1-2 ft/s velocity); and fast riffle (< 2 ft, 2 ft/s velocity); (Aadland 1993).

Sixteen representative target species-life stages, known to occur in the Rock River, were selected from the six habitat-preference guilds for habitat modeling in three seasons (Table 4). Seasons were delineated based on historic regional temperature data combined with known preferred spawning temperatures. Appropriate species-life stages from the target list were selected for each season. The three seasons were spring (March 17 - May 15), summer/fall (May 16 – November 17), and winter (November 18 – March 16). The habitat suitability criteria for the guild representatives modeled for the Rock River Watershed are provided in Appendix A.

Table 1. Composite list of fish species present in the Rock River Watershed and their habitat guilds by life stage, where YOY=young-of-year; SP=shallow pool; MP=medium pool; DP=deep pool; SR=slow riffle; FR=fast riffle; and RW=raceway. Guilds are listed for only those species that the Stream Habitat Program has developed HSCs. A dashed line indicates species that mature at 1 year or the juvenile life stage uses the same habitat as adults.

		HabitatGuilds			
Common Name	Scientific Name	YOY	Juvenile	Adult	Spawning
Longnose gar	*Lepisosteus osseus*				
Central mudminnow	*Umbra limi*				
Northern pike	*Esox lucius*			DP	
Central stoneroller	*Campostoma anomalum*	FR	SR	SR	SR
Carp	*Cyprinus carpio*				
Brassy minnow	*Hybognathus hankinsoni*			SP	
Golden shiner	*Notemigonus crysoleucas*				
Emerald shiner	*Notropis atherinoides*	SP	--	SR	
River shiner	*Notropis blennius*	FR	--	SR	
Common shiner	*Luxilus cornutus*	SP	DP	MP	SR
Bigmouth shiner	*Notropis dorsalis*	SP	--	SR	
Blacknose shiner	*Notropis heterolepis*	SP	–	DP	
Red shiner	*Cyprinella lutrensis*				
Spotfin shiner	*Notropis spilopterus*	SR	--	SR	MP
Sand shiner	*Notropis stramineus*	SR	--	SR	SR
Topeka shiner	*Notropis topeka*		–	MP	MP
Mimic shiner	*Notropis volucellus*	SR	--	SP	
Southern red belly dace	*Phoxinus erythrogaster*				
Bluntnose minnow	*Pimephales notatus*	SP	--	SR	
Fathead minnow	*Pimephales promelas*	SP	--	SP	SP
Blacknose dace	*Rhinichthys atratulus*	SP	--	SR	
Longnose dace	*Rhinichthys cataractae*	SP	--	FR	SR
Creek chub	*Semotilus atromaculatus*	SP	DP	MP	
River carpsucker	*Carpiodes carpio*	SP			
Quillback carpsucker	*Carpiodes cyprinus*	SP			
White sucker	*Catostomus commersoni*	SR	SR	DP	
Golden redhorse	*Moxostoma erythyrurum*	SP	MP	DP	
Shorthead redhorse	*Moxostoma macrolepidotum*	SR	RW	RW	FR
Greater redhorse	*Moxostoma valenciennesi*	SP	MP	RW	SR
Black bullhead	*Ameiurus melas*	SP	SR		
Channel catfish	*Ictalurus punctatus*	SR	MP	MP	
Stonecat	*Noturus flavus*	SR	FR	FR	
Tadpole madtom	*Noturus gyrinus*	SP	--	SR	
Trout-perch	*Percopsis omiscomaycus*				
Plains topminnow	*Fundulus sciadicus*				
Brook stickleback	*Culea inconstans*	SP	--	SP	

Table 1. Continued.

Common Name	Scientific Name	Habitat Guilds			
		YOY	Juvenile	Adult	Spawning
Green sunfish	*Lepomis cyanellus*	SP	--	SP	
Pumpkinseed sunfish	*Lepomis gibbosus*				
Orangespotted sunfish	*Lepomis humilis*	SP	--	MP	MP
Bluegill sunfish	*Lepomis macrochirus*	SP	SP	DP	
Largemouth bass	*Micropterus salmoides*	DP	MP		
Black crappie	*Pomoxis nigromaculatus*	SP	MP	DP	
Iowa darter	*Etheostoma exile*		--	DP	
Johnny darter	*Etheostoma nigrum*	SP	--	SR	
Yellow perch	*Perca flavescens*	FR	DP	DP	

Table 2: Mussel species present in the Rock River Watershed and their habitat guilds where MP=medium pool; SR=slow riffle; and RW=raceway. Guilds are listed for only those species that the Stream Habitat Program has developed HSCs.

Common Name	Scientific Name	Habitat Guild
Threeridge	*Amblema plicata*	RW
Wabash pigtoe	*Fusconaia flava*	RW
Giant floater	*Anodonta grandis*	RW
Cylindrical papershell	*Anodontoides ferussacianus*	MP
Squawfoot	*Strophitus undulatus*	RW
White heelsplitter	*Lasmigona complanata*	MP
Creek heelsplitter	*Lasmigona compressa*	
Pondmussel	*Ligumia subrostrata*	
Fat mucket	*Lampsilis siliquoidea*	RW
Plain pocketbook	*Lampsilis cardium*	SR
Lilliput	*Toxolasma parvus*	

Table 3. Rivers sampled for Topeka shiners.

River - site	Location	Year sampled	# of cells sampled	Number of Topeka shiners captured
Ash Creek	Clinton Township, Rock County (T101N R45W S24)	1997	12	1
Champepadan Creek	Leota Township, Nobles County (T140N R43W S29)	1999	30	5
Elk Creek	Magnolia Township, Rock County (T102N R44W S21)	1998	10	3
Mound Creek	Blue Mounds State Park, Mound Township, Rock County (T103N R45W S24)	1998 1999	24 30	18 26
Rock - upper	Luverne city park, Luverne Township, Rock County (T102N	1998	19	8
Rock - lower	Clinton Township, Rock County (T101N R45W S24)	1997	54	2

Table 4. Habitat-preference guild representatives modeled for the Rock River by season.

Season	Shallow Pool	Medium Pool	Deep Pool	Raceway	Slow Riffle	Fast Riffle
March 17-May 15				Giant Floater Shorthead redhorse,		
May 16-November 17	Brassy minnow, Adult Larval fish Orangespotted sunfish, YOY	Orangespotted sunfish, Adult Orangespotted sunfish, Spawning Topeka shiner, Adult Topeka shiner, Spawning	Channel catfish, Adult Northern Pike, Adult	Channel catfish, YOY Giant Floater	Central stoneroller, Adult Stonecat, Adult	Longnose dace, Adult Stonecat, Juvenile
November 18 - March 16	Brassy minnow, Adult Larval fish Orangespotted sunfish, YOY	Orangespotted sunfish, Adult Topeka shiner, Adult	Channel catfish, Adult Northern Pike, Adult	Channel catfish, YOY Giant Floater	Central stoneroller, Adult Stonecat, Adult	Longnose dace, Adult Stonecat, Juvenile

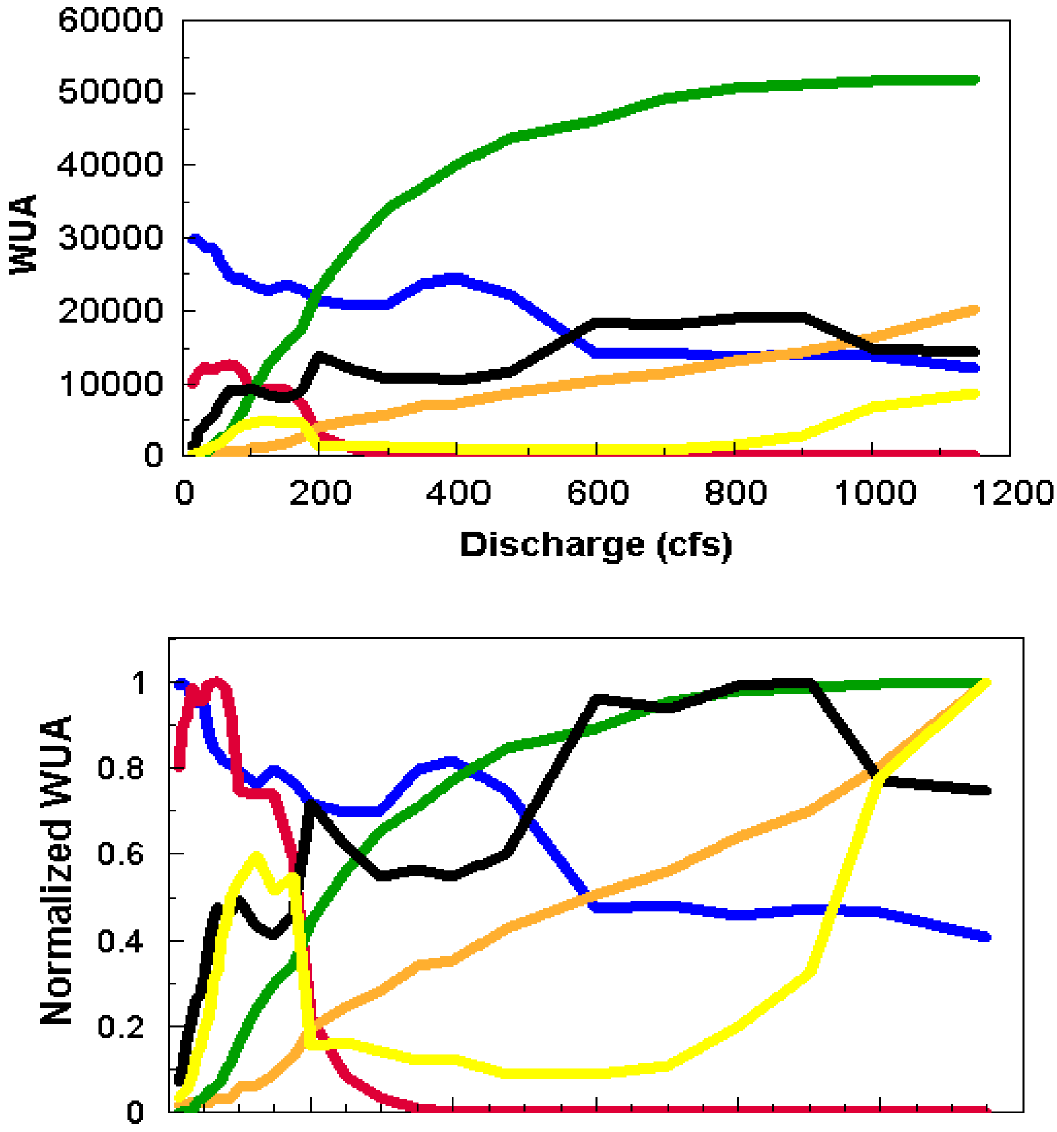


FIGURE 3. Upper Rock River site - Normalized and non-normalized weighted usable area as a function of discharge for habitat types, where SP=shallow pool, MP=medium pool, DP=deep pool, RW=raceway, SR=slow riffle, and FR=fast riffle.

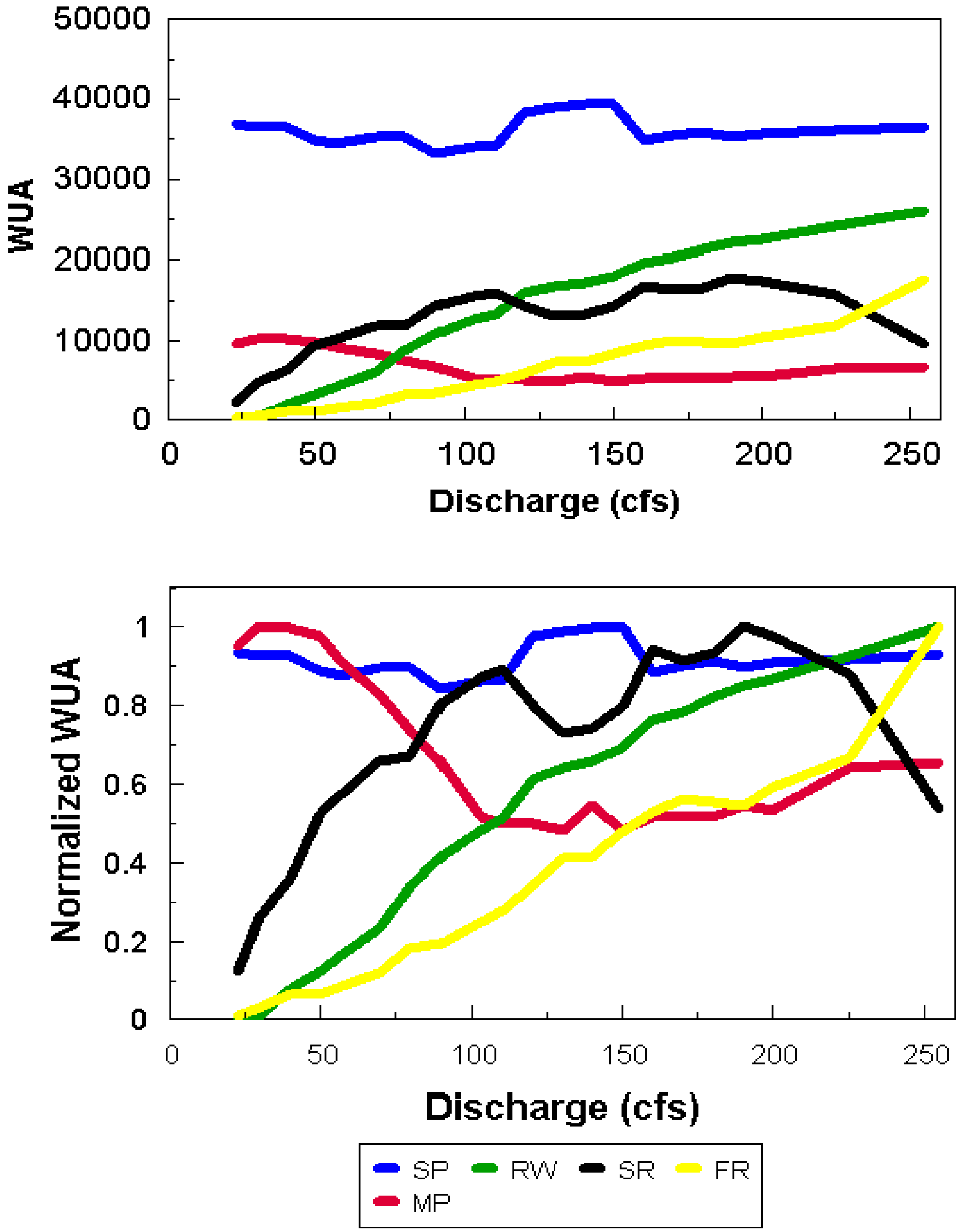


FIGURE 4. Lower Rock River site - Normalized and non-normalized weighted usable area as a function of discharge for habitat types, where SP=shallow pool, MP=medium pool, DP=deep pool, RW=raceway, SR=slow riffle, and FR=fast riffle.

RESULTS

Habitat Suitability Criteria

A total of 18,630 fish were sampled, representing 36 species and 88 species-life stages (Table 5). This included 67 Topeka shiners, of which 57 were adults and 10 were spawners. No young-of-the-year Topeka shiners were captured. Habitat suitability criteria developed for Topeka shiner adults and spawners are presented in Figures 5 and 6. Topeka shiner adults prefer medium pool habitat with depths of 0.5 - 2 feet and velocities less than 1.0 ft/s and have a strong preference for silt covered cobble substrate with wood cover. Spawners prefer medium pool habitat with depths of 0.5- 2 feet and velocities of 0.5 – 1.5 ft/s and rubble substrates with wood cover.

Habitat Modeling

The diversity of available habitat types change in relation to the changes in flow, generally following the same pattern from river to river. Shallow and medium pool habitat peak at low flows and decrease as flows increase, slow and fast riffle habitat peak at intermediate flows and decrease as flows decrease or increase, and raceway and deep pool habitat increase as flows increase, peaking at a high flow. Habitat diversity is generally highest at intermediate flows.

For the Rock River sites, the habitat types followed the general pattern with a couple of exceptions (Figures 3 and 4). At the upper site, fast riffle habitat has a bimodal relationship, having moderate availability of habitat at lower flows, then decreasing, and then peaking at very high flows. At the lower site, there is no deep pool habitat and the availability of shallow pool habitat is almost constant.

The availability of habitat for Topeka shiner adults and spawners over the range of flows for each of the mainstem sites is presented in Figures 7 and 8. Topeka shiner adults and spawners' habitat peaked at low flows and decreased at higher flows with Topeka shiner spawners peaking at slightly higher flows than the adults. This is consistent with both life stages preference for medium pools.

The availability of habitat for each target species by season is presented in Figures 9 – 11. Habitat versus flow relations varied considerably among the species-life stages modeled (Figures 9 - 11). Most species-life stages relations fell into one of the three general categories: 1) WUA peaked at low flows and decreased as flow increased (e.g., Topeka shiner adults, medium pool guild) (Figure 10), 2) WUA increased as flow increased, peaking at a high flow (e.g., spawning shorthead redhorse, raceway guild) (Figure 9), and 3) WUA peaked at an intermediate flow and decreased as flow either increased or decreased (e.g., central stoneroller adults, slow riffle guild) (Figure 10).

DISCUSSION AND CONCLUSION

Several factors may be related to the endangered status of Topeka shiners. While most other fishes found in prairie streams are generalists, Topeka shiners are specialized to live in prairie streams. Prairie streams of the Midwest tend to be severely degraded due to intensive farming practices (Waters 1995),

Table 5. Species sampled in the Rock River watershed. The total number of fish caught was 18,630.

Common Name	Scientific Name	Ash Creek	Champepadan Creek	Elk Creek	Mound Creek	Rock River	Number of fish caught
Northern pike	*Esox lucius*				X	X	5
Central stoneroller	*Campostoma anomalum*	X	X	X	X	X	1938
Carp	*Cyprinus carpio*	X			X	X	15
Brassy minnow	*Hybognathus hankinsoni*		X			X	36
River shiner	*Notropis blennius*					X	4
Common shiner	*Luxilus cornutus*	X	X	X	X	X	1643
Bigmouth shiner	*Notropis dorsalis*	X	X	X	X	X	690
Blacknose shiner	*Notropis heterolepis*		X				1
Red shiner	*Cyprinella lutrensis*	X				X	60
Sand shiner	*Notropis stramineus*	X	X	X	X	X	3551
Topeka shiner	***Notropis topeka***	**X**	**X**	**X**	**X**	**X**	**67**
Mimic shiner	*Notropis volucellus*					X	2
Bluntnose minnow	*Pimephales notatus*	X	X	X	X	X	435
Fathead minnow	*Pimephales promelas*	X	X	X	X	X	3274
Blacknose dace	*Rhinichthys atratulus*	X	X	X	X	X	319
Creek chub	*Semotilus atromaculatus*	X	X	X	X	X	1943
River carpsucker	*Carpiodes carpio*					X	15
Quillback carpsucker	*Carpiodes cyprinus*		X		X	X	39
White sucker	*Catostomus commersoni*	X	X	X	X	X	1850
Shorthead redhorse	*Moxostoma macrolepidotum*				X	X	35
Greater redhorse	*Moxostoma valenciennesi*					X	3
Black bullhead	*Ameiurus melas*		X		X	X	696
Channel catfish	*Ictalurus punctatus*				X	X	35
Stonecat	*Noturus flavus*		X	X		X	21
Tadpole madtom	*Noturus gyrinus*				X	X	15
Trout-perch	*Percopsis omiscomaycus*					X	40
Plains topminnow	*Fundulus sciadicus*				X	X	8
Brook stickleback	*Culea inconstans*	X		X	X		18
Green sunfish	*Lepomis cyanellus*				X	X	88
Pumpkinseed sunfish	*Lepomis gibbosus*				X	X	5
Orangespotted sunfish	*Lepomis humilis*		X		X	X	986
Bluegill sunfish	*Lepomis macrochirus*				X	X	60
Largemouth bass	*Micropterus salmoides*				X	X	6
Iowa darter	*Etheostoma exile*			X	X		8
Johnny darter	*Etheostoma nigrum*	X	X	X	X	X	675
Yellow perch	*Perca flavescens*				X	X	44

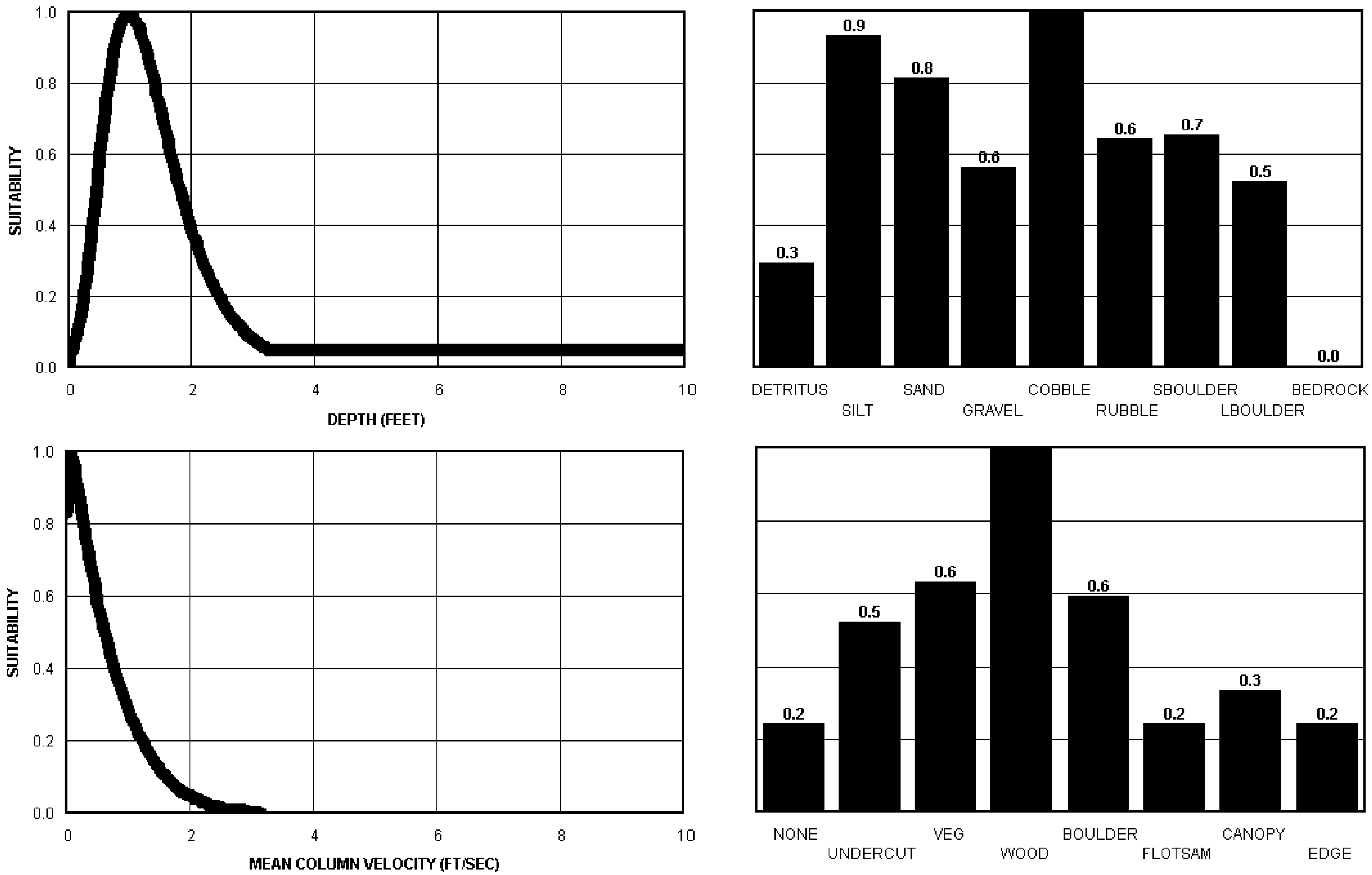


FIGURE 5. Habitat suitability criteria for Topeka shiner adults.

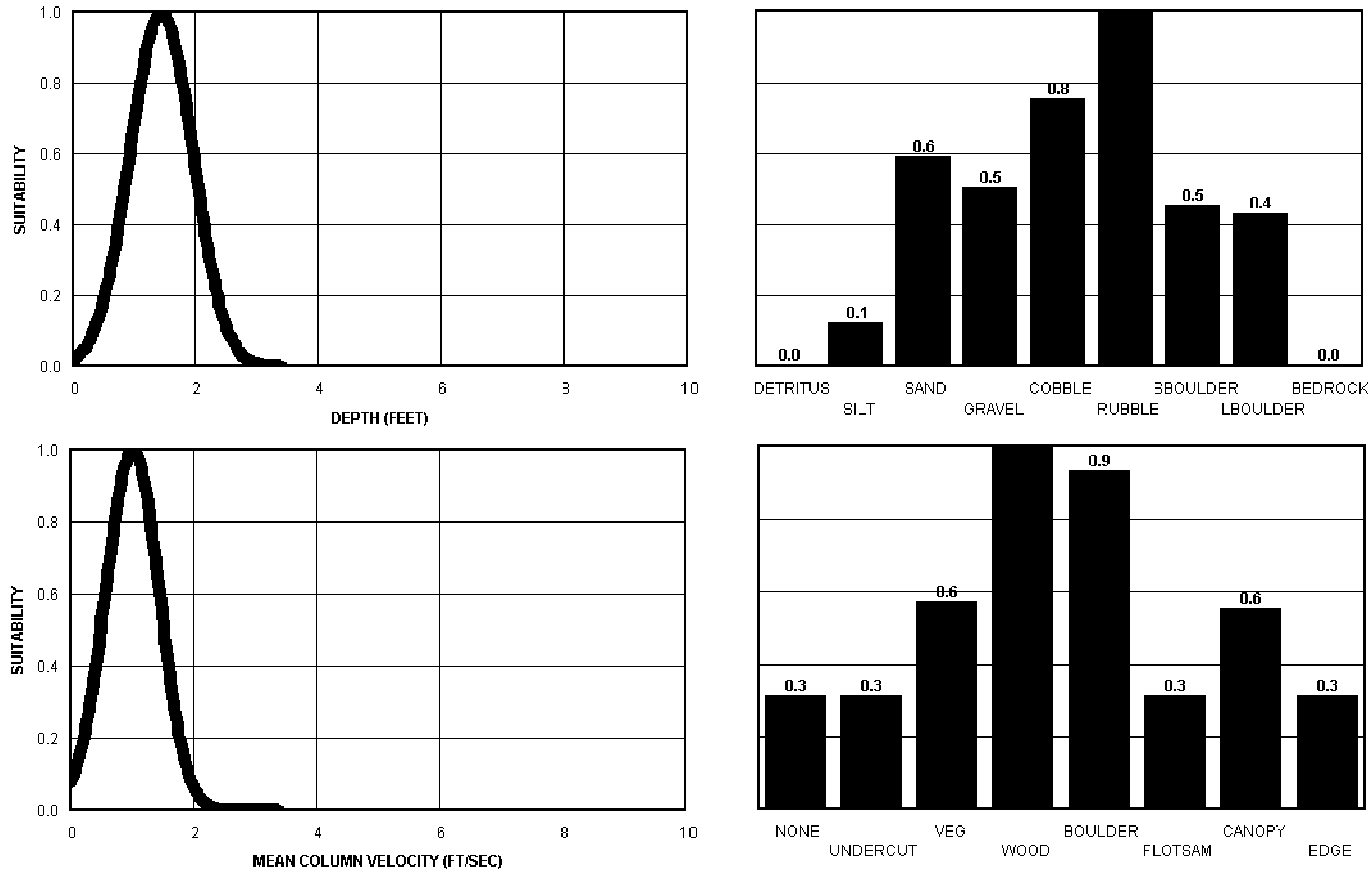


FIGURE 6. Habitat suitability criteria for Topeka shiner - spawning.

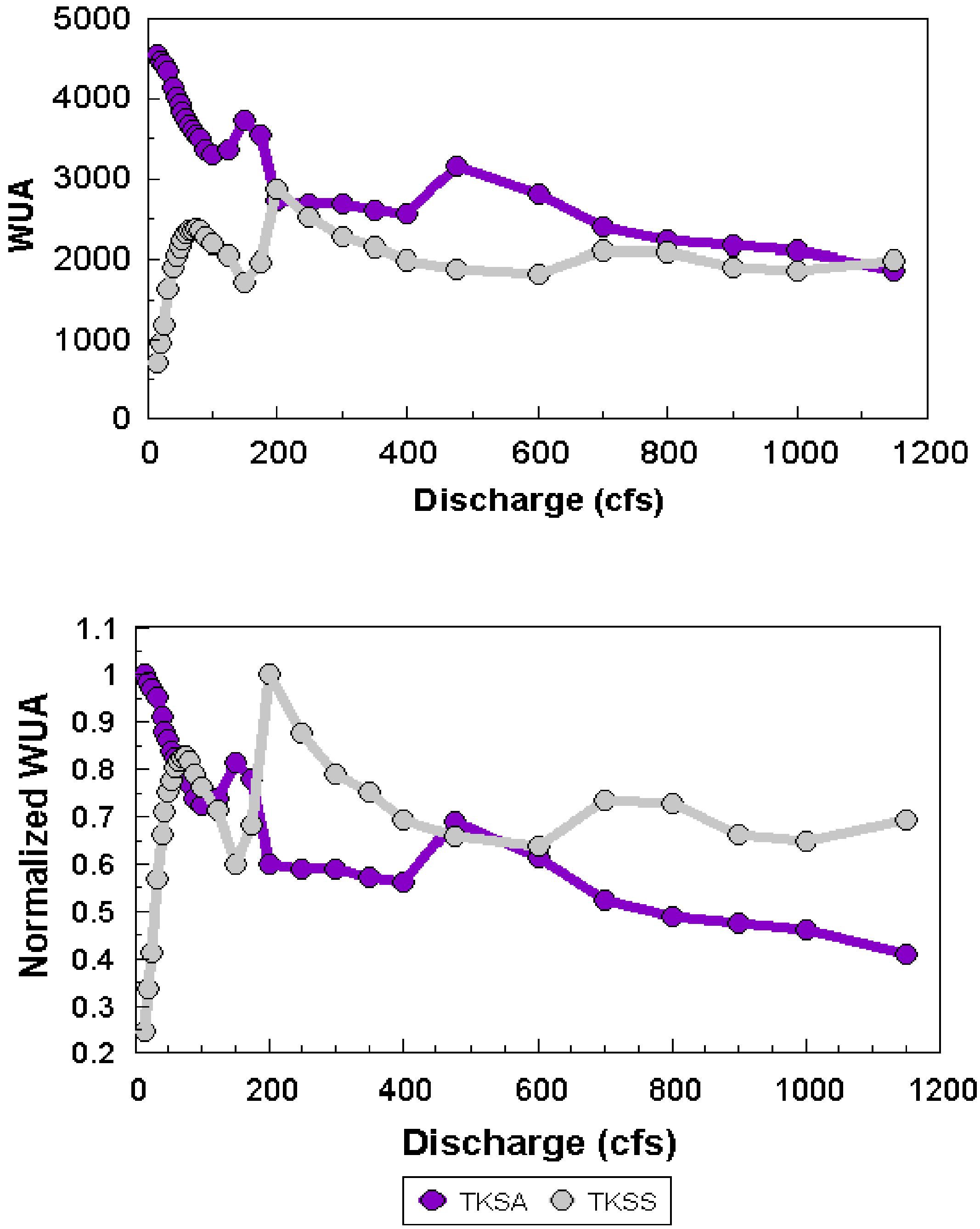


FIGURE 7. Upper Rock River site - Normalized and non-normalized weighted usable area as a function of discharge for Topeka shiners, where TKSA = Topeka shiner adults and TKSS = Topeka shiner-spawning.

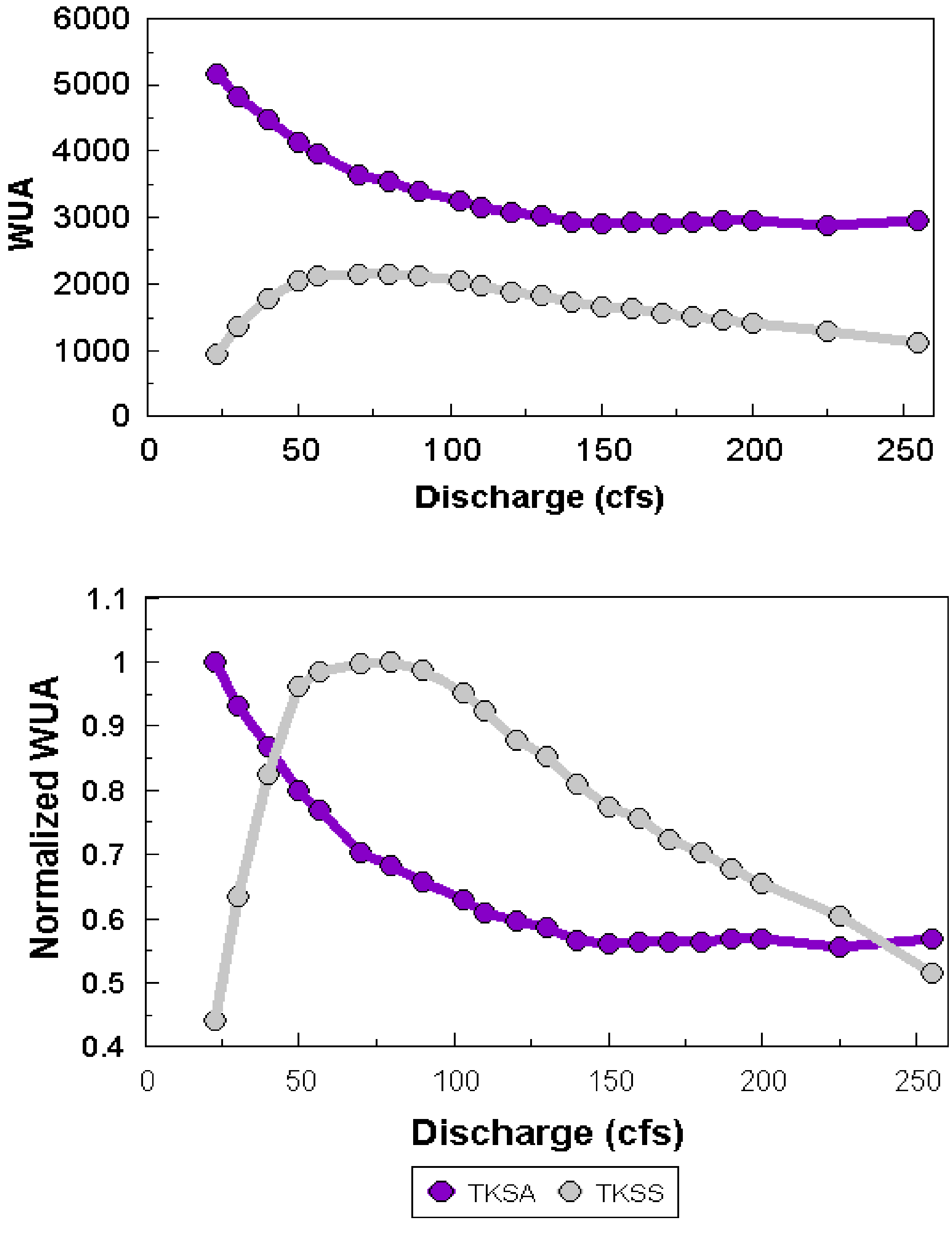
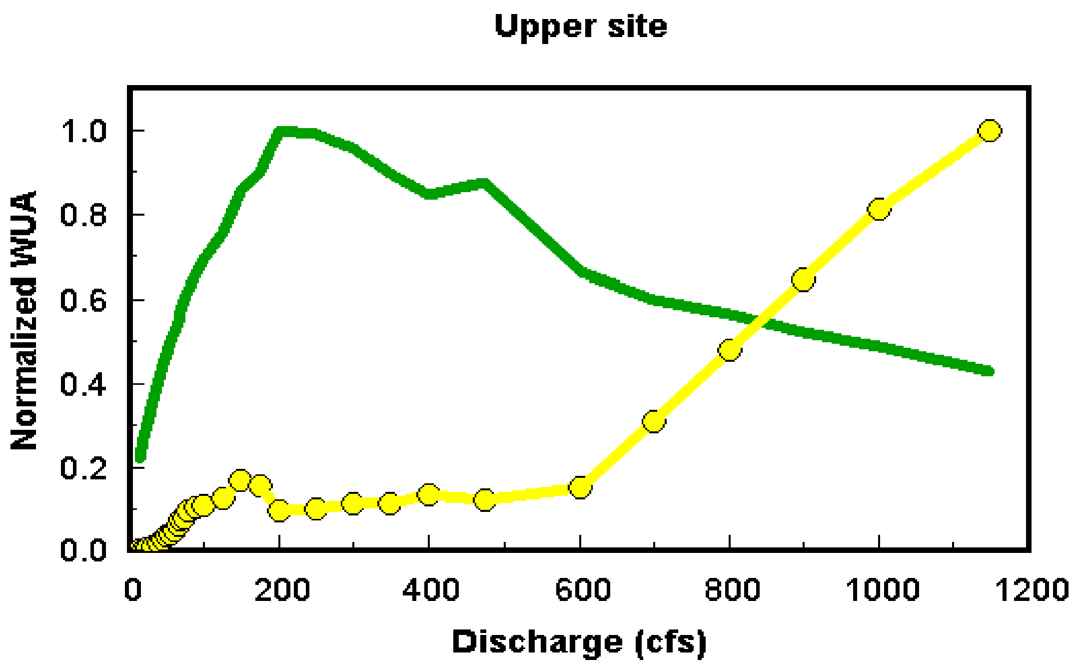


FIGURE 8. Lower Rock River site - Normalized and non-normalized weighted usable area as a function of discharge for Topeka shiners, where TKSA = Topeka shiner adults and TKSS = Topeka shiner-spawning.

Key for Figures 9 - 11

BRMA	BRASSY MINNOW - ADULT		OSSA	ORANGESPOTTED SUNFISH - ADULT	
CCFA	CHANNEL CATFISH - ADULT		OSSS	ORANGESPOTTED SUNFISH - SPAWNING	
CCFY	CHANNEL CATFISH - YOY		OSSY	ORANGESPOTTED SUNFISH - YOY	
CSRA	CENTRAL STONEROLLER - ADULT		SHRS	SHORTHEAD REDHORSE - SPAWNING	
GFT	GIANT FLOATER		STCA	STONECAT - ADULT	
LARV	LARVAL FISH		STCJ	STONECAT - JUVENILE	
LNDA	LONGNOSE DACE - ADULT		TKSA	TOPEKA SHINER - ADULT	
NOPA	NORTHERN PIKE - ADULT		TKSS	TOPEKA SHINER - SPAWNING	



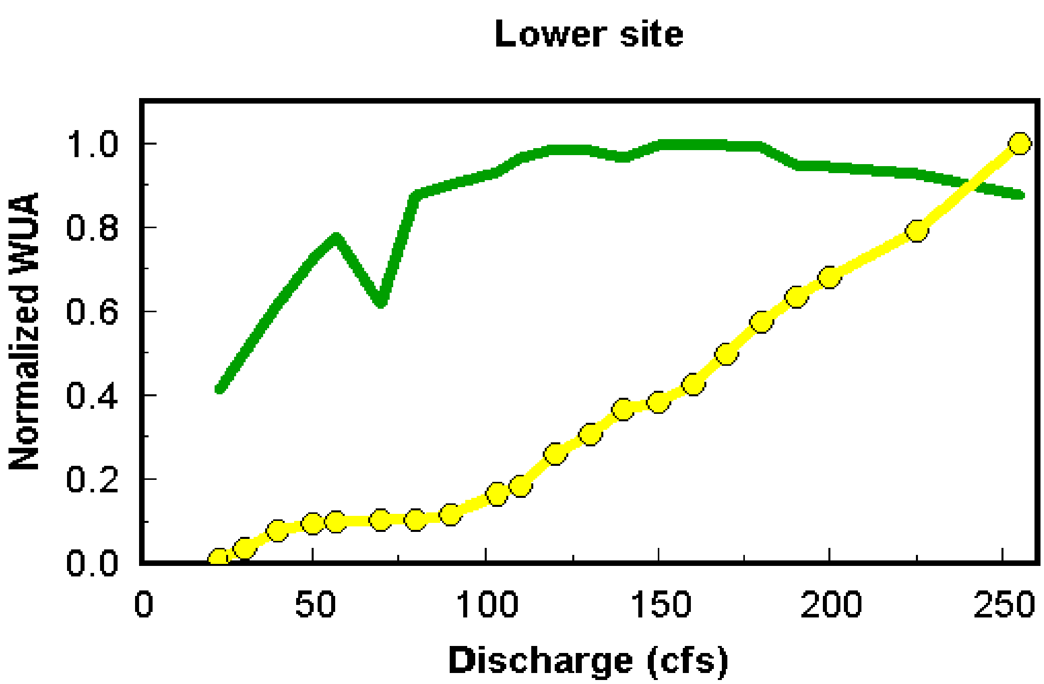
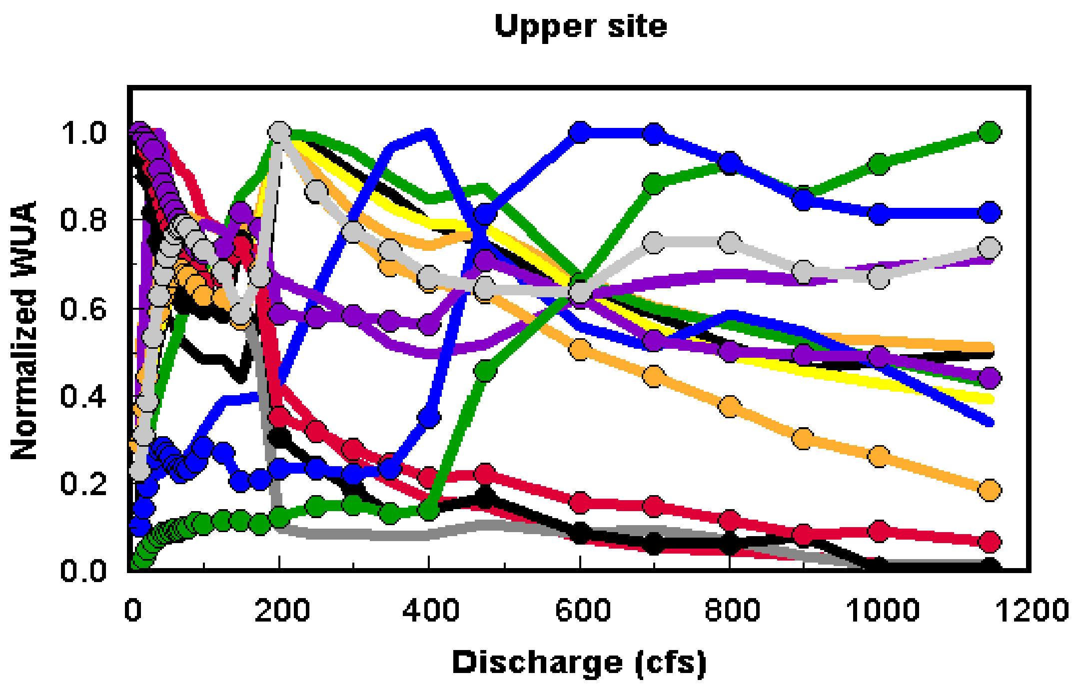


FIGURE 9. Normalized WUA for the upper and lower Rock River site for the season March 17 - May 15 (see legend between figures 8 and 9).



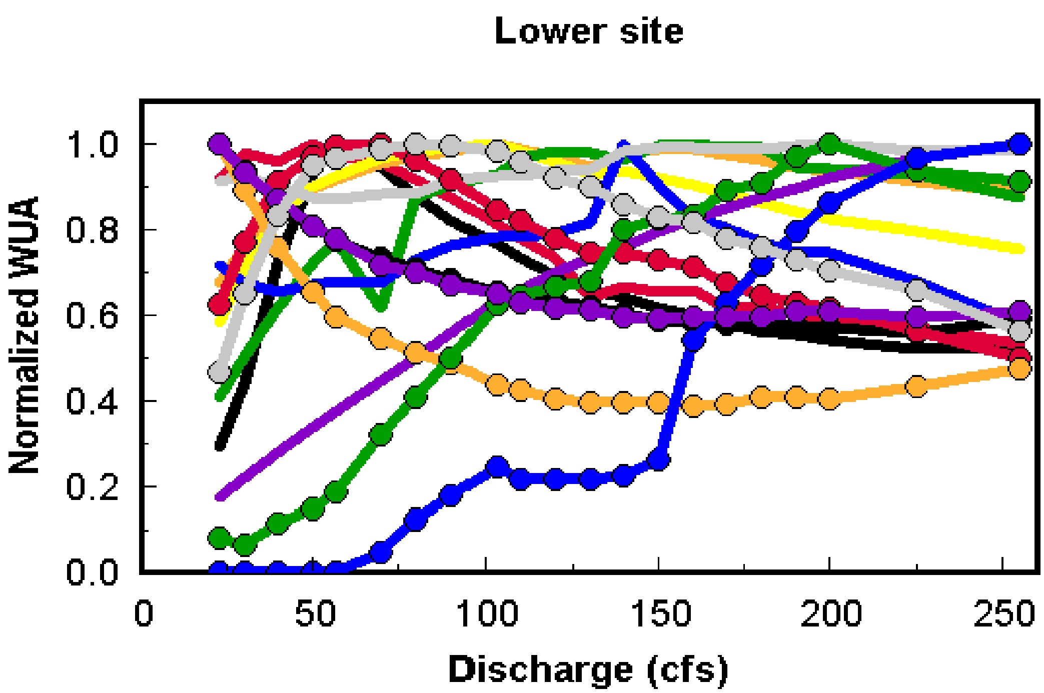


FIGURE 10. Normalized WUA for the upper and lower Rock River site for the season May 16 - November 17 (see legend between figures 8 and 9).

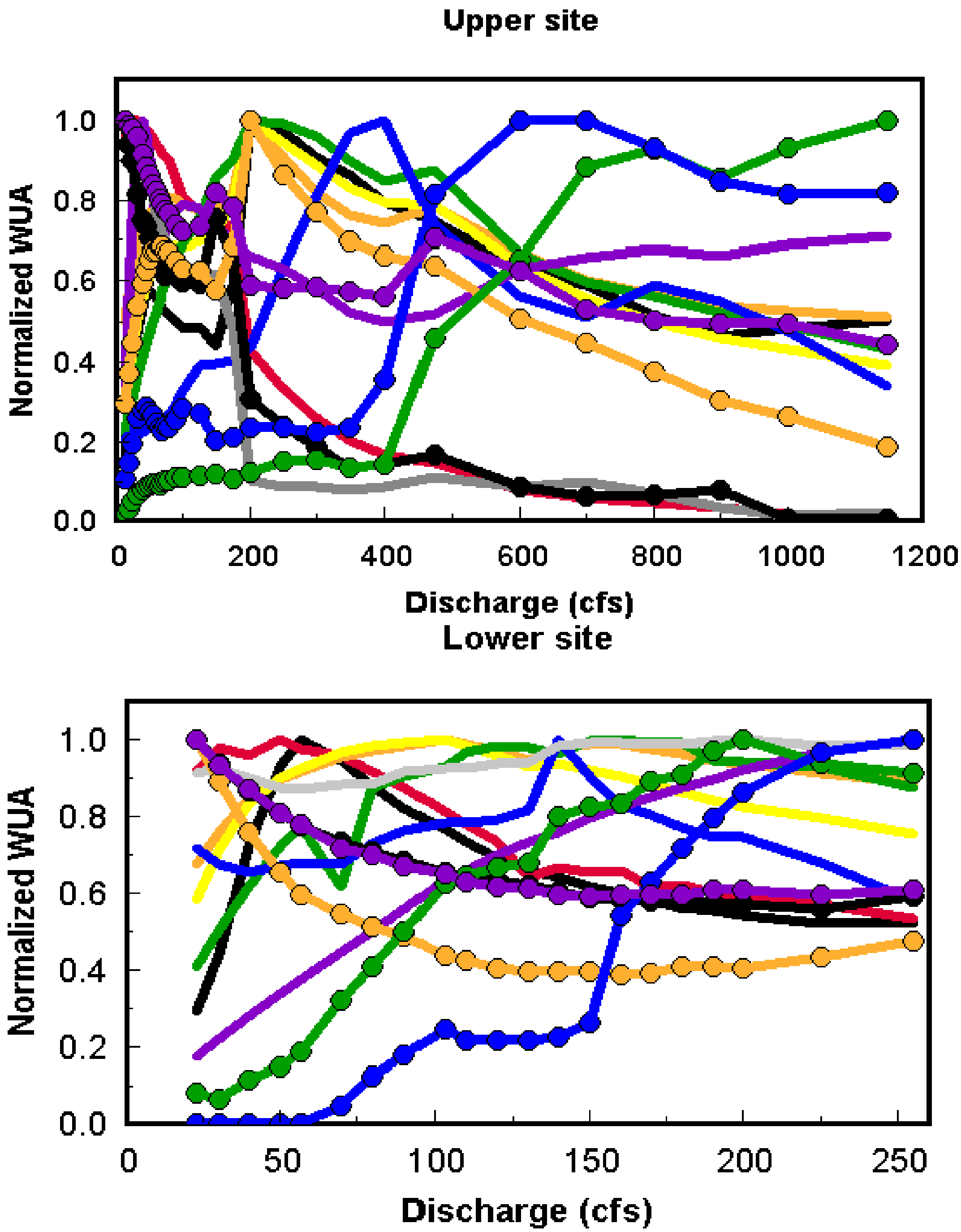


FIGURE 11. Normalized WUA for the upper and lower Rock River site for the season November 17 - March 16 (see legend between figures 8 and 9).

channelization, dam construction, removal of riparian vegetation, and increased runoff of both water and sediment. In the Rock River Watershed, Topeka shiners were more abundant in relatively stable stream channels than in unstable, degraded stream channels. While we found Topeka shiners in generally turbid streams, most individuals we collected were found in clearer, vegetated backwaters. Topeka shiner recruitment may also be affected by the turbidity of the streams. Topeka shiners lay their eggs in centrarchid nests (Becker 1983) and turbidity has been shown to affect egg survival for nest spawning species (Becker 1983).

Connectivity between upstream and downstream reaches is another likely factor affecting Topeka shiners. Since many prairie streams are intermittent, fish species must have the ability to recolonize in order to survive. Dams limit this ability to recolonize by blocking migrations. There are nine dams in the Rock River Watershed in Minnesota (U. S. Army Corps of Engineers 2000), one of which is located on the mainstem of the Rock River. The remaining dams are found on tributaries. The mainstem dam, located in Luverne, is the downstream most dam in the watershed. We collected pre-spawn Topeka shiners below the dam in Luverne and the dams in Blue Mound State Park.

For the flows modeled, the needs of the Topeka shiners and the rest of the fish community are met at flows ranging from 25 to 200 cfs. Unfortunately, we do not know how those flows relate to the natural flow regime of the river. The Rock River in Minnesota has only seven years of stream flow data (from September 1911 to September 1914 and October 1995 to1997) (Mitton et al. 1997). This is not enough to compare flow needs with the flow regime. A permanent gage needs to be established in order to better understand the flow regime of the Rock River and how that relates to Topeka shiner survival.

River restoration may improve Topeka shiner survival. Restoration options include removal of dams that block fish migrations, restoration of stream channels and reestablishment of riparian corridors. Removing dams would not only provide fishes inhabiting the lower reaches of the Rock River and the Big Sioux access to the high quality, high gradient, and ecological important habitats located upstream, but would also restore many ecological processes and functions needed to sustain healthy riverine ecosystems. While dam removal would be the preferred option, providing fish passage at the dams would be a viable alternative. The number and diversity of fish using the recently installed fish passage at Breckenridge Dam on the lower reach of the Otter Tail River has been impressive (MNDNR unpublished data).

Restoration efforts should also focus on restoring stream channel morphology and stability. To achieve long-term stream stability and function, stream channel restoration efforts must incorporate the integrative relations among fluvial processes, stream morphology, and the natural self-stabilizing tendencies of stream channels (Jackson et al. 1995; Kauffman et al. 1997). The stream classification system developed by Rosgen (1994, 1996) incorporates these relations, and we recommend that it be used to guide and monitor channel restoration efforts. The Rosgen classification system can be used to determine if a stream channel is physically degraded and unstable and, if so, to determine the degraded channel=s most probable stable form, or stream type. Once this determination is made, the morphological characteristics of an un-impacted stable reach of the same stream type can be used as a blueprint for guiding the restoration of the degraded, unstable channel. This approach could prove very useful in restoring some of the many miles of channelized, degraded stream channels throughout the Rock River Watershed.

Most importantly, a concerted effort to stabilize stream banks needs to be made throughout the watershed. Bank erosion is a severe problem and a major contributor to the high sediment load of the rivers in the watershed (personal observation). Bank erosion is especially severe in areas where riparian vegetation has been removed, where row crops are grown too close to the stream channel, and where cattle are allowed easy access to the river. Cooperative efforts with riparian landowners to restore and manage streamside vegetation and riparian buffers should be pursued to reduce sedimentation and improve habitat and water quality. These practices would improve habitat for Topeka shiners as well as the rest of the riverine community.

The rivers and streams of Minnesota provide an array of resource values, including ecological, recreational, aesthetic, educational, economic, social, and cultural. They harbor a diverse and unique assemblage of habitats, and fish and wildlife species that depend upon these habitats. Unfortunately, many resource values are being lost and an alarming number of riverine species are in trouble in Minnesota and across North America due to the degradation of stream habitat (NRC 1992). For example, nearly three fourths of the nearly 200 species of mussels native to North America are considered endangered, threatened, or of special concern, primarily resulting from the loss of riverine habitat (Williams et al. 1993). Similarly, many riverine fishes are vanishing due to degraded habitat (Miller et al. 1989; Williams et al. 1989), Topeka shiners being a prime example.

Restoring and maintaining the integrity of riverine habitats and their biotic communities, as well as meeting the increasing demand for resource values placed on river ecosystems, will require a management approach that works with watershed processes that form and maintain stable river systems (NRC 1992; Rosgen 1996; Kauffman et al. 1997; Roper et al. 1997). The challenge ahead is to restore and wisely manage the Rock River Watershed to ensure Topeka shiners' existence in Minnesota.

ACKNOWLEDGMENTS

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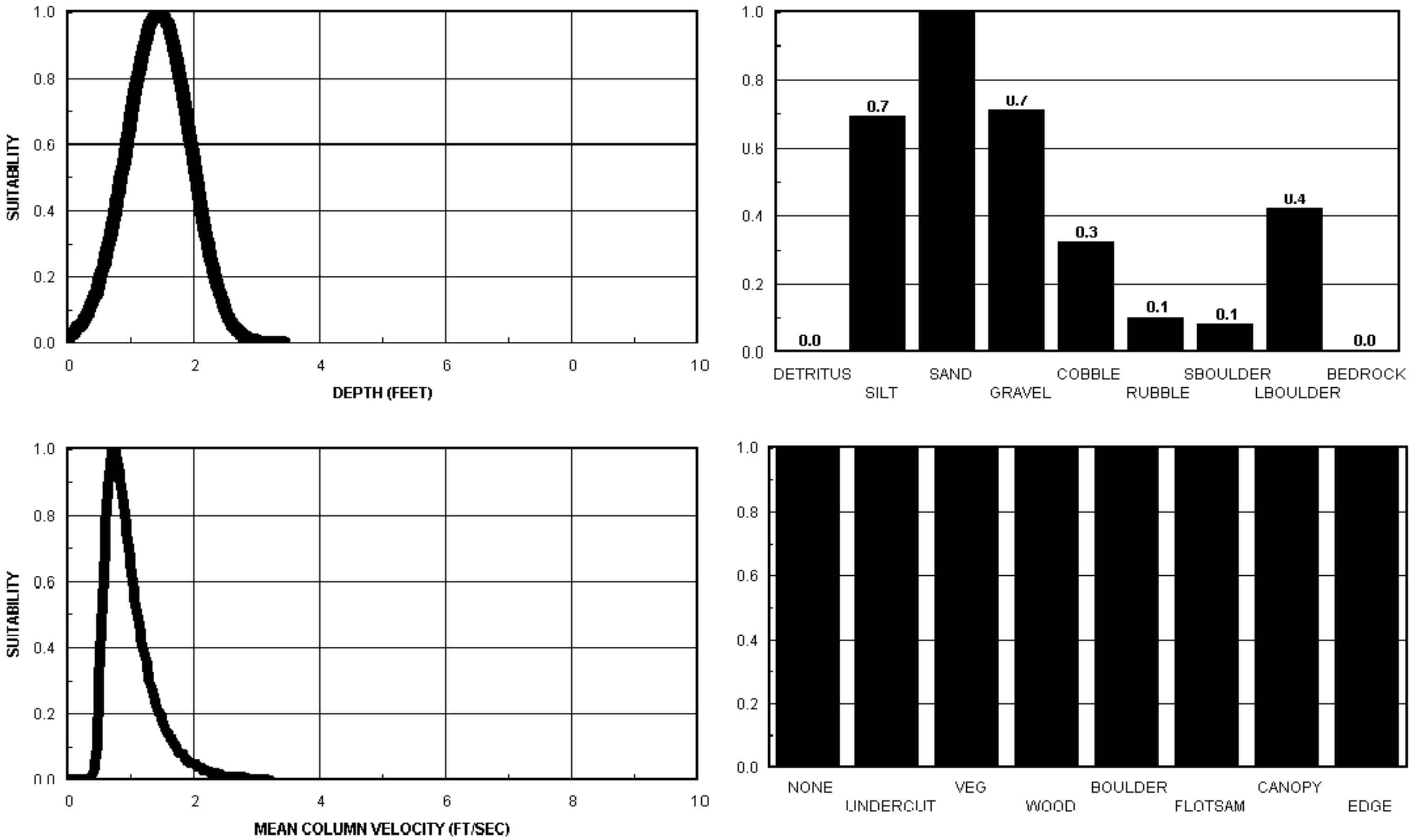
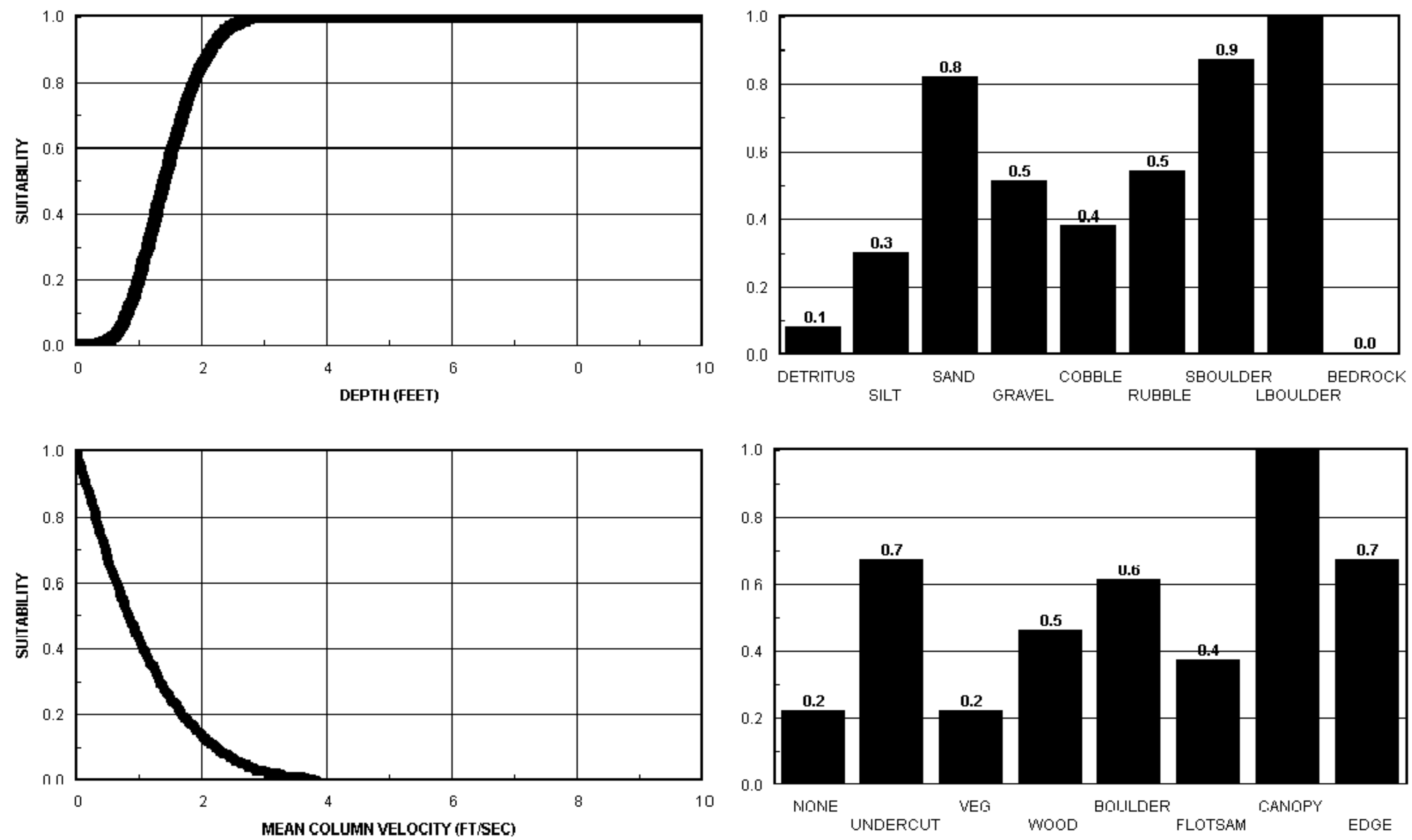
Appendix A. This appendix contains scatter graphs and bar charts showing the depth, velocity, substrate, and cover habitat suitability criteria for each of the 16 species-life stages modeled for the Rock River Watershed.

BRASSY MINNOW ADULT

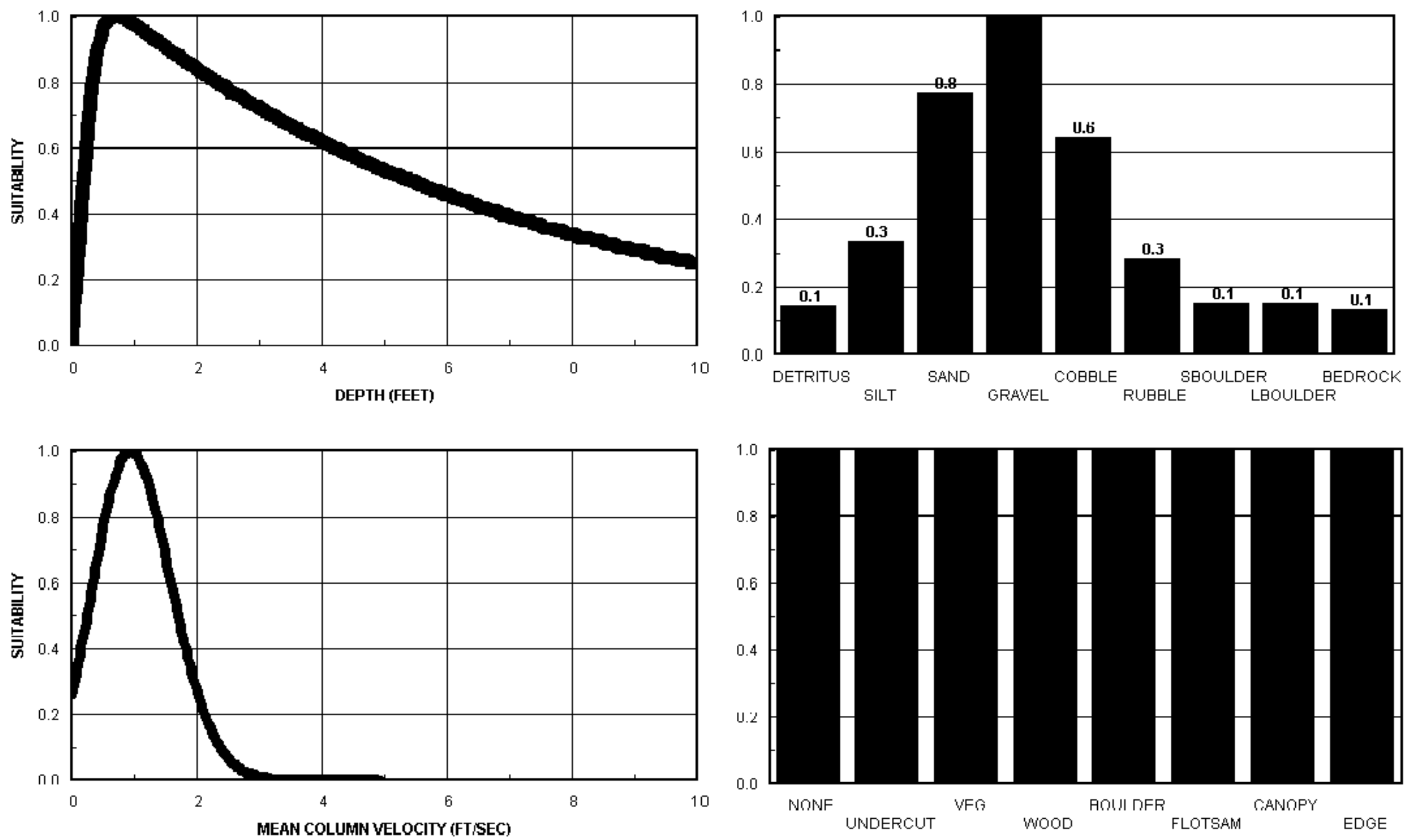


Appendix A continued

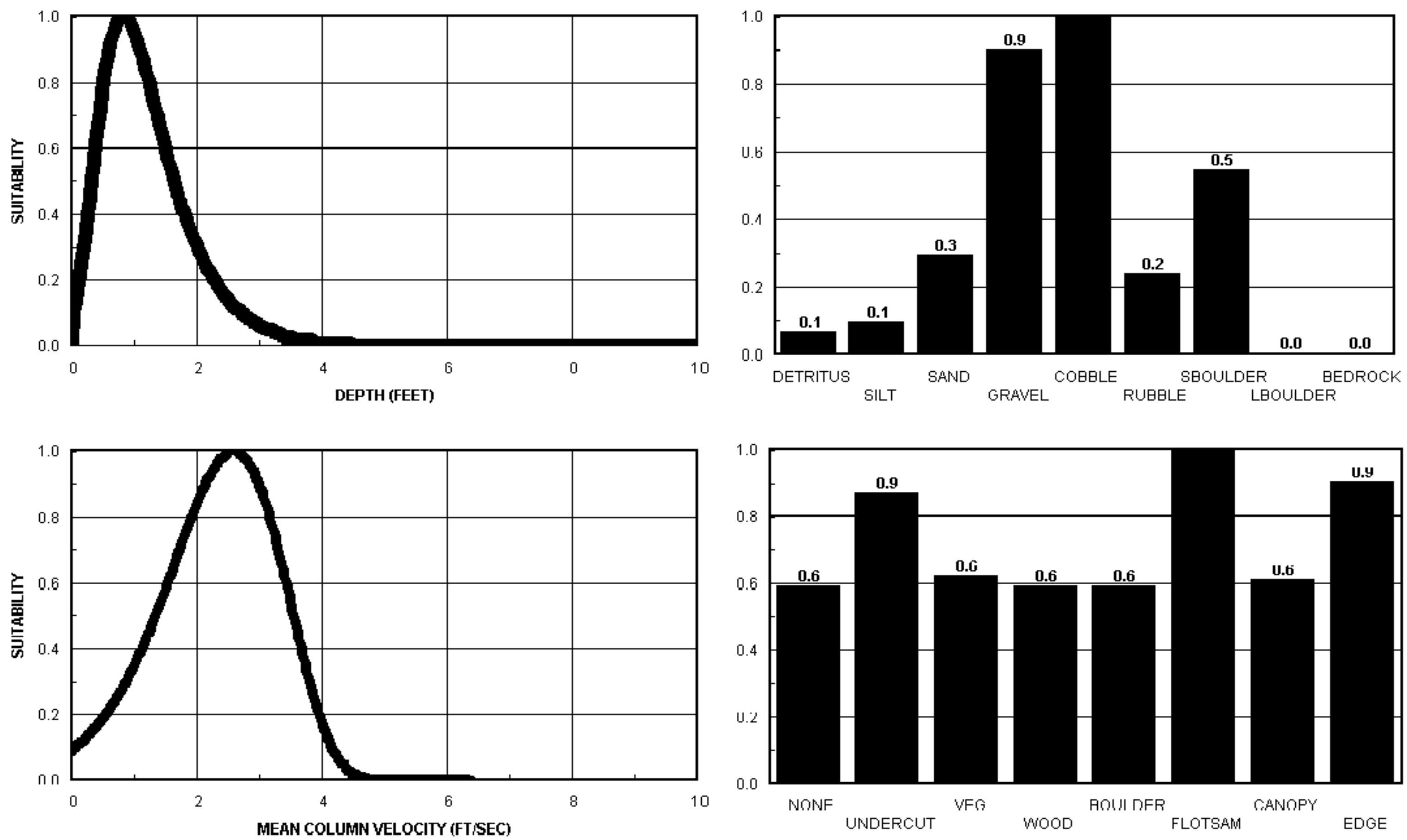
CHANNEL CATFISH ADULT



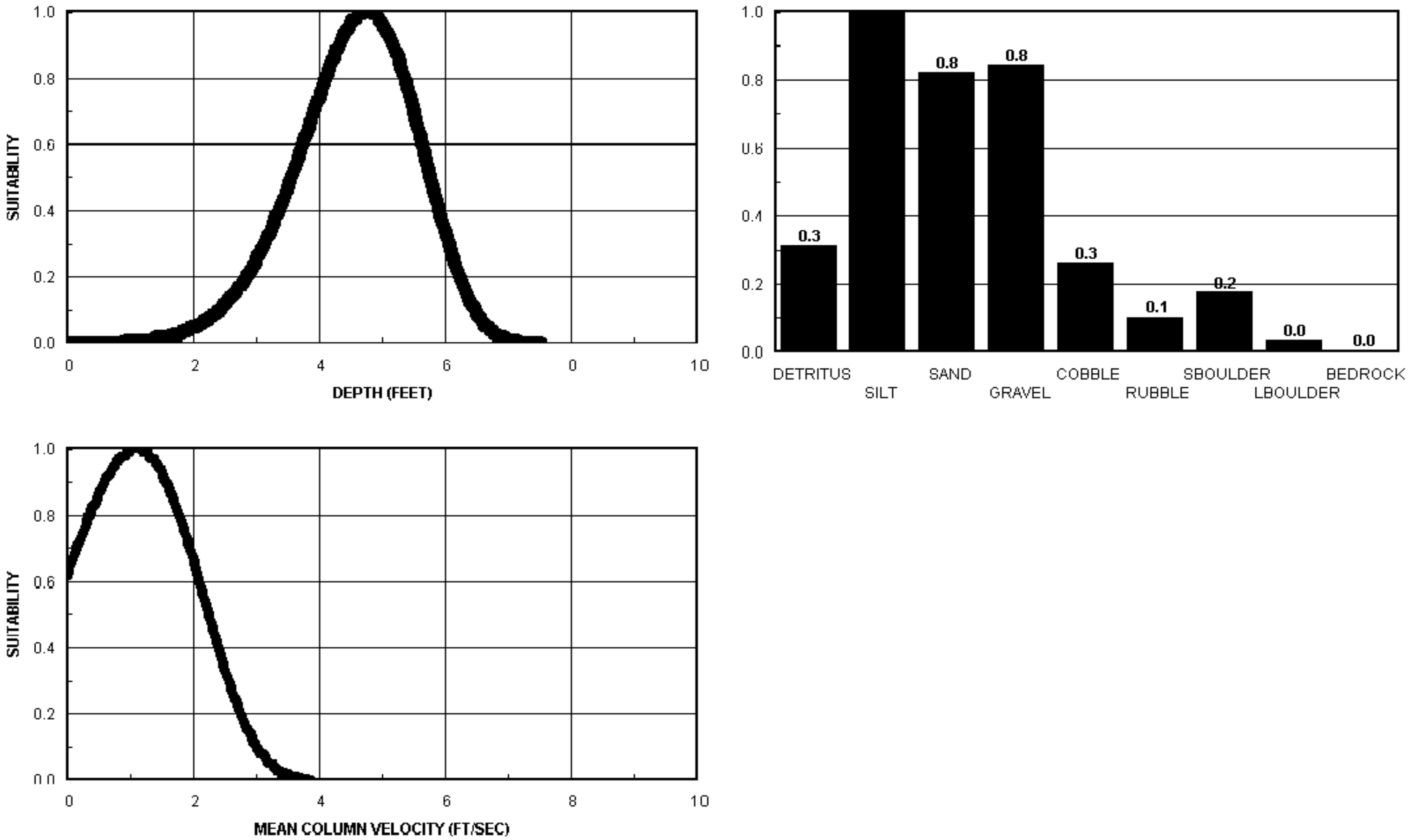
CHANNEL CATFISH YOY



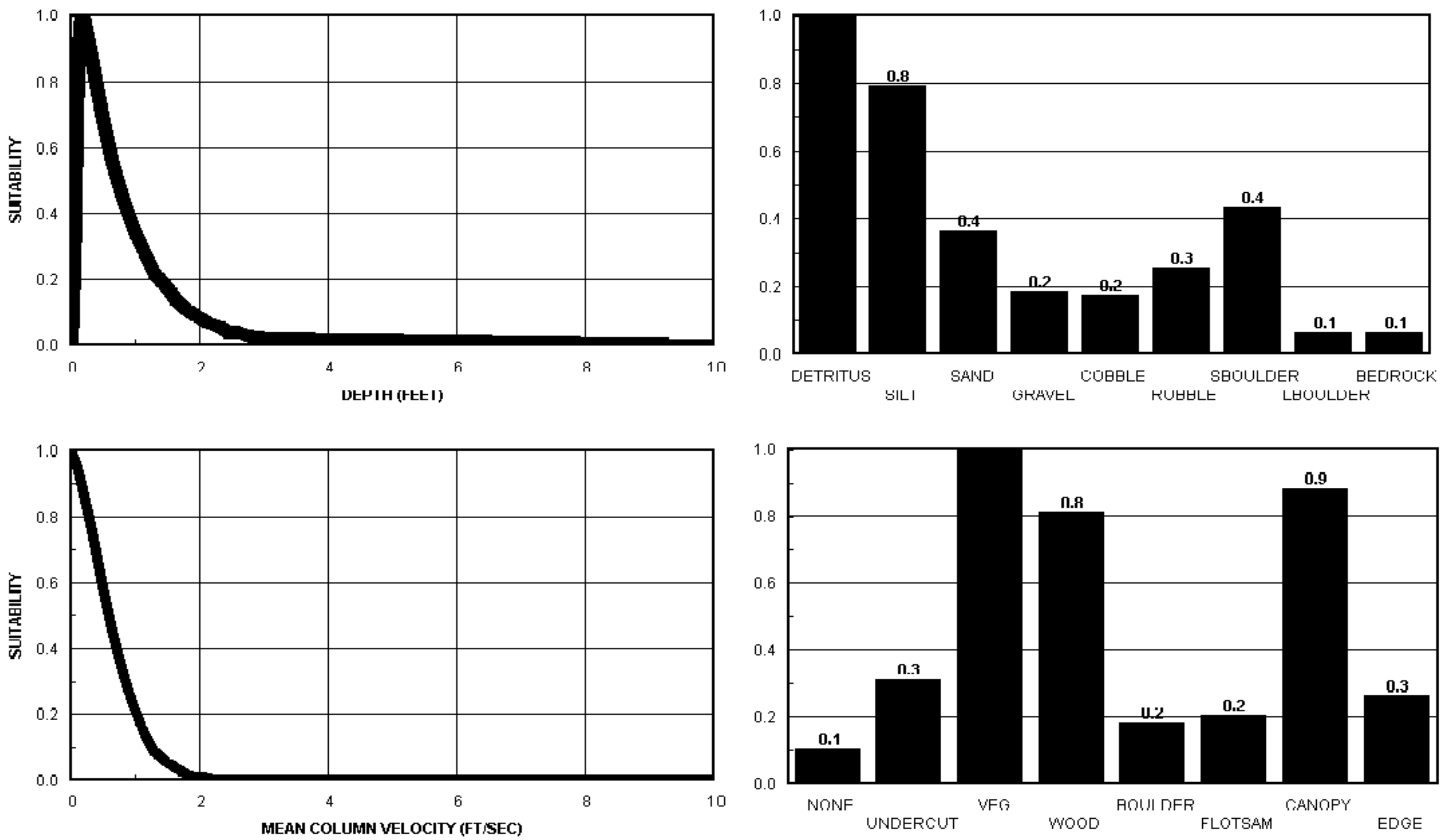
CENTRAL STONEROLLER ADULT



GIANT FLOATER MUSSEL

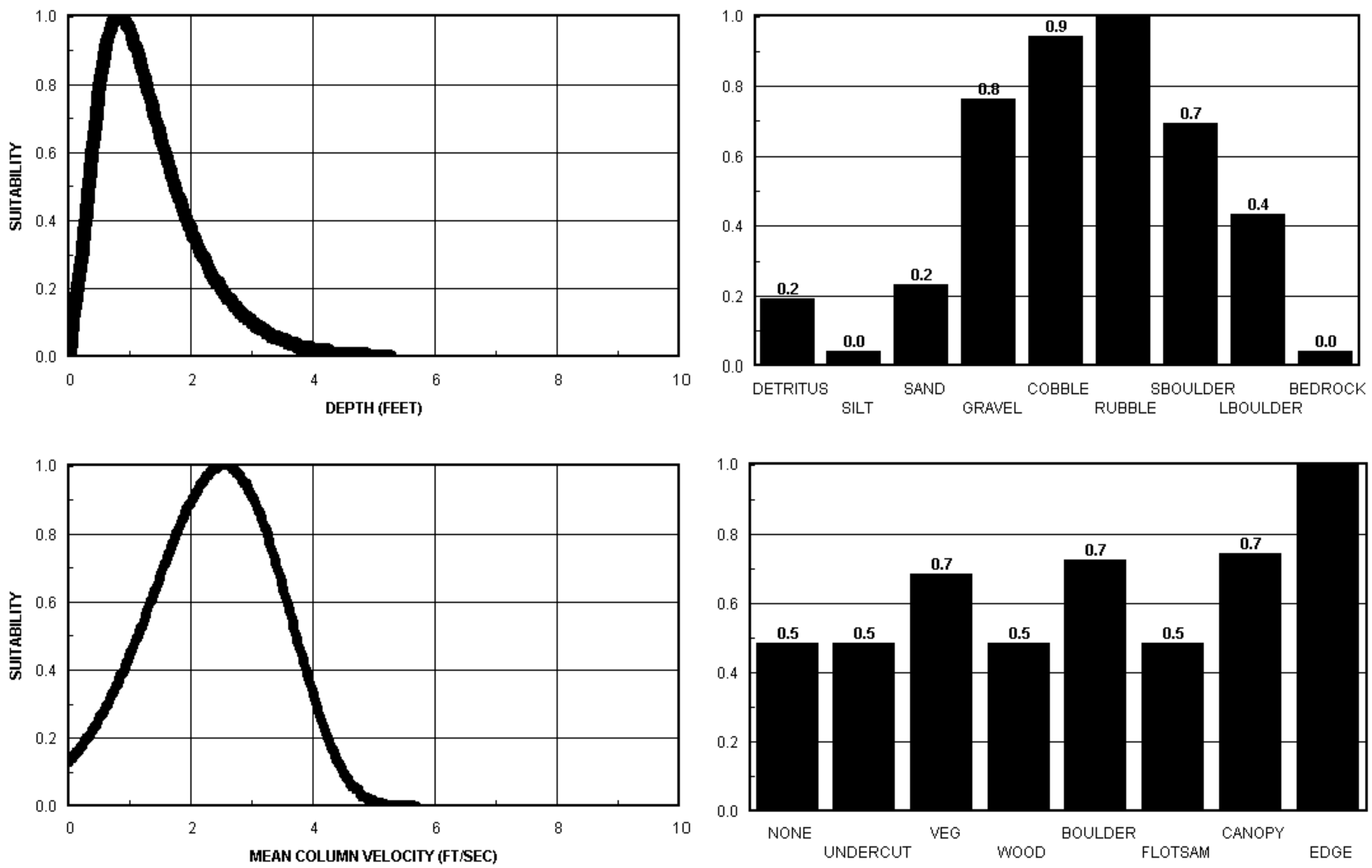


LARVAL FISH

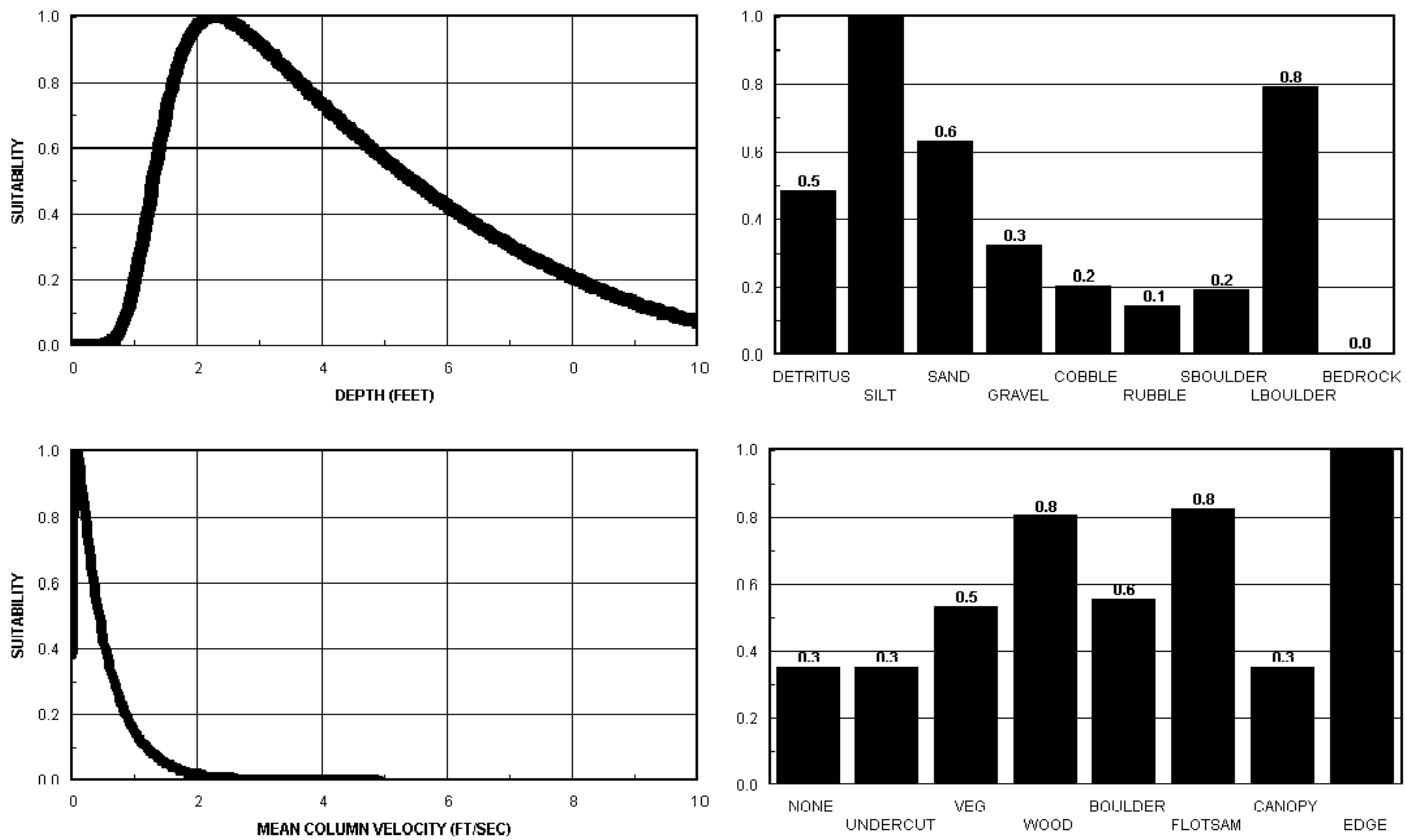


SUITABILITY
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
DEPTH (FEET)
0.8
0.4
0.2
0.2
0.3
0.4
0.1
0.1
DETRITUS
SILT
SAND
GRAVEL
COBBLE
RUBBLE
SBOULDER
LBOULDER
BEDROCK
SUITABILITY
MEAN COLUMN VELOCITY (FT/SEC)
0.1
0.3
0.8
0.2
0.2
0.9
0.3
NONE
UNDERCUT
VEG
WOOD
BOULDER
FLOTSAM
CANOPY
EDGE

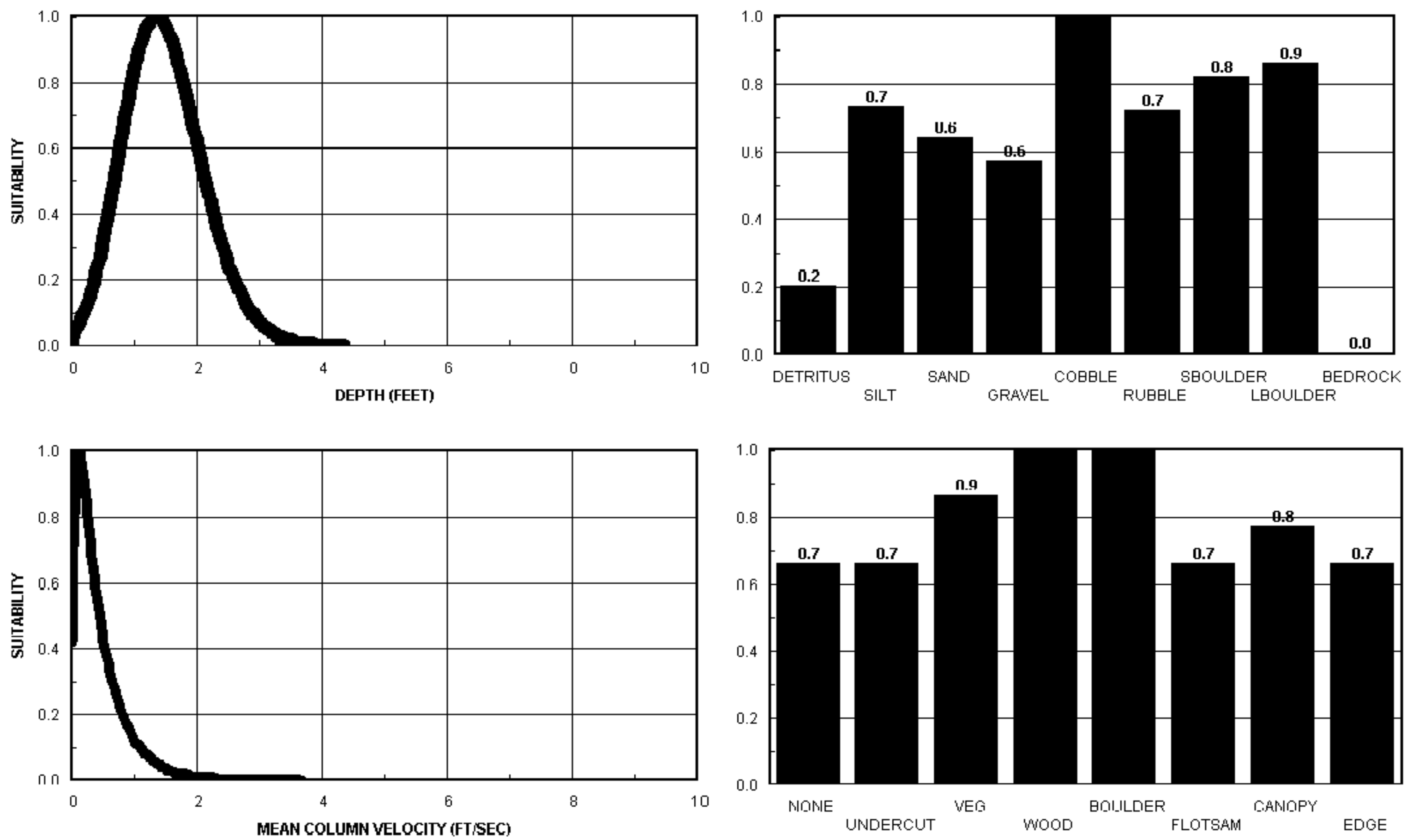
LONGNOSE DACE ADULT



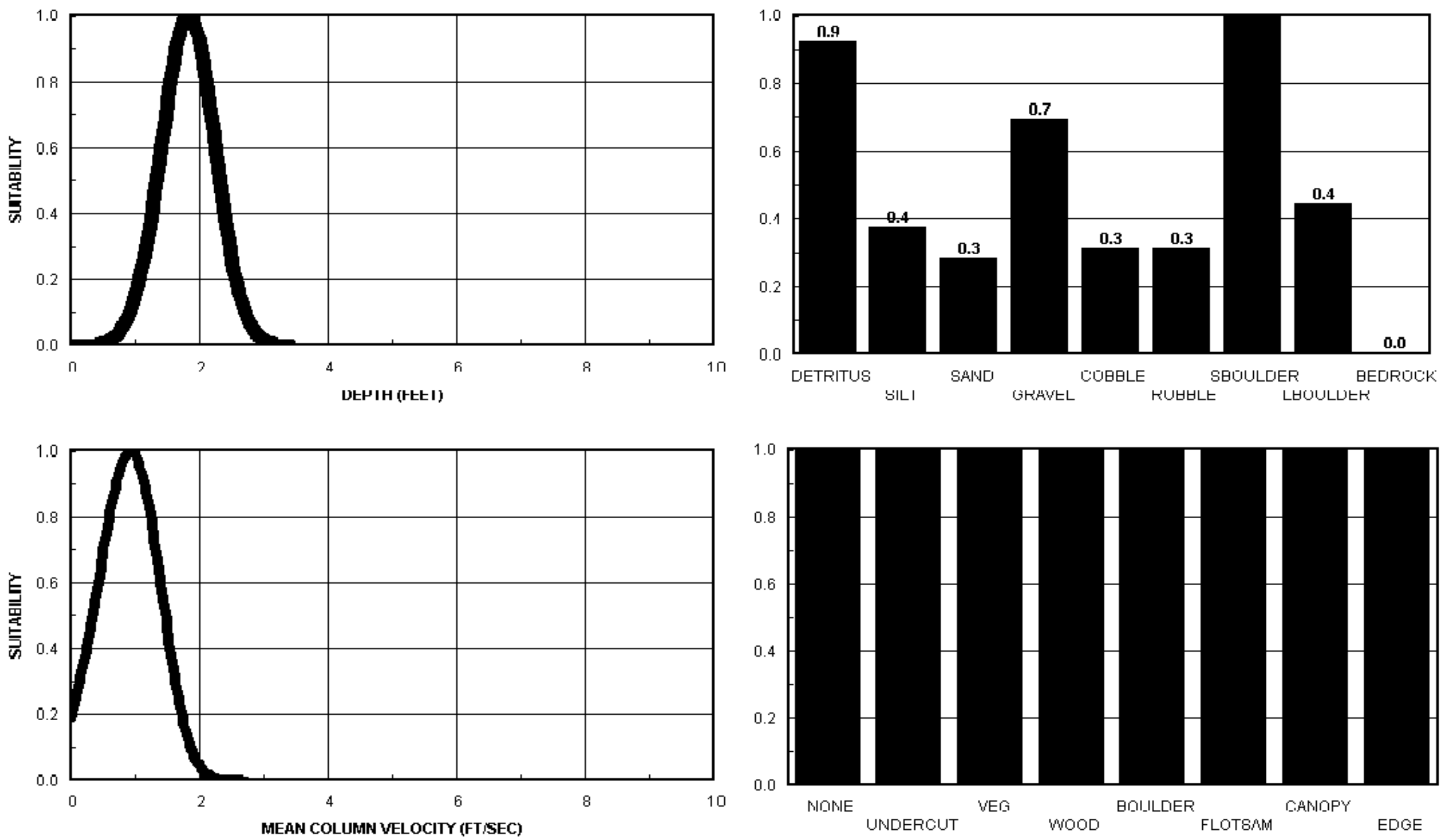
NORTHERN PIKE ADULT



ORANGE SPOTTED SUNFISH ADULT



ORANGE SPOTTED SUNFISH SPAWNING



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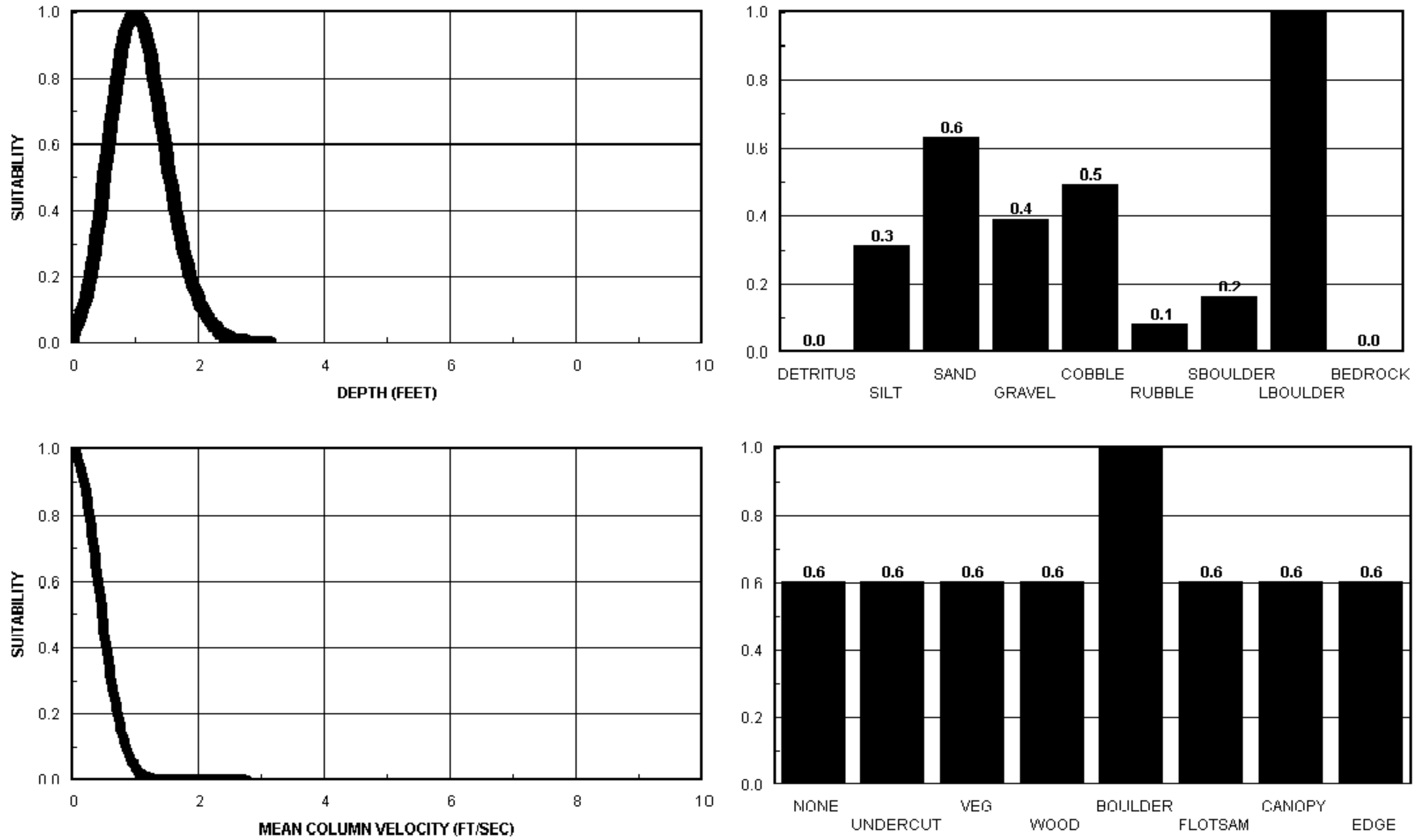
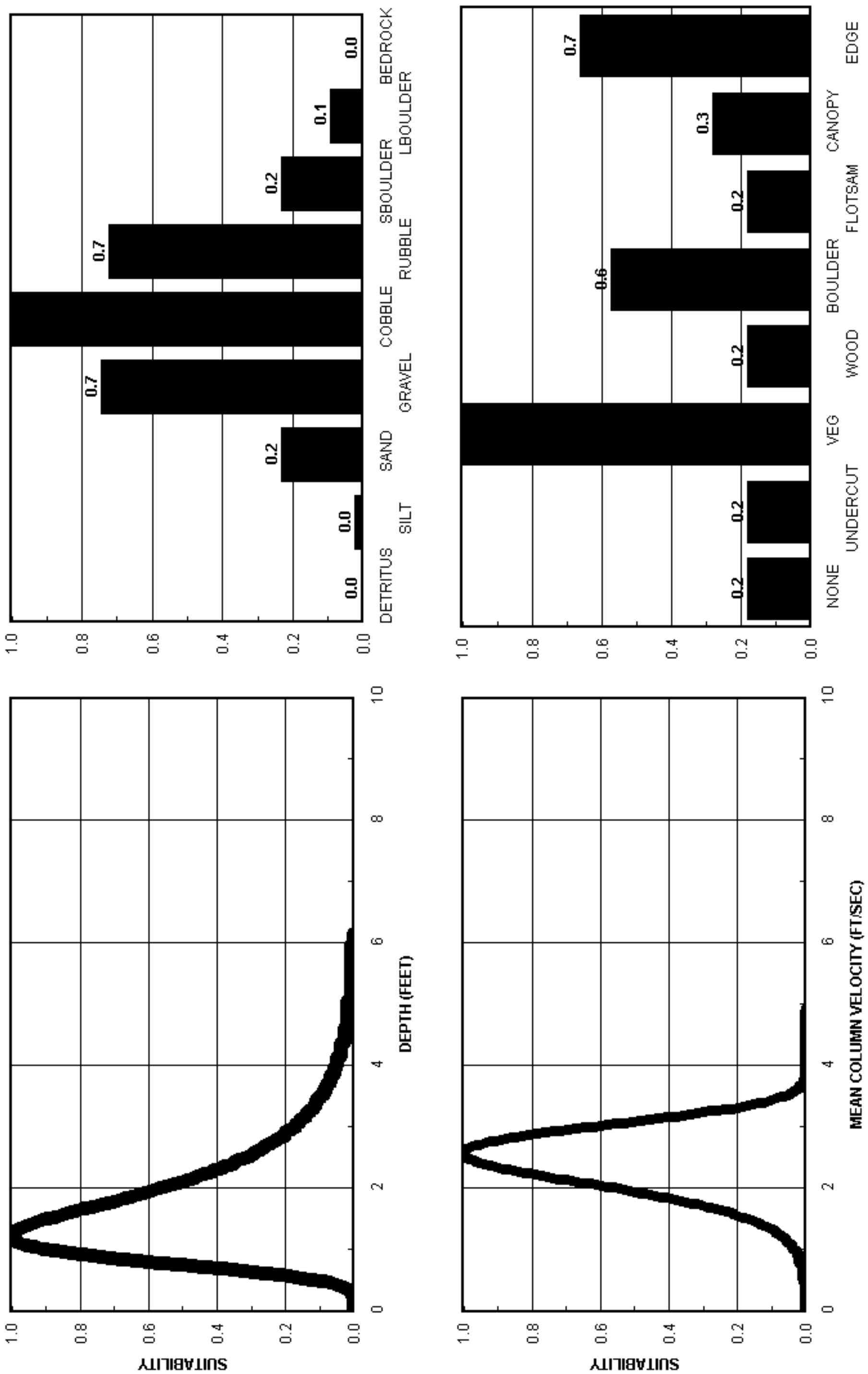
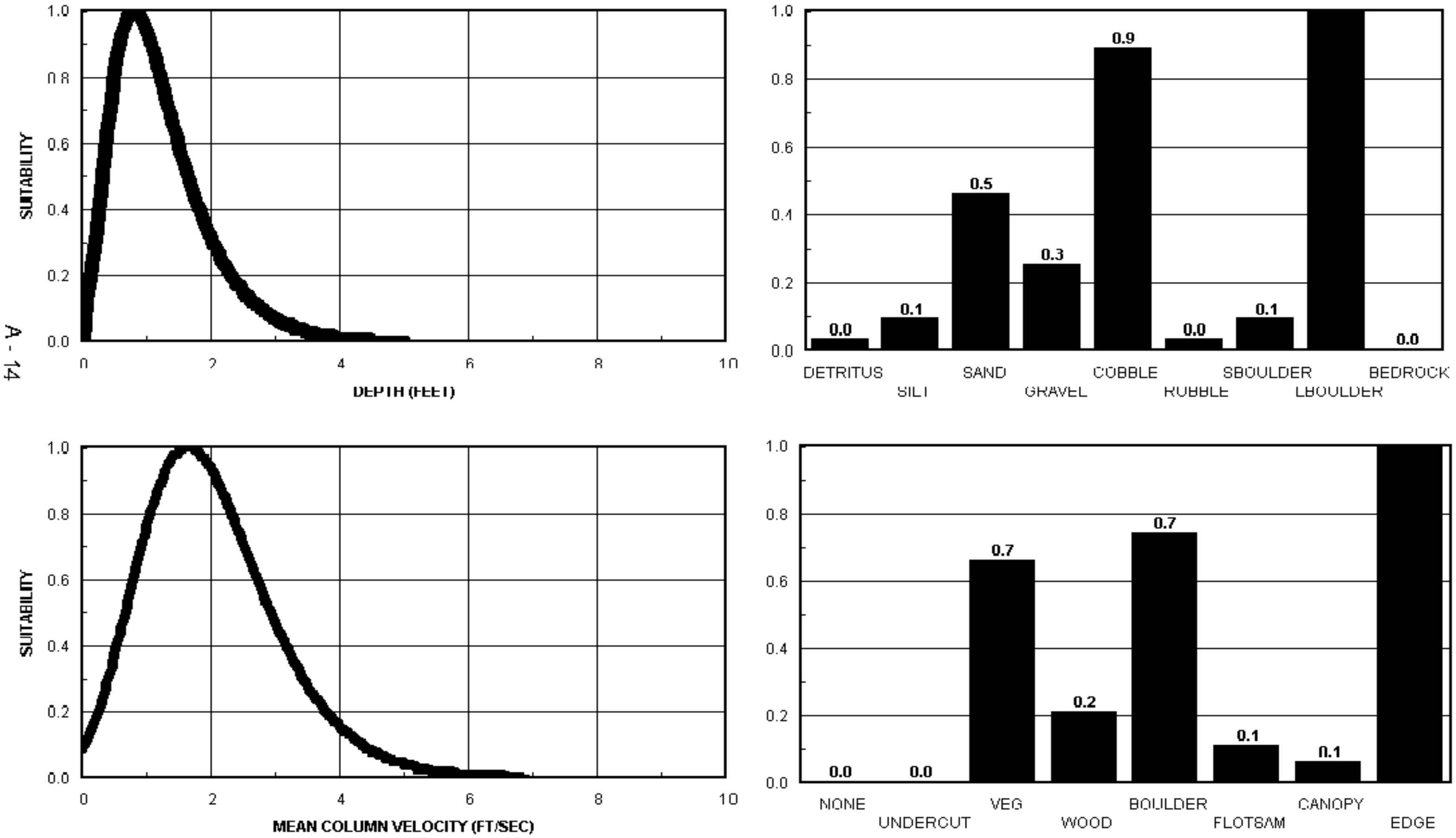


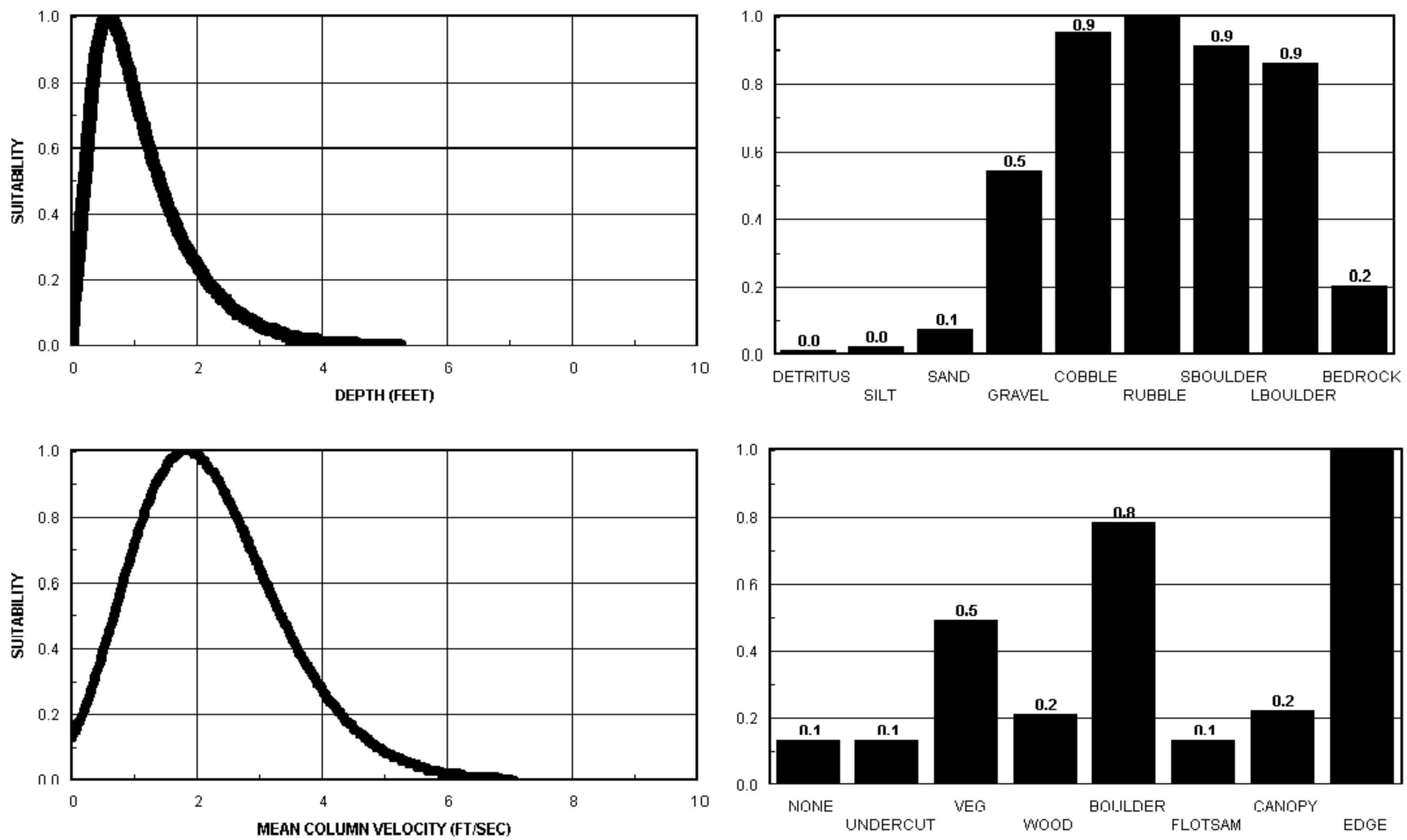
SHORTHEAD REDHORSE SPAWNING



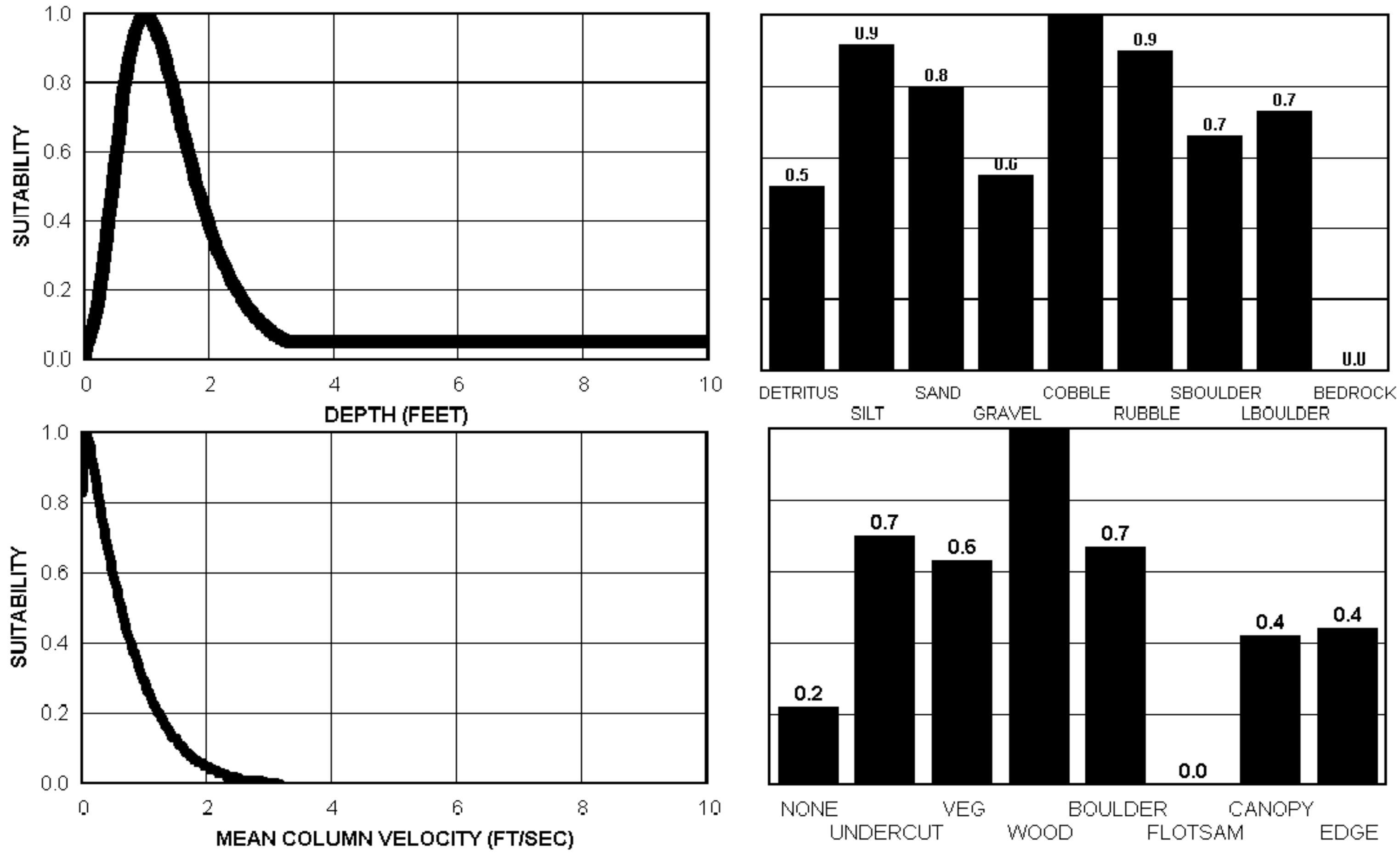
STONECAT ADULT

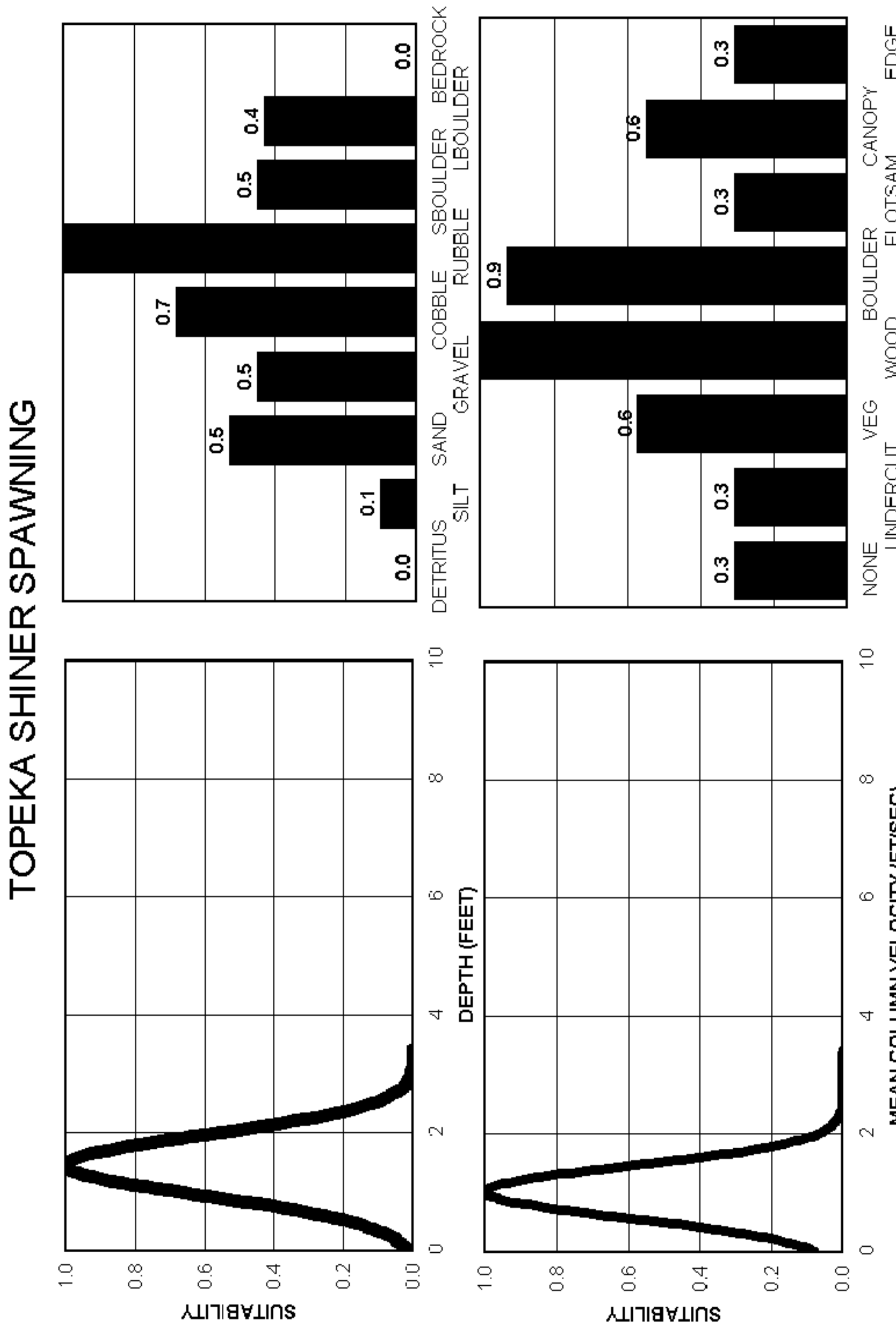


STONECAT JUVENILE



TOPEKA SHINER ADULT





TOPEKA SHINER SPAWNING
SUITABILITY
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
DEPTH (FEET)
DETRITUS
SILT
SAND
GRAVEL
COBBLE
RUBBLE
SBOULDER
LBOULDER
BEDROCK
0.0
0.1
0.5
0.5
0.7
0.5
0.4
0.0
MEAN COLUMN VELOCITY (FT/SEC)
NONE
UNDERCUT
VEG
WOOD
BOULDER
FLOTSAM
CANOPY
EDGE
0.3
0.3
0.6
0.9
0.3
0.6
0.3