HABITAT SUITABILITY CRITERIA
FOR STREAM FISHES AND MUSSELS OF MINNESOTA

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1.0 INTRODUCTION

The rivers and streams of Minnesota are home to many species of fish and wildlife with diverse habitat requirements that are defined by hydrology, fluvial geomorphology, water quality, biology, and connectivity (Annear et al. 2004). Habitat in rivers is often described on several scales including macrohabitat (usually identified on a stream reach level), mesohabitat (usually a geomorphically similar habitat such as a riffle or pool), and microhabitat (usually defined in terms of a localized area with a specific depth, velocity, substrate, and cover type). While groups or guilds of aquatic organisms may have similar macro-, meso- or micro-habitat (Aadland 1993), a species' fundamental niche is often unique due to behavioral or physiological characteristics. It is generally believed greater spatial habitat diversity yields greater biodiversity (Gorman and Karr 1978; Schlosser 1982). Temporal variability, such as high flows that create flood plain habitat and low flows that provide slow velocity habitat favored by larval fish, can also have a favorable effect on biodiversity. However, extremely variable hydrology due to watershed changes and flow regulation can create adverse conditions that reduce biodiversity (Aadland et al. 2005; Schlosser 1982; Horowitz 1978).

It has been well documented that both land use and in-channel changes can negatively impact the physical habitats on which fish depend. For example, water in rivers has been diverted, impounded, regulated by dams, cut-off from floodplains, and altered by land use practices, such as wetland drainage and ditching. These alterations have degraded habitat and water quality, created channel instability, altered important ecological processes, interrupted the flux of nutrients and energy, and severed the connectivity among channel, hyporheic, riparian, and floodplain attributes (Junk et al. 1989; Stanford and Ward 1993; Leopold 1994). Consequently, the biotic communities of rivers have been adversely impacted and resource values have been lost (Bain et al. 1988; Petts 1989).

A survey of Minnesota Department of Natural Resources (MNDNR) area fisheries managers revealed insufficient flow as the primary concern in regards to the survival, productivity, or use by riverine fish communities (Olson et al. 1988); therefore, effective protected flows must be established. A protected flow is defined as the volume of water required to protect instream resources, such as water-based recreation, navigation, aesthetics, fish and wildlife habitat, and water quality. Various methods to establish protected flows were considered by the MNDNR Division of Waters (DOW) (Olson et al. 1988), including Tennant's Method, the Northern Great Plains Resource Program (flow duration analysis), wetted perimeter, and the Instream Flow Incremental Methodology (IFIM). The MNDNR DOW determined that IFIM, the most widely used and accepted instream flow methodology in North America (Reiser et al. 1989), was the most comprehensive method for predicting changes in habitat relative to changes in hydraulic and physical parameters (Olson et al. 1988). Therefore, IFIM is being used by the MNDNR Division of Ecological Services Stream Habitat Program to address the flow-related habitat requirements of fish, wildlife, and recreation and to develop protected flows for Minnesota's streams.

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 used in PHABSIM describe the preferences of an aquatic organism for the variables depth, 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; Gore 1978; Aadland 1993; Hart 1995). Because changes in flow translate into changes in these habitat features, streamflow regulation can adversely alter the structure, function, and composition of stream communities by altering the availability of various habitat types on both spatial and temporal scales (Fisher and LaVoy 1972; Ward 1976; Williams and Winget 1979; Cushman 1985; Bain et al. 1988; Sparks 1992).

Flow recommendations for individual streams have been developed using a community-based approach to IFIM habitat analysis (Leonard and Orth 1988; Aadland 1993). In previous IFIM analysis, game fish were typically targeted for modeling in coldwater streams in the western United States, but due to the high diversity of aquatic organisms in the warmwater stream communities in Minnesota and the need for a more ecologically complete view, a broader approach must be used. Minnesota's streams may have 45 or more fish species along with a diverse assemblage of mussel and other macroinvertebrate species (Phillips et al. 1982; Aadland et al. 1991; Aadland 1993; Hart 1995; Hart et al. 2001; Sietman 2003; Simons et al. 2001). Each species-life stage may require a different type of habitat (Bain et al. 1988; Meffe and Sheldon 1988; Mullen and Burton 1995; Goodinho et al. 2000), and maintaining a diversity of habitats is fundamental in preserving the diversity of the stream ecosystem (Gorman and Karr 1978; Schlosser 1982). However, it is impractical to simulate conditions for every species at all life stages. Therefore, representative species and species-life stages are selected from each of six habitat-preference guilds identified by Aadland (1993) for Minnesota warmwater streams. This approach assumes that species within a guild have similar habitat versus flow relations; therefore, meeting the flow-related habitat needs of the representative target species should also fulfill the needs of the other species within the same habitat guild. Furthermore, this approach recognizes that certain habitat types (e.g., riffles) are more sensitive to changes in flow than other habitat types (e.g., pools) (Dare et al. 2002). By selecting representative species and life stages occupying each habitat type, paying special attention to flow-sensitive habitat types, the instream flow needs of the entire community are addressed.

As fish habitat suitability criteria (HSC) are a major component of IFIM, one goal of the MNDNR Stream Habitat Program is to build a database on fish habitat preferences. In 1991, Aadland et al. published the habitat preference criteria for 31 species-life stages of fish inhabiting Minnesota rivers. The Stream Habitat Program continues to study fish habitat preferences and currently has habitat preference criteria for 147 species-life stages, including updated criteria for the 31 original species-life stages. This report includes all habitat preference criteria developed to date.

2.0 STUDY SITES

In 1988 and 1989, the Snake, Yellow Medicine, and Zumbro rivers (Figure 1), were chosen as study rivers for fish habitat criteria. These rivers were chosen for their diverse instream habitat and for the different ecoregions within the state (Omerick and Gallant 1988) they represent. Two study sites, 400 m long (measured along the thalweg), were chosen on each river (Aadland et al. 1991).

2.1 SNAKE RIVER

In the North Central Hardwood Forests ecoregion, the Snake River is a river of contrasts, from the high, granite-walled gorges in the upper reaches to the long, quiet pools of the middle reaches, ending with a 19 km stretch of near continuous rapids at the confluence with the St. Croix River (Waters 1977). Both sites on the Snake River are located in Pine County. The upstream site is in Pine City Township approximately 1 km downstream of Cross Lake. The downstream site is in Chengwatana Township about 1.9 km upstream of the confluence with the St. Croix. Habitat data were also collected at the Snake River sites in 1995.

2.2 YELLOW MEDICINE RIVER

The Yellow Medicine River, a tributary of the Minnesota River, is in the Coteau des Prairies region of southwestern Minnesota in the Northern Glaciated Plains ecoregion. The Coteau des Prairies, a 500 to 800 foot plateau, sets the topographical stage for the watershed (Waters 1977). Both sites on the Yellow Medicine River are located southeast of the city of Granite Falls in Yellow Medicine County, Hawk Creek Township, approximately 4 and 5 km above the river's confluence with the Minnesota River.

2.3 ZUMBRO RIVER

In the Western Corn Belt Plains ecoregion, the Zumbro River is located in the "driftless" area of southeastern Minnesota, an area not covered with the remains of the last glacial period (Waters 1977). The Zumbro River consists of three major forks which originate in the cultivated

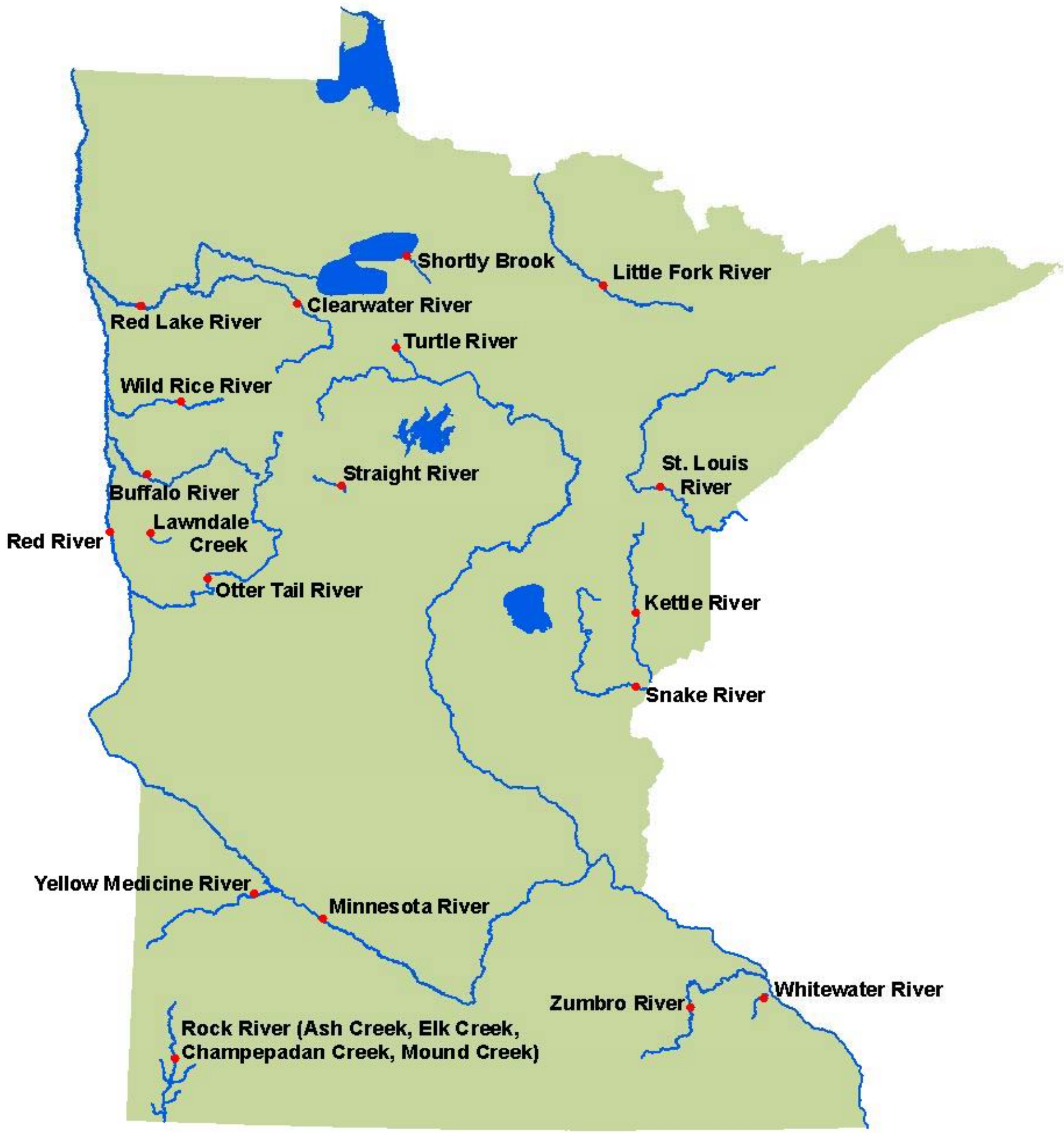

Figure 1. Map of Minnesota showing location of study streams and sites where habitat suitability data were collected.

till plain, converging near the town of Mazeppa where it flows through deep gorges until it connects with the Mississippi River (Waters 1977). Both study sites are located in Mazeppa Township, Wabasha County, approximately 1.9 and 6.4 km downstream of Zumbro Dam. In addition to these study sites, habitat data were collected on smallmouth bass (*Micropterus dolomieu)* nests from the dam to the bottom of the downstream site.

2.4 WALLEYE SPAWNING SITES

Spawning walleye (*Sander vitreus*) observations were made on four sites (Figure 1) in Beltrami County. Two sites are located on the Mississippi River, approximately 9.6 and 12.9 km downstream from Lake Bemidji. The third site is located on the Turtle River, a tributary of the Mississippi River and the fourth site is located on Shotley Brook, a small stream that flows into Upper Red Lake.

2.5 OTTER TAIL RIVER

The Stream Habitat Program established two long-term study sites to study fish communities and to collect data for developing HSC. These sites were picked for their habitat diversity and for the contrasting characteristics of their watersheds, such as land use, hydrology, and major drainage areas. The Yellow Medicine River was one of the rivers chosen; and since 1990 habitat data collection has been done annually at the downstream site. In 1991, the Otter Tail River was chosen for a second long-term study site. The Otter Tail River is a tributary of the Red River of the North in former Glacial Lake Agassiz. Due to the many lakes along its course, the Otter Tail River is probably the most stable river in Minnesota with water levels and discharge unusually constant along the entire river and rarely flooding (Waters 1977). The Otter Tail River site (Figure 1) is in Orwell Township, Otter Tail County, 1.1 km downstream of Orwell Reservoir. Habitat data collection has been done annually at this site since 1991 with the exception of 2001. Data were also collected at a second site on the Otter Tail River, located in Broken Down Dam Park in Fergus Falls. Data were collected in 1992, 1994, and 1995 at this second site.

2.6 ADDITIONAL STUDY SITES

Data have been collected on other rivers to attain site-specific data for IFIM sites or to increase the HSC database. These include the St. Louis, Little Fork, Minnesota, Kettle, Clearwater, Mississippi, Straight, Whitewater, Rock and several tributaries, Red, Red Lake, Buffalo, and Wild Rice rivers and Lawndale Creek (Figure 1). Sites for fish habitat data collection were chosen for their diversity of habitat, with the exception of Champepedan, Elk, and Mound creeks. On these rivers, sites known to have Topeka shiners present were chosen with the help of Jay T. Hatch, of the University of Minnesota. The Universal Transverse Mercator (UTM) coordinates for all sites are presented in Table 1. Topographic and aerial maps of all study sites are available in Appendix A.

2.6.1 ST. LOUIS RIVER

The St. Louis River watershed is located in northeastern Minnesota and at 9,283 km^2 is one of the largest watersheds in Minnesota (Waters 1977). The St. Louis River starts out in a high plateau, bordered by glacial moraines and old mountains before dropping 137 m through the lower gorge to Lake Superior (Waters 1977). Data were collected on the St. Louis River in 1989 at a study site located approximately 1 km downstream from its confluence with the Cloquet River in St. Louis County.

2.6.2 LITTLE FORK RIVER

The Little Fork River travels through some of the most remote river reaches in Minnesota (Waters 1977). Originating in a swampy brook, the river alternates between flat water and rapids for the majority of its course, becoming a wide, flat river the final 32 km before joining the Rainy River. Data were collected in 1990 on a spawning lake sturgeon (*Acipenser fulvascens)* site by Flat Rock Rapids.

2.6.3 MINNESOTA RIVER

The Minnesota River in southwestern Minnesota is surrounded by steep bluffs as it flows through the river valley shaped by the Glacial

Table 1. Drainage area and UTM coordinates for all sites are for the downstream end of the site. Drainage area calculated using the 30M DEM and DNR Hydro tools for flow accumulation, with the following exceptions. Lower Clearwater watershed was estimated using existing boundaries for upstream subwatersheds due to lack of connectivity in the flow accumulation grid. The Minnesota watershed in Minnesota delineated from the DEM, watershed in North Dakota estimated from the known major watershed boundary. The Red River of the North watershed was estimated by selecting the contributing subwatersheds and creating a freehand polygon of the additional partial subwatershed area upstream of the site. Flow accumulation grids did not flow into the Red River.
Coordinates are for UTM Zone 15 and North American Datum 83.

River	Site	Drainage area (km″)	Year collected	Northing	Easting
Buffalo		911	2004	5192454	245005
Clearwater	Upper	425	1993	5289230	334151
	Lower	3380*	1992	5306298	263227
Kettle		2141	1992	5106373	510876
Lawndale Creek	Upper	24	2004	5159583	240403
	Middle	54	2004	5161690	234996
	Lower	62	2004	5163759	234935
Little Fork		4227	1990	5355784	461159
Minnesota		15131 MN* 4027 ND	1990	4948294	321630
Mississippi – muskellunge		25159*	1993	5114792	394449
Mississippi – walleye	Upper	1541	1989	5260323	369819
	lower	1547	1989	5258181	370774
Otter Tail	Orwell	4552	1991 – 2000 2002-2004	5122199	254003
	BDD	3073	1992,1994,1995	5130807	267112
Red		8920*	2002	5139053	221564
Red Lake	Upper	12525	2003, 2004	5309572	254259
	Lower	13058	2004	5306543	243874
Rock	Upper	1086	1998	4837932	242167
	Lower	1365	1997, 1998	4825663	242440
	Ash Creek	36	1997	4825663	242369
	Champepadan Creek	129	1999	4851590	256033
	Elk Creek	100	1998	4836411	248777
	Mound Creek	44	1998, 1999	4845018	244311
St. Louis		8445	1989	5188703	532391
Shotley Brook		91	1989	5323559	385536
Snake	Upper	2448	1987, 1995	5076396	505644
	Lower	2516	1987, 1995	5074496	517207
Straight	Upper	87	1995	5197687	328483
	Middle	119	1995	5196384	332913
	Lower	156	1995	5193341	343375
Turtle		225	1989	5273661	368344
Whitewater	1	777	1996,1998,1999 2000, 2003	4894853	584151
	2	756	1996,1998,1999	4892950	581616
	3	411	1996,1998 – 2000	4882609	579024
	4	767	2000, 2003	4893487	582172
	5	236	2003	4892366	580644
Wild Rice	Upper	2208	2004	5240155	260893
	Lower	2838		5239693	231172
Yellow Medicine	Upper	1837*	1987,1988	4956104	305467
	Lower	1840	1987,1988 1990 - 2004	4956111	305431
Zumbro	Upper	2158	1987,1988	4896444	541737
	Lower	2175	1987,1988	4899937	541572

River Warren (Waters 1977). The oversized valley gives the Minnesota River a unique quality and has a major effect on the tributaries as they suddenly drop to the river valley. Data were collected on the Minnesota River in 1990 at a study site at Paterson Rapids near Redwood Falls in Redwood County.

2.6.4 KETTLE RIVER

The Kettle River flows for 129 km, changing its character several times along the way. It originates from the Corona Bog in Carlton County giving the Kettle River its brown-stained waters. It starts out rocky and swift becoming slow and flat after the Moose River joins it (Waters 1977). The river then goes through the Kettle River gorge and becomes one of the best whitewater canoeing areas in the country. The final stretch is a series of rapids until it joins the St. Croix River. Data were collected on spawning lake sturgeon in 1992 at a site just below the former Sandstone Dam.

2.6.5 CLEARWATER RIVER

The Clearwater River, in the Red River of the North watershed, is characterized by remains of Glacial Lake Agassiz, originating in the beach ridge area as a trout stream and changing into a plains stream as it flows into the flat lakebed (Waters 1977). The upper study site is located in Clearwater County, approximately 305 m downstream of Clearwater Lake and data were collected in 1993. Data were collected on spawning hornyhead chub (*Nocomis biguttatus)* nests at a lower study site in Red Lake County, about 7.4 km downstream of the CR 12 bridge crossing.

2.6.6 MISSISSIPPI RIVER

After flowing through the conifers in the north, the Mississippi River between Aitkin and Little Falls flows through pine ridges and sand hills with hardwood forests (Waters 1977). In this section, the river is shallow with a sand and gravel bottom. Data were collected on muskellunge (*Esox masquinongy)* spawning sites in 1993. Numerous sites between Brainerd and Fort Ripley were sampled.

2.6.7 STRAIGHT RIVER

The Straight River, part of the Crow Wing River watershed, is one of the most recognized trout streams in Minnesota (Waters 1977). Largely spring fed, this river was sampled to develop habitat curves for brown trout (*Salmo trutta)* as part of a study to determine the effects of increased groundwater pumping in the area. Data were collected at three sites in 1995. Two sites are located in Osage Township in Becker County. The first is approximately 1.3 km downstream of Straight Lake, and the second is approximately 762 m downstream of the County Road 125 bridge. The third site is located in Straight River Township, Hubbard County, approximately 457 m downstream of Township Road 111 bridge, approximately 3.2 km south of the city of Park Rapids.

2.6.8 WHITEWATER RIVER

The Whitewater River is also located in the “driftless” area of southeastern Minnesota. Typical of the streams of this region, the upper reaches cut through rocky bluffs while the lower reaches meander across valley floodplains (Waters 1977). The Whitewater River was channelized in 1958, resulting in river downcutting and channel incision. The channelized reach of the Whitewater River was restored in 1999, blocking off the channelized section, allowing the river to return to its original channel. To monitor changes in the fish community, data have been collected on the Whitewater River in 1996, 1998, 1999, 2000, and 2003. Data were collected at three sites each year to compare fish populations throughout the river. Site 1, the downstream control, is in Watopa Township, Wabasha County in the Whitewater Wildlife Management Area (WMA). Data have been collected at this site every year. The second site is in Whitewater Township, Winona County in the Whitewater WMA and is in the channelized reach. Data were collected here in 1996, 1998 and 1999. Site 3, the upper control, is in Elba Township, Winona County, immediately downstream of the CR 26 bridge, just outside of Elba. Data were collected at this site in 1996, 1998, 1999, and 2000. Site 4 is an excavated restored site in Whitewater Township, Winona County in the Whitewater WMA. Data were collected at this site in 2000 and 2003. Site 5 is within the historic channel that was restored in 1999 and is located in Whitewater Township, Winona County in the Whitewater Wildlife Management Area (WMA). Data were collected at this site in 2003.

2.6.9 ROCK RIVER AND TRIBUTARIES

The Rock River in southwestern Minnesota is the only river in Minnesota that is a part of the Missouri River Watershed and has a watershed with no natural lakes (Waters 1977). It starts in the Coteau des Prairies and drops into an undulating prairie flowing south to the Iowa border (Waters 1977). As part of a study of the endangered Topeka shiner (*Notropis topeka)*, data were collected on two sites on the Rock River and one site on each of the following tributaries: Ash, Mound, Elk, and Champepadan creeks. Data were collected at the lower Rock River site in 1997 and 1998. This site is located in Clinton Township, Rock County, approximately 1.4 km downstream of the CR 1 bridge. The upper Rock River site is located in the Luverne City Park, and data were collected in 1998. Data were collected on Ash Creek in 1997 at a site located just upstream of the confluence with the Rock River. The Mound Creek site is located in Blue Mounds State Park, Rock County, and data were collected in 1998 and 1999. The Elk Creek site is located in Magnolia Township in Rock County, and data were collected in 1998. The Champepadan Creek site is located in Leota Township, Nobles County, and data were collected in 1999.

2.6.10 RED RIVER OF THE NORTH

The Red River of the North mainstem a product of Glacial Lake Agassiz and has a very low gradient. It has a flat and shallow channel and is a small stream relative to its vast watershed (Waters 1977). Data were collected at a site downstream of Brushvale in Connelly Township, Wilkin County in 2002. Unlike the lower Red River of the North that has a largely silt and sand bed, this site is dominated by boulder and rubble riffles and fine substrates in backwaters and pools.

2.6.11 RED LAKE RIVER

The Red Lake River runs its entire course through the lake bed of Glacial Lake Agassiz. It is a flat plains stream except where it cuts through the Campbell beach ridges (Waters 1977). Data were collected on the Red Lake River at two sites in Red Lake County. One site is located downstream of the confluence of the Clearwater River and data were collected in 2003 and 2004. This site is characterized by boulder rapids and was acknowleged as an important spring fishery for lake sturgeon in the journal of Alexander Henry who toured the area in 1799-1808 (Gough 1988). It is likely that it was a key spawning area for this species since the available habitat is similar to habitat in which lake sturgeon have been observed spawning in the Little Fork River and other sturgeon streams. The second site is upstream of the public access in Huot, and data were collected in 2004.

2.6.12 BUFFALO AND WILD RICE RIVERS

Like all tributaries to the Red River of the North, the Buffalo and Wild Rice rivers are influenced by Glacial Lake Agassiz. Both rivers start in the glacial moraines, cut through the beach ridges, and then flow through the flat lakebed (Waters 1977). In 2004, data were collected at one site on the Buffalo River and on two sites on the Wild Rice River. The Buffalo River site is upstream of the 220th Street bridge in Clay County near Hawley, and the Wild Rice River sites are in Norman County. One site is upstream of the town of Twin Valley, starting about 457 m downstream of CR 175, while the other site is southeast of the town of Ada, just upstream of Highway 20.

2.6.13 LAWNDALE CREEK

Lawndale Creek is a small stream in the Buffalo River watershed, located on the Campbell Beach Ridge of Glacial Lake Agassiz. It is one of very few coldwater prairie streams in the Red River of the North Basin. The stream's perennial flow begins at springs in the Rothsay Wildlife Management Area about 12 km upstream of its confluence with Deerhorn Creek. A project to restore a legal ditch back into about 3 miles of meandering channel has been proposed.

Data were collected at three sites on the stream to evaluate the current fish community and provide pre-project data for monitoring the restoration. Sites are located in meandering reaches upstream and downstream of the proposed project area and at a site in the ditched section of the stream. The downstream site is located upstream of the confluence with Deerhorn Creek, the middle site is upstream of Highway 30, and the upstream site is about 4 km downstream of the headwater springs.

3.0 METHODS

Habitat preference criteria were developed by sampling a section of river for fish and determining the habitat type used by the individuals captured. First, fish were captured using one of the sampling gear types described in the following sections. The same area (13.9 m^2) was sampled regardless of gear type. For each area sampled, the collected fish were immediately placed into a container of water. Each fish was identified to species, its total length measured in millimeters, and life stages were assigned based on length, or in the case of spawning adults, the emission of eggs or milt during palpitation. Fish were designated as young-of-the-year if their total length was less than published average lengths for individuals of that species at the first annulus in similar latitudes (Becker 1983). Juveniles were fish of typical age-1 to adult lengths. Species known to mature in their first year were not assigned a juvenile life stage.

Spawning adults were fish that released eggs or milt during palpitation, or individuals observed on a nest or displaying obvious spawning behavior. When many fish of a particular species-life stage were captured, only the first 10 fish were measured. The length range and number of the remaining fish was determined and recorded. The fish were immediately returned to the river once identification and measurements were completed.

Microhabitat data were recorded at each sampling location, regardless of whether any fish were captured. Variables recorded with each sample included: river, site location, date, weather conditions, water and air temperature, sample location, gear type, three water depths, three mean column velocities, substrate types, and cover types (Bovee 1986).

Water depth was measured with a top setting wading rod. Mean column water velocity was measured at 0.6 of the depth in water <0.76 m deep and at 0.2 and 0.8 of the depth in water ≥0.76 m deep (Buchanon and Somers 1969). Water velocity was measured with a commercially available current meter attached to a top-setting wading rod. Meters were tested or calibrated prior to use.

Substrate and cover were described according to the criteria in Table 2 (Aadland 1993). The percentage of a cell area covered by a particular substrate category was visually estimated to the nearest 10% in each cell. All cover types present within a cell were recorded.

3.1 SAMPLING GEAR

Several types of sampling gear were used to collect habitat preference criteria, but the majority were sampled with a prepositioned area shocker (PAS). The PAS is the most versatile and quantitative of all the sampling gear used for this study. It was employed within most cells, unless they were too deep to be effectively sampled. Deep cells were sampled with a purse seine or electric trawl.

3.1.1 PREPOSITIONED AREA ELECTROSHOCKER

The PAS used was a modified version of the one described by Bain et al. (1985). The PAS samples an area 1.8 x 7.6 m. Once the unit was set, it was left undisturbed for a minimum of 11 minutes, as recommended by Bain et al. (1985). A 3,000 or 5,000 W generator was used for the power source, and 120-V AC was used. A 1.2 x 1.8 m catch net was held immediately downstream of the PAS to collect the stunned fish. The current was activated for 20 seconds, after which time the area was thoroughly searched with dip nets for fish that did not drift into the net.

3.1.2 PURSE SEINE

Areas too deep to be effectively sampled with the PAS were sampled with a 3.7 x 15.2 m purse seine. It was deployed to encompass

Table 2: Dimensions of substrate categories and descriptions of cover categories (Aadland 1993).

SUBSTRATE	DIMENSION (mm)	COVER	DESCRIPTION
Organic detritus	organic matter	Undercut	undercut bank
Silt	<0.062	Vegetation	rooted or unrooted plants
Sand	0.062 – 3.2	Wood	woody matter
Gravel	3.2 – 64	Boulder	boulders >10 cm above streambed
Cobble	64 – 128	Flotsam	Thick foam on water surface
Rubble	128 – 256	Overhang	canopy or overhead structure
Small boulder	256 – 508	Edge	a break from high to low velocities
Large boulder	508 – 1016		
Bedrock	>1016		

approximately the same area as the PAS. The area to be sampled would be encircled as quickly as possible, and then the bottom of the net would be cinched and the net brought to shore to empty the catch. Care was taken to assure the bottom rings remained on the channel bottom throughout the procedure.

3.1.3 ELECTRIC TRAWL

Areas too deep to be sampled with the purse seine were sampled with a 0.19 x 0.56 m electric trawl used with a Smith-Root DC electrofishing boat (Aadland and Cook 1992). The electric field in front of the trawl stuns benthic fish and collects them in the trawl. A spherical anode at the surface, approximately 0.5 m in front of the boat, allowed fish exhibiting electrotaxis to be collected at the surface. The electric trawl was towed upstream through the cell and then winched to the surface to empty the catch. The trawl was towed for about 7.5 m to encompass the same area as the PAS.

3.1.4 VISUAL OBSERVATION

Habitat use data were recorded through visual observation to collect spawning data on several species of fish: brown trout, horneyhead chub, muskellunge, smallmouth bass, and walleye. Spawning and/or nesting areas were observed while wading the stream or drifting in a boat (Aadland et al. 1991). In some cases, MN DNR Fisheries personnel marked a group of known spawning sites, and collected habitat data immediately afterwards. This approach avoided duplication of specific habitat locations (Aadland et al. 1991).

3.1.5 OTHER GEAR TYPES

Several other gear types were tried in 1987 to determine their effectiveness. These were cast nets, conventional seine, electric seine, mobile probes, and snorkeling. Due to limitations found in their effectiveness compared to the PAS, purse seine or electric trawl, none of these gear types have been used since 1987 for multispecies habitat sampling (Aadland et al. 1991).

3.2 SAMPLING DESIGN

Since 1991, two techniques have been used for location of the cells to be sampled. The first technique involved mapping the habitat throughout the site (Figure 2). The sampling area was then subjectively divided and classified as pool, riffle, raceway, or shoreline. These strata were then divided into individual cells measuring approximately 3 x 7.6 m. Sampling locations within these strata were then chosen using a stratified random design; a random numbers table is used to choose cells. Each selected cell was sampled once to avoid bias of repeated sampling of the same cell.

With the second method, the placement of the PAS in relation to the distance from the left bank was determined using a random numbers table (Figure 3). Once a sample was taken, the PAS was moved upstream a minimum of 7.6 m and its location from the left bank was again randomly determined. This process is repeated until the length of stream sampled is 10-12 times the width of the stream.

The mapped design was used on the Otter Tail, Snake, and Zumbro rivers. The random number design was used on all other rivers. The mapped design was used on the Yellow Medicine River until 1997; since then, the random number design has been used.

4.0 DATA ANALYSIS

Most curves presented here are density-based rather than presence/absence characteristic of HSI curves developed using SCUBA and snorkeling. This gives an area component to observations and eliminates the need for separate habitat availability data. Curves developed based on a single point (observed fish) in space have the problem of requiring separate efforts to establish available habitat and create bias if sampling designs for fish observations and habitat availability differ. An exception to this approach was used for some of the spawning life stages where only use-data were collected. In these cases, habitat data was collected only where the spawning had occurred, such as horneyhead chub nests or observed deposition of lake sturgeon eggs. We did not attempt to quantify available habitat for spawning fish because lake sturgeon and other

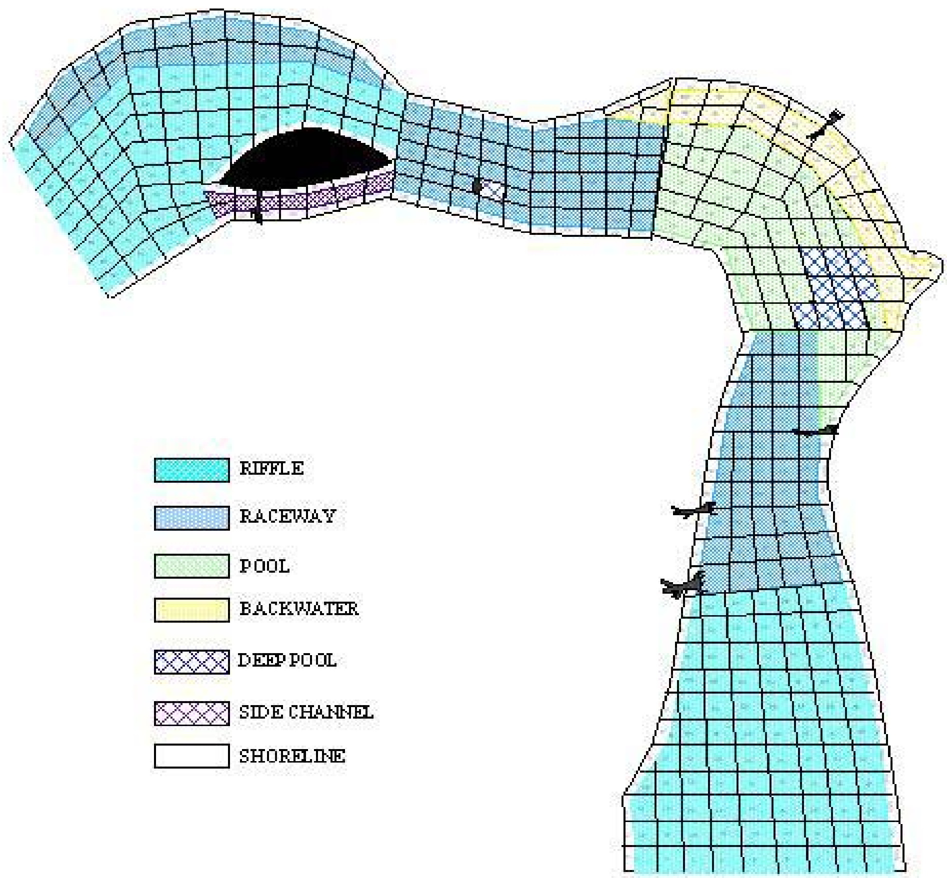

Figure 2. Example of stratified random sampling habitat map of the Otter Tail River.

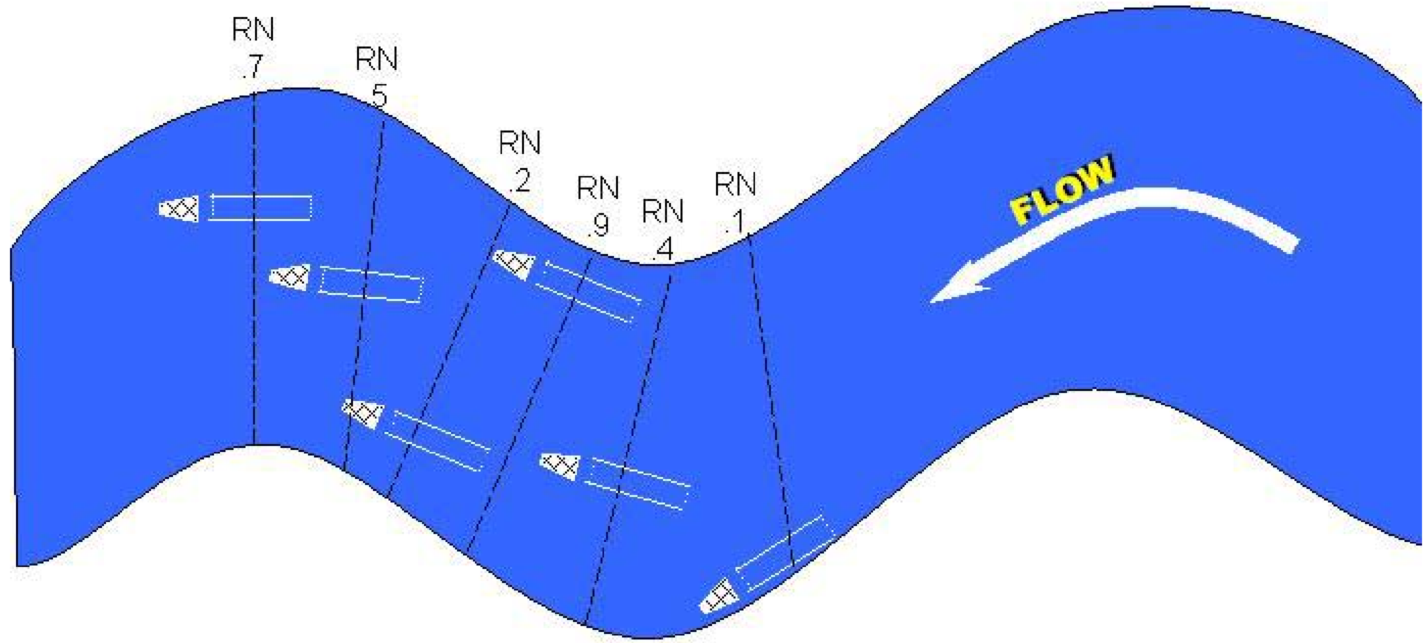

Figure 3. Example of stratified random sampling with random number defining the proportion of stream width from the left bank.

species are known to migrate hundreds of miles to find suitable spawning habitat. Therefore, quantification of available habitat would need to include the range of unused habitats along this migration route. We assume this "ignored" habitat covers a large range of depths, velocities, substrates, and cover types and the used habitat was selected from this large set of available habitat. We have assumed in the development of these criteria that cover is not avoided. Fish having higher densities in areas of no cover are assumed to do so because of the distribution of cover rather than true avoidance. The preference for all cover types is assumed to be no less than the preference for no cover. For example, young-of-year banded darters (*Etheostoma zonale)* have a preference of 1.00 for vegetation, 0.54 for boulder and 0.45 for no cover. All other cover types had a preference of less than 0.45, but were assigned a preference of 0.45 as we assumed fish will not avoid these cover types if the preferred depth, velocity, and substrate is available.

4.1 HABITAT PREFERENCE RELATIONSHIPS

Habitat preference values for most species-life stages were calculated for depth, velocity, substrate, and cover. Preference values were calculated as follows:

1) Each habitat variable was divided into intervals (e.g., depth intervals were 0 - 5 cm, 5.1 – 15 cm, 15.1 – 25 cm, etc.).

2) The number of samples taken within each interval was summed, yielding available habitat.

3) The number of fish collected within each interval was summed, yielding habitat use.

4) Habitat preference values were calculated by dividing the habitat-use for each interval by the available habitat for that interval.

5) Preference values were expressed on a normalized scale from 0.0 to 1.0 by dividing each preference value by the maximum preference value.

A preference value of 0.0 indicates the least preferred or least suitable habitat while a value of 1.0 indicates the most preferred or most suitable habitat. Preference values were calculated for each site sampled or for each flow if the flow changed significantly during a sampling period. A composite preference curve was then calculated by weighting the preference data for each site/flow by the number of observations at that flow and fitting a curve to the composite preference values.

4.2 HABITAT USE RELATIONSHIPS

Data collected for spawning brown trout, horneyhead chub, lake sturgeon, muskellunge, and walleye were developed with use data. The habitat variables were only measured where these species were spawning or where nests were found. As no other habitat was measured, preference could not be determined. Habitat use values were calculated for each species-life stage for depth, velocity, substrate, and cover. To calculate these:

1) Each habitat variable was divided into intervals (e.g. depth intervals were 0 - 5 cm, 5.1 - 15, 15.1 – 25 cm,. etc.).

2) Each habitat variable interval (habitat-use) was averaged.

4.3 DEVELOPMENT OF HABITAT PREFERENCE CURVES

Preference curves were constructed for each species-life stage and represent the optimum range of microhabitat variables of depth and velocity. Several techniques were used to construct the habitat preference curves from preference values, including histogram analysis and nonlinear regression. Preferences curves were developed for depth and velocity, while histograms were used to depict preferences between substrate and cover types.

4.3.1 HISTOGRAM ANALYSIS

Histograms were created by plotting the preference values against the habitat variable being examined (depth, velocity, substrate, or cover). This technique is the simplest, but may misrepresent the preference relationship. Sampling error tends to produce irregular histograms, especially when the sample size is small for certain portions of the variable range. For example, greater depths have smaller sample sizes and greater error. These irregularities can be reduced somewhat by widening the intervals from which the preference values are derived or averaging adjacent cells.

4.3.2 NONLINEAR REGRESSION

Nonlinear regressions were calculated to fit curves to preference values using the NONLIN module of SYSTAT statistical software (Engelman 2002). Nonlinear regression requires input of an appropriate equation to describe the preferences function and derives best-fit coefficients. Preference values for depth or velocity and the equation used to describe the relationship are input into the program. Coefficients in the equation are manipulated by the computer until the sum of squared deviations of the preference values from the curve is minimized (least squares). Finding the right equation to describe the data is important. In most cases, the generalized Poisson density function was used, as it yields a low least squares value, and accurately fits skewed distributions typical of habitat preference data. The generalized Poisson equation is as follows:

Preference = (((B-X)/(B-A))^C)*2.718^((C/D)*(1-((B-X)/(B-A))^D))

where: A = value of "X" where f(X) = 1.0
B = value of "X" where f(X) = 0.0 (X<B)
C = shape parameter for part of the curve to the right of X=A
D = shape parameter for part of the curve to the left of X=A
X = habitat variable (Bovee 1986).

Preference data for some fishes that appeared to have an asymptotic relationship to depth (selected for deep water and did not appear to have a maximum preferred depth) were fitted using the arctangent function as follows:

Preference = B+(C/3.1416)*atn((3.1416*D)*(X-A))

where: A = "x" location of inflection point
B = "y" location of inflection point
C = step size (distance from the maximum point to the minimum point)
D = slope of line at inflection point
X = habitat variable (Bovee 1986).

Once a nonlinear equation is selected, two NONLIN minimization models, Quasi-Newton and Simplex, are used to fit the equation to the preference data. The Quasi-Newton is more methodical and quicker than Simplex. By using first and second derivatives of the least squares function, it calculates the degree to which it should change the coefficients from one iteration to the next. The Simplex is a more random technique but is capable of solving nonlinear regression equations in some situations where the Quasi-Newton is not. Both methods were explored for all equations. Once satisfactory coefficients were attained, the equation was transferred to a spreadsheet and the estimates for any value of the habitat variable were calculated (Engelman 2002).

Once criteria have been established, histogram analysis is done yearly. The new histogram is subjectively compared to the established curve to determine if a new curve should be fitted to the histogram. Curves are updated when it is determined that a significant change in the data has occurred.

4.4 GUILD IDENTIFICATION

To simplify selection of species-life stages for the IFIM analysis, habitat-preference guilds were identified. Aadland et al. (1989) recommended six guilds based on cluster analyses of habitat parameter means for sampled species-life stages. The six guilds are shallow pool (< 60 cm deep and velocities < 30 cm/s), medium pool (60 - 149 cm deep and velocities < 30 cm/s), deep pool ($150 cm deep), raceway (60 - 149 cm deep and velocities $30 cm/s), slow riffle (<60 cm deep and velocities $30 - 59 cm/s), and fast riffle (<60 cm deep and velocities $ 60 cm/s). These guilds were then refined based on actual density within each habitat type and each species-life stage was assigned to the guild corresponding to the habitat type in which it had the highest density (Aadland 1993).

5.0 FRESHWATER MUSSELS

Freshwater mussels are the most endangered class of organisms in the United States (Williams et al. 1993) and have been greatly affected by dams, stream channelization, pollution, siltation, and low stream flows. While some may argue that mussels are sessile organisms, studies have shown that mussels do move to preferred habitat (Kat 1982, Amyot-Downing, 1998

MNDNR unpublished data).

Mussels were sampled on the Clearwater, Kettle, and Otter Tail rivers. Mussel data were collected on the upper Clearwater River site and both Otter Tail River fish study sites. The Kettle River study site is downstream of the gorge in the area of where the Sandstone Dam stood until its removal in 1994 (Figure 1).

To sample mussels, transects were established across the river at each study site. Transects were chosen to represent various habitat types: pool, riffle, and run. For the Clearwater and Otter Tail river sites, transects that had been established for a PHABSIM study were used.

For the Kettle River, the study reach was stratified into four habitat types: rapids, pool, fast run, and slow run. Three areas of each habitat type were sampled. One transect was established within each unit to sample for mussels. These transects were established before dam removal. After dam removal, two transects were established in the reservoir area to monitor sediment change in the former reservoir.

Once transects were established, 30 samples were taken across each transect using a 0.37 m^2 quadrat. Quadrat placement was randomly chosen. First the width of the transect was determined. The width was then multiplied by numbers on a random number table. The numbers were then numerically sorted. Numbers that were on dry land were eliminated, as were quadrats that overlapped with a previous one to prevent duplication.

Using snorkeling or scuba gear, each quadrat was examined for the presence of mussels. All mussels within the quadrat were removed, identified, recorded, and returned to the quadrat. Once sampling of mussels was completed, microhabitat data were collected using the same standards as for fish sampling with two exceptions. Only one depth and velocity reading was recorded per quadrat and cover was not recorded. Habitat suitability criteria and guild type were determined using the same procedures as for fish.

6.0 RESULTS

Through 2004, the Stream Habitat Program collected habitat suitability data on 18 mussel species and 127,474 fish (99 species and 240 species-life stages). Table 3 shows all the species sampled and the rivers where they were sampled. Sufficient data have been collected to develop fish habitat criteria for 9 mussel species and 147 fish species-life stages, including larval fish. Larval fish are centrarchid and cyprinid species $\leq$ 25 mm. These species-life stages represent each of the six habitat guilds (Tables 4 - 9).

7.0 MODEL CONSIDERATIONS FOR HABITAT SUITABILITY CRITERIA

The habitat preference curves for depth and velocity and the histograms for substrate and cover for all species-life stages are shown in Figures 4 - 151. (Table 10 lists the figure for each species-life stage.) The following suitability criteria describe habitat in terms of preferred depth, velocity, substrate, and cover. However, they may not describe all components of suitable habitat. Our observations of spawning lake sturgeon, for instance, indicate very specific geomorphic characteristics of habitat in which they actually spawn. Sturgeon key in on areas below bedrock or boulder outcroppings that create cascades. These cascades create undercurrents and upwellings that actually bring air bubbles to the riverbed and may be critical in keeping eggs well aerated. Unfortunately, these complex settings are also difficult to fully quantify. It is also important that all suitability criteria are applied only to reaches that have the geomorphic mesohabitat where the species is found. Instream flow models can be very misleading if, for example, riffle species are modeled for reaches that have no riffles. Such models can lead to the assumption that suitable habitat exists where it does not, or that large amounts of minimally suitable habitat equal small amounts of quality habitat.

Table 3. Composite list of all fish and mussel species and the rivers in which they were captured. C indicates a species that habitat suitability criteria have been developed for at least one life stage and X indicates a species with insufficient data to develop habitat suitability criteria.

Common Name	Ash Creek	Buffalo River	Champepadan Creek	Clearwater River	Elk Creek	Kettle River	Lawndale Creek	Little Fork River	Minnesota River	Mound Creek	Mississilll River	Oter Tail River – Broken Down Dam	Otter Tail River – Orewll	Red River	Red Lake River	Rock River	Shotley Brrok	St. Louis River	Sanke River	Straight River	Turtle Brook	Whitewater River	Wild Rice River	Yellow Medicine River	Zumbro River
Chestnut lamprey													X		X				X						
Silver lamprey															X										
American brook lamprey																						X			
Lake sturgeon						C		C																	
Shortnose gar									X															X	
Bowfin													X												
Goldeye		X											X										X		
Mooneye													X	X											
Gizzard shad									C															C	C
Central stoneroller	C		C		C					C		C	C			C				C		C		C	C
Largescale stoneroller									C															C	
Red shiner	X									X															
Spotfin shiner							C		C				C	C					C			C	C	C	C
Comman carp	C								C	C			C	C		C			C			C	C	C	C
Brassy minnow			C													C								C	
Common shiner	C	C	C	C	C					C		C	C	C	C	C			C	C		C	C	C	C
Hornyhead chub		C		C								C	C		C				C	C			C	C	C
Golden shiner				X															X			X	X	X	
Pugnose shiner													X												
Emerald shiner									C				C	C	C							C		C	C
River shiner									C				C			C				C		C		C	C
Bigmouth shiner	C	C	C		C					C		C	C			C				C		C	C	C	
Blackchin shiner												X	X						X					X	
Blacknose shiner			C	C								C							C						
Spottail shiner													C		C			C	C	C				C	C
Rosyface shiner															X								X	X	
Sand shiner	C	C	C		C		C		C	C		C	C	C	C	C			C	C		C	C	C	C
Weed shiner														X											
Topeka shiner	C		C		C					C						C									
Mimic shiner												C	C			C		C	C	C				C	C
Suckermouth minnow																									X
Northern red belly dace																				X					
Finescale dace							X																		
Bluntnose minnow	C		C		C				C	C		C	C			C			C	C				C	C
Fathead minnow	C	C	C	C	C					C		C	C		C	C						C		C	C
Bullhead minnow																								X	
Eastern blacknose dace	C		C	C	C		C		C	C		C				C		C		C		C	C	C	C
Longnose dace		C		C			C					C	C		C			C	C	C		C	C		C
Creek chub	C	C	C	C	C		C		C	C		C	C		C	C		C		C		C	C	C	C

Common Name	Ash Creek	Buffalo River	Champepadan Creek	Clearwater River	Elk Creek	Kettle River	Lawndale Creek	Little Fork River	Minnesota River	Mound Creek	Mississi[l] River	Oter Tail River – Broken Down Dam	Otter Tail River – Orewll	Red River	Red Lake River	Rock River	Shotley Brrok	St. Louis River	Sanke River	Straight River	Turtle Brook	Whitewater River	Wild Rice River	Yellow Medicine River	Zumbro River
River carpsucker									C				C			C								C	C
Quillback			C							C			C	C		C								C	C
Highfin carpsucker																								C	
White sucker	C	C	C	C	C		C			C		C	C			C		C	C	C		C	C	C	C
Northern hogsucker												C	C						C			C		C	C
Smallmouth bufflao									X				X											X	X
Bigmouth buffalo													X		X									X	
Spotted sucker																									
Silver redhorse									C			C	C						C			C	C	C	C
River redhorse																			X						X
Golden redhorse		C										C	C	C	C				C			C	C	C	C
Shorthead redhorse		C							C	C		C	C	C	C	C		C	C	C		C	C	C	C
Greater redhorse												C	C			C			C	C		C		C	C
Black bullhead		C	C	C						C		C	C			C			C					C	
Yellow bullhead												X	X						X						
Channel catfish									C	C			C	C		C		C	C				C	C	C
Stonecat		C	C		C		C		C				C		C	C			C				C	C	C
Tadpole madtom										C		C	C			C		C							
Flathead catfish									X															X	
Northern pike		C		C			C			C		C	C			C		C	C					C	
Muskellunge											C														
Central mudminnow				X			X					X							X			X			
Rainbow trout																						X			
Brown trout																				C		C			
Brook trout							X																		
Trout-perch														X		X		X					X		
Burbot																			X						
Brook silverside																									X
Plains topminnow										X						X									
Brook stickleback	C			C	C		C			C			C							C		C		C	
Mottled sculpin																		X		X					
White bass																								C	C
Rock bass				C								C	C		C			C	C					C	C
Green sunfish									C	C		C	C			C						C	C	C	C
Pumpkinseed sunfish										X			X			X						X			
Orangespotted sunfish			C						C	C				C		C								C	
Bluegill sunfish		C		C					C	C			C			C		C	C	C		C		C	C
Smallmouth bass									C				C	C	C			C	C					C	C

Common Name	Ash Creek	Buffalo River	Champepadan Creek	Clearwater River	Elk Creek	Kettle River	Lawndale Creek	Little Fork River	Minnesota River	Mound Creek	Mississilll River	Oter Tail River – Broken Down Dam	Otter Tail River – Orewll	Red River	Red Lake River	Rock River	Shotley Brrok	St. Louis River	Sanke River	Straight River	Turtle Brook	Whitewater River	Wild Rice River	Yellow Medicine River	Zumbro River
Largemouth bass				C						C		C	C			C				C		C		C	C
White crappie													X	X					X						X
Black crappie													C	C				C	C						C
Rainbow darter									C				C											C	C
Iowa darter				C	C					C		C	C									C		C	
Fantail darter																								C	
Least darter												X													
Johnny darter	C	C	C	C	C		C		C	C		C	C	C	C	C		C	C	C		C	C	C	C
Banded darter									C															C	C
Yellow perch		C		C						C		C	C			C			C	C				C	C
Logperch												C	C					C	C	C		C		C	C
Gilt darter																			X						
Blackside darter		C		C			C		C			C	C		C				C			C		C	C
Slenderhead darter									C										C					C	C
Sauger																							X	X	
Walleye									C		C	C	C				C	C	C	C	C			C	C
Freshwater drum									C				C	C										C	
Mapleleaf						X																			
Pimpleback						X																			
Threeridge				C		C						C	C												
Wabash pigtoe				C		C						C	C												
Elephant ear																									
Spike						C																			
Giant floater				X																					
Cylindrical papershell													X												
Creeper				C		C						C	C												
Elktoe						X																			
White heelsplitter				X		X						X	X												
Fluted shell						C																			
Mucket						C																			
Hickorynut						X																			
Black sandshell						C																			
Fat mucket				C		C						C	C												
Plain pocketbook						C																			

Table 4. Species-life stages that prefer shallow pool (depth <60 cm and velocity < 30 cm/s). Year is the year the current HSC was developed, N1 equals the number of fish observations the curve is based on; and N2 equals the total of fish observations to date. Life stages are adult (A), juvenile (J), spawning (S), and young-of-year (Y), split into fry (FR) and fingerling (FI) for smallmouth bass.

Common Name	Scientific Name	Life stage	Year	N1	N2
Brassy minnow	*Hybognathus hankinsoni*	A	2000	48	49
Hornyhead chub	*Nocomis biguttatus*	S	1996	184	184
		Y	2002	490	540
Emerald shiner	*Notropis atherinoides*	A	2002	5887	6204
		Y	2002	1529	1532
River shiner	*Notropis blennius*	Y	2002	137	142
Bigmouth shiner	*Notropis dorsalis*	A	2002	663	690
Sand shiner	*Notropis stramineus*	A	2002	8291	8747
Mimic shiner	*Notropis volucellus*	A	2000	140	149
Bluntnose minnow	*Pimephales notatus*	Y	2002	4118	4497
Fathead minnow	*Pimephales promelas*	S	2000	23	23
		Y	2002	1621	1777
Longnose dace	*Rhinichthys cataractae*	Y	2002	662	712
Creek chub	*Semotilus atromaculatus*	Y	2002	1494	1749
River carpsucker	*Carpiodes carpio*	Y	1998	91	101
Quillback	*Carpiodes cyprinus*	Y`	2002	82	82
Greater redhorse	*Moxostoma valenciennesi*	Y	1998	46	46
Black bullhead	*Ameiurus melas*	Y	2000	640	640
Brown trout	*Salmo trutta*	Y	2002	518	519
Brook stickleback	*Culaea inconstans*	A	2000	43	54
		Y	1998	175	179
Rock bass	*Ambloplites rupestris*	A	2002	196	210
Green sunfish	*Lepomis cyanellus*	A	2002	159	166
		Y	2002	151	155
Orangespotted sunfish	*Lepomis humilis*	Y	2000	93	93
Bluegill sunfish	*Lepomis macrochirus*	J	2002	1077	1144
		Y	2002	179	247
Smallmouth bass	*Micropterus dolomieu*	FI	2002	333	415
		FR	2002	130	170
Black crappie	*Pomoxis nigromaculatus*	Y	1998	139	159
Johnny darter	*Etheostoma nigrum*	Y	2002	2206	2519
Larval fish		Y	2005	2604	2604

Table 5. Species-life stages that prefer medium pools (depth 60 - 149 cm and velocity < 30 cm/s). Date is the date the HSC was developed, N1 equals the number of fish observations the curve is based on and N2 equals the total of fish observations to date. Life stages are adult (A), juvenile (J), spawning (S), and young-of-year (Y).

Common Name	Scientific Name	Life stage	Date	N1	N2
Gizzard shad	*Dorosoma cepedianum*	A	3/98	110	112
Common carp	*Cyprinus carpio*	A	6/02	249	303
		J	6/02	77	88
		Y	6/02	195	198
Common shiner	*Luxilus cornutus*	A	4/02	3812	3987
Topeka shiner	*Notropis topeka*	A	1/00	57	57
		S	1/00	10	10
Fathead minnow	*Pimephales promelas*	A	6/02	3265	3583
Quillback	*Carpiodes cyprinus*	A	12/03	44	48
White sucker	*Catostomus commersonii*	A	4/02	151	172
Silver redhorse	*Moxostoma anisurum*	A	4/02	108	164
Golden redhorse	*Moxostoma erythrurum*	J	4/02	88	114
Greater redhorse	*Moxostoma valenciennesi*	J	4/05	136	136
Channel catfish	*Ictalurus punctatus*	J	1/01	231	383
Tadpole madtom	*Noturus gyrinus*	Y	6/02	54	54
Northern pike	*Esox lucius*	A	4/02	43	48
Muskellunge	*Esox masquinongy*	S	3/98	33	33
Rock bass	*Ambloplites rupestris*	Y	4/02	126	130
Orangespotted sunfish	*Lepomis humilis*	A	6/02	991	998
		S	1/00	11	11
Smallmouth bass	*Micropterus dolomieu*	S	6/02	178	178
Largemouth bass	*Micropterus salmoides*	J	1/00	67	68
Black crappie	*Pomoxis nigromaculatus*	J	3/98	152	162
Walleye	*Sander vitreus*	J	4/02	55	71
		Y	4/02	38	38
Freshwater drum	*Aplodinotus grunniens*	Y	1/00	86	90
Spike	*Elliptio dilatata*	A	1/95	29	29
Fluted shell	*Lasmigona costata*	A	1/95	78	78

Table 6. Species-life stages that prefer deep pools (depth >= 150 cm). Date is the date the HSC was developed, N1 equals the number of fish observations the curve is based on and N2 equals the total of fish observations to date. Life stages are adult (A), juvenile (J), spawning (S), and young-of-year (Y).

Common Name	Scientific Name	Life stage	Date	N1	N2
Lake sturgeon	*Acipenser fulvescens*	A	11/97	5	5
Blacknose shiner	*Notropis heterolepis*	A	3/98	493	495
Golden redhorse	*Moxostoma erythrurum*	A	4/05	217	217
Channel catfish	*Ictalurus punctatus*	A	1/01	30	42
Bluegill sunfish	*Lepomis macrochirus*	A	6/02	106	107
Largemouth bass	*Micropterus salmoides*	Y	6/02	166	173
Black crappie	*Pomoxis nigromaculatus*	A	6/02	36	36
Yellow perch	*Perca flavescens*	A	4/02	69	69
		J	4/02	306	306
Walleye	*Sander vitreus*	A	4/98	27	30

Table 7. Species-life stages that prefer raceways (depth 60 - 149 cm and velocity >= 30 cm/s). Date is the date the HSC was developed, N1 equals the number of fish observations the curve is based on and N2 equals the total of fish observations to date. Life stages are adult (A), juvenile (J), spawning (S), and young-of-year (Y).

Common Name	Scientific Name	Life stage	Date	N1	N2
Lake sturgeon	*Acipenser fulvascens*	S	1/96	54	54
Hornyhead chub	*Nocomis biguttatus*	A	3/98	339	358
Northern hogsucker	*Hypentelium nigricans*	A	4/02	476	517
Shorthead redhorse	*Moxostoma macrolepidotum*	A	4/02	1028	1221
		J	4/02	460	508
Greater redhorse	*Moxostoma valenciennesi*	A	4/05	100	100
Channel catfish	*Ictalurus punctatus*	Y	4/02	152	164
Smallmouth bass	*Micropterus dolomieu*	A	4/02	141	203
Brown trout	*Salmo trutta*	A	4/02	134	144
		J	4/05	245	245
Logperch	*Percina caprodes*	S	6/02	16	16
Walleye	*Sander vitreus*	S	6/02	217	217
Threeridge	*Amblema plicata*	A	1/95	637	637
Wabash pigtoe	*Fusconaia flava*	A	1/95	546	546
Creeper	*Strophitus undulatus*	A	1/95	44	44
Mucket	*Actinonaias ligamentina*	A	1/95	251	251
Black sandshell	*Ligumia recta*	A	1/95	40	40
Fat mucket	*Lampsilis siliquoidea*	A	1/95	218	218

Table 8. Species-life stages that prefer slow riffles (depth <60 cm and velocity 30-59 cm/s). Date is the date the HSC was developed, N1 equals the number of fish observations the curve is based on and N2 equals the total of fish observations to date. Life stages are adult (A), juvenile (J), spawning (S), and young-of-year (Y).

Common Name	Scientific Name	Life stage	Date	N1	N2
Gizzard shad	*Dorosoma cepedianum*	Y	1/01	193	197
Central stoneroller	*Campostoma anomalum*	A	4/02	3428	3428
		J	4/02	1084	1085
		S	3/98	39	39
Largescale stoneroller	*Campostoma oligolepis*	A	4/02	348	505
		J	4/02	80	92
		Y	6/02	214	367
Spotfin shiner	*Cyprinella spiloptera*	A	4/02	10473	13279
		S	4/02	248	252
		Y	4/02	2821	3000
Common shiner	*Luxilus cornutus*	J	4/02	3583	3745
		S	1/00	25	25
		Y	4/02	2091	2409
Hornyhead chub	*Nocomis biguttatus*	J	4/02	849	875
River shiner	*Notropis blennius*	A	4/02	1991	2000
Bigmouth shiner	*Notropis dorsalis*	Y	4/02	127	131
Blacknose shiner	*Notropis heterolepis*	Y	4/02	722	722
Spottail shiner	*Notropis hudsonius*	A	3/98	461	900
		Y	1/01	2361	2664
Sand shiner	*Notropis stramineus*	S	4/02	72	72
		Y	4/02	2619	2834
Mimic shiner	*Notropis volucellus*	Y	1/00	60	149
Bluntnose minnow	*Pimephales notatus*	A	4/02	3669	4052
Eastern blacknose	*Rhinichthys atratulus*	A	3/98	1836	2069
		Y	4/05	172	172
Longnose dace	*Rhinichthys cataractae*	S	1/96	25	25
Creek chub	*Semotilus atromaculatus*	A	4/05	1304	1304
		J	4/02	571	678
White sucker	*Catostomus commersonii*	J	4/02	3046	3183
		Y	4/02	3223	3766
Northern hogsucker	*Hypentelium nigricans*	J	4/02	299	327
		S	3/98	31	31
		Y	4/02	227	246
Silver redhorse	*Moxostoma anisurum*	Y	4/02	267	279
Shorthead redhorse	*Moxostoma macrolepidotum*	Y	4/02	833	922
Greater redhorse	*Moxostoma valenciennesi*	S	3/98	18	18
Black bullhead	*Ameiurus melas*	J	1/00	122	123
Tadpole madtom	*Noturus gyrinus*	A	2/01	79	79
Brown trout	*Salmo trutta*	S	12/97	26	26
White bass	*Morone chrysops*	Y	4/02	106	106
Smallmouth bass	*Micropterus dolomieu*	J	4/02	384	432
Rainbow darter	*Etheostoma caeruleum*	Y	4/02	127	138
Iowa darter	*Etheostoma exile*	A	3/98	62	77
Fantail darter	*Etheostoma flabellare*	Y	6/02	249	278
Johnny darter	*Etheostoma nigrum*	A	4/02	444	474
Logperch	*Percina caprodes*	Y	5/97	146	149
Blackside darter	*Percina maculata*	A	1/01	97	110
		Y	4/02	461	524
Plain pocketbook	*Lampsilis cardium*	A	1/95	30	30

Table 9. Species-life stages that prefer fast riffles (depth <60 cm and velocity >= 60 cm/s). Year is the year the HSC was developed, N1 equals the number of fish observations the curve is based on; and N2 equals the total of fish observations to date. Life stages are adult (A), juvenile (J), spawning (S), and young-of-year (Y).

Common Name	Scientific Name	Life stage	Year	N1	N2
Central stoneroller	*Campostoma anomalum*	Y	2002	2211	2228
Longnose dace	*Rhinichthys cataractae*	A	2005	1928	1928
Golden redhorse	*Moxostoma erythrurum*	Y	2002	870	1084
Shorthead redhorse	*Moxostoma macrolepidotum*	S	2001	170	170
Stonecat	*Noturus flavus*	A	2005	75	75
		J	2005	100	100
		Y	2005	196	196
Rainbow darter	*Etheostoma caeruleum*	A	2002	429	446
		S	1998	55	55
Fantail darter	*Etheostoma flabellare*	A	2002	421	443
		S	2000	12	12
Banded darter	*Etheostoma zonale*	A	2002	1801	1900
		S	1998	59	59
		Y	2002	314	358
Yellow perch	*Perca flavescens*	Y	2002	388	389
Logperch	*Percina caprodes*	A	2000	1756	1807
Slenderhead darter	*Percina phoxocephala*	A	2005	1273	1273
		S	1998	62	63
		Y	2005	94	94

Table 10. Lists the figures for each species-life stage.

Species-life stage	Figure		Species-life stage	Figure
Banded darter adult	4		Channel catfish juvenile	35
Banded darter spawning	5		Channel catfish young-of-year	36
Banded darter young-of-year	6		Common carp adult	37
Bigmouth shiner adult	7		Common carp juvenile	38
Bigmouth shiner young-of-year	8		Common carp young-of-year	39
Black bullhead juvenile	9		Common shiner adult	40
Black bullhead young-of-year	10		Common shiner juvenile	41
Black crappie adult	11		Common shiner spawning	42
Black crappie juvenile	12		Common shiner young-of-year	43
Black crappie young-of –year	13		Creek chub adult	44
Blacknose shiner adult	14		Creek chub juvenile	45
Blacknose shiner young-of-year	15		Creek chub young-of-year	46
Blackside darter adult	16		Eastern blacknose dace adult	47
Blackside darter young-of-year	17		Eastern blacknose dace young-of -year	48
Bluegill adult	18		Emerald shiner adult	49
Bluegill juvenile	19		Emerald shiner young-of-year	50
Bluegill young-of –year	20		Fantail darter adult	51
Bluntnose minnow adult	21		Fantail darter spawning	52
Bluntnose minnow young-of-year	22		Fantail darter young-of-year	53
Brassy minnow adult	23		Fathead minnow adult	54
Brook stickleback adult	24		Fathead minnow spawning	55
Brook stickleback young-of-year	25		Fathead minnow young-of-year	56
Brown trout adult	26		Freshwater drum young-of-year	57
Brown trout juvenile	27		Gizzard shad adult	58
Brown trout spawning	28		Gizzard shad young-of-year	59
Brown trout young-of-year	29		Golden redhorse adult	60
Central stoneroller adult	30		Golden redhorse juvenile	61
Central stoneroller juvenile	31		Golden redhorse young-of-year	62
Central stoneroller spawning	32		Greater redhorse adult	63
Central stoneroller young-of-year	33		Greater redhorse juvenile	64
Channel catfish adult	34		Greater redhorse spawning	65
Greater redhorse young-of-year	66		Orangespotted sunfish adult	98
Green sunfish adult	67		Orangespotted sunfish spawning	99
Green sunfish young-of-year	68		Orangespotted sunfish young-of-year	100
Hornyhead chub adult	69		Quillback adult	101
Hornyhead chub juvenile	70		Quillback young-of-year	102
Hornyhead chub spawning	71		Rainbow darter adult	103
Hornyhead chub young-of-year	72		Rainbow darter spawning	104
Iowa darter adult	73		Rainbow darter young-of-year	105
Johnny darter adult	74		River carpsucker young-of-year	106
Johnny darter young-of-year	75		River shiner adult	107
Lake sturgeon adult	76		River shiner young-of-year	108

Species-life stage	Figure		Species-life stage	Figure
Lake sturgeon spawning	77		Rock bass adult	109
Largemouth bass juvenile	78		Rock bass young-of-year	110
Largemouth bass young-of-year	79		Sand shiner adult	111
Largescale stoneroller adult	80		Sand shiner spawning	112
Largescale stoneroller juvenile	81		Sand shiner young-of-year	113
Largescale stoneroller young-of-year	82		Shorthead redhorse adult	114
Larval fish	83		Shorthead redhorse juvenile	115
Logperch adult	84		Shorthead redhorse spawning	116
Logperch spawning	85		Shorthead redhorse young-of-year	117
Logperch young-of-year	86		Silver redhorse adult	118
Longnose dace adult	87		Silver redhorse young-of-year	119
Longnose dace spawning	88		Slenderhead darter adult	120
Longnose dace young-of-year	89		Slenderhead darter spawning	121
Mimic shiner adult	90		Slenderhead darter young-of-year	122
Mimic shiner young-of-year	91		Smallmouth bass adult	123
Muskellunge spawning	92		Smallmouth bass fingerling	124
Northern hogsucker adult	93		Smallmouth bass fry	125
Northern hogsucker juvenile	94		Smallmouth bass juvenile	126
Northern hogsucker spawning	95		Smallmouth bass spawning	127
Northern hogsucker young-of-year	96		Spotfin shiner adult	128
Northern pike adult	97		Spotfin shiner spawning	129
Spotfin shiner young-of-year	130		White sucker adult	145
Spottail shiner adult	131		White sucker juvenile	146
Spottail shiner young-of-year	132		White sucker young-of-year	147
Stonecat adult	133		Yellow perch adult	148
Stonecat juvenile	134		Yellow perch juvenile	149
Stonecat young-of-year	135		Yellow perch young-of-year	150
Tadpole madtom adult	136		Black sandshell	151
Tadpole madtom young-of-year	137		Creeper	152
Topeka shiner adult	138		Fat mucket	153
Topeka shiner spawning	139		Fluted shell	154
Walleye adult	140		Mucket	155
Walleye juvenile	141		Plain pocketbook	156
Walleye spawning	142		Wabash pogtoe	157
Walleye young-of-year	143		Spike	158
White bass young-of-year	144		Threeridge	159

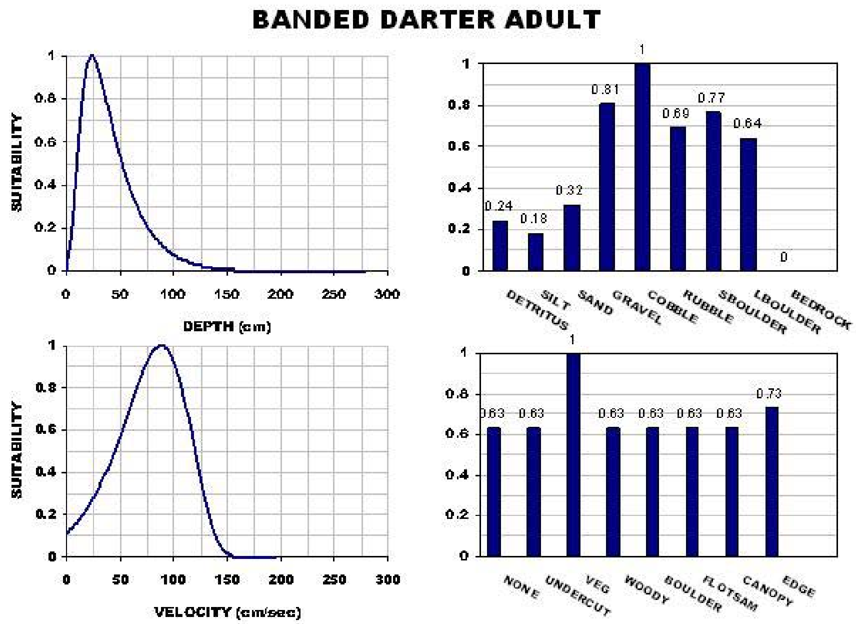

Figure 4. Habitat suitability curves and preference histograms for banded darter adults.

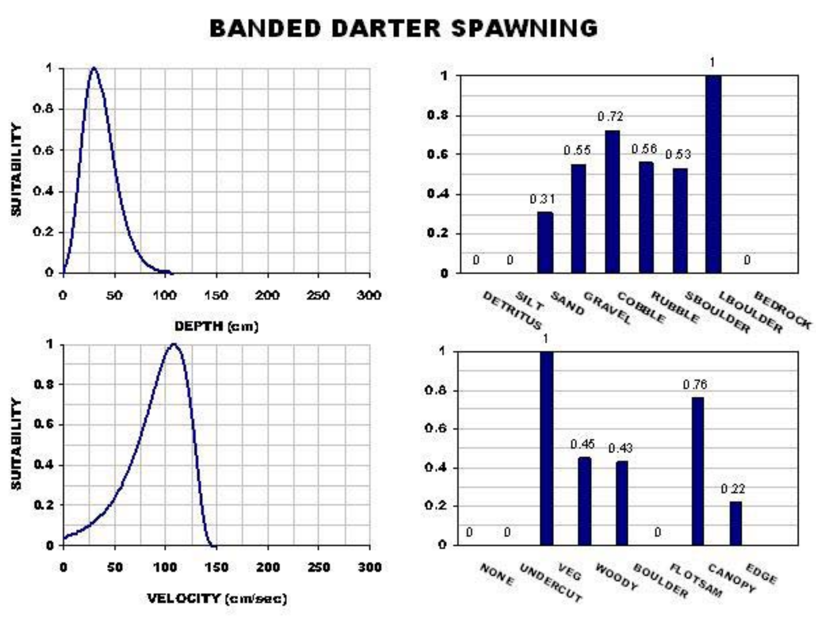

Figure 5. Habitat suitability curves and preference histograms for spawning banded darters.

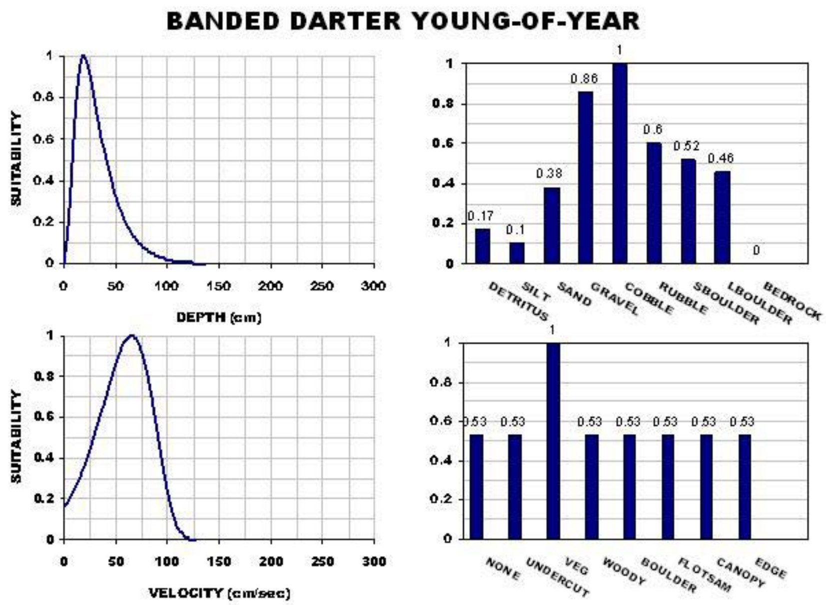

Figure 6. Habitat suitability curves and preference histograms for banded darters young-of-year.

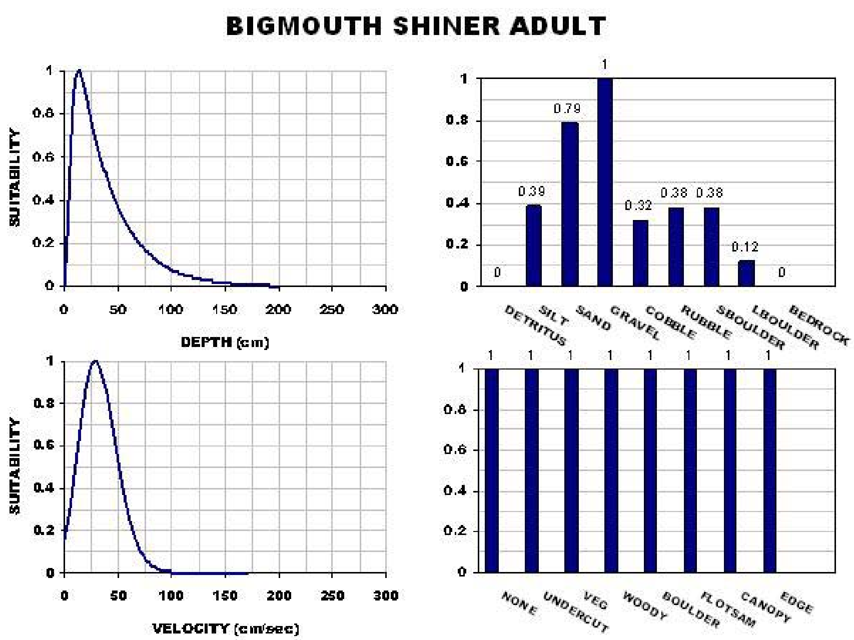

Figure 7. Habitat suitability curves and preference histograms for bigmouth shiner adult.

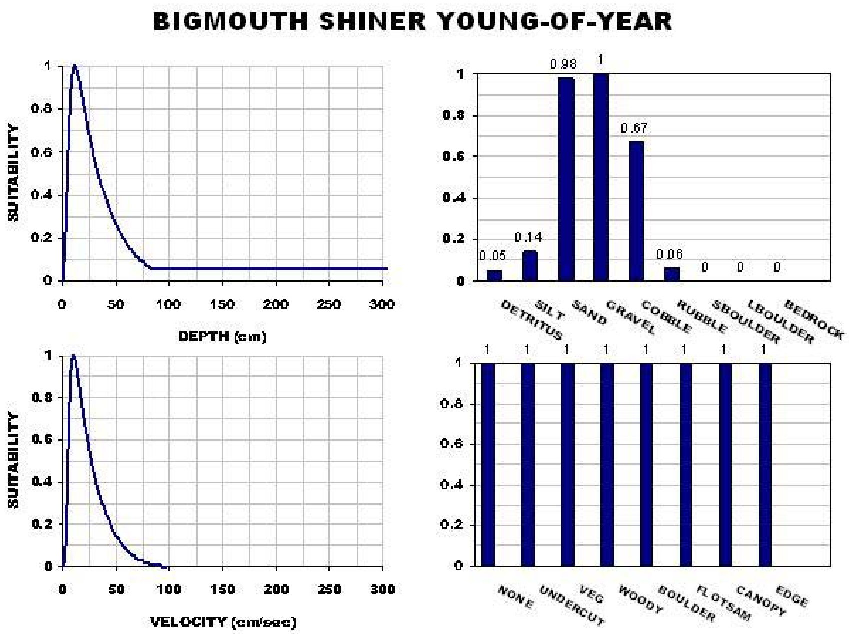

Figure 8. Habitat suitability curves and preference histograms for bigmouth shiner young-of-year.

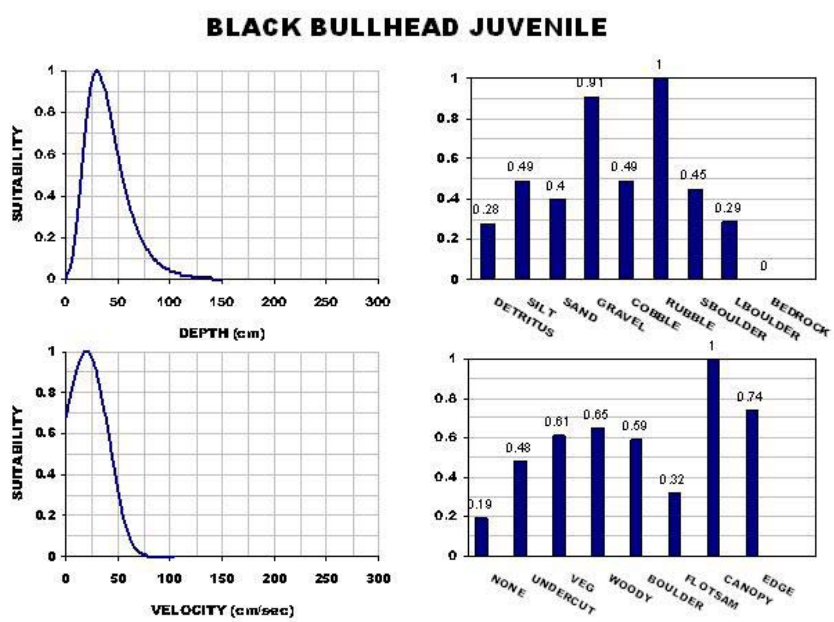

Figure 9. Habitat suitability curves and preference histograms for black bullhead juveniles.

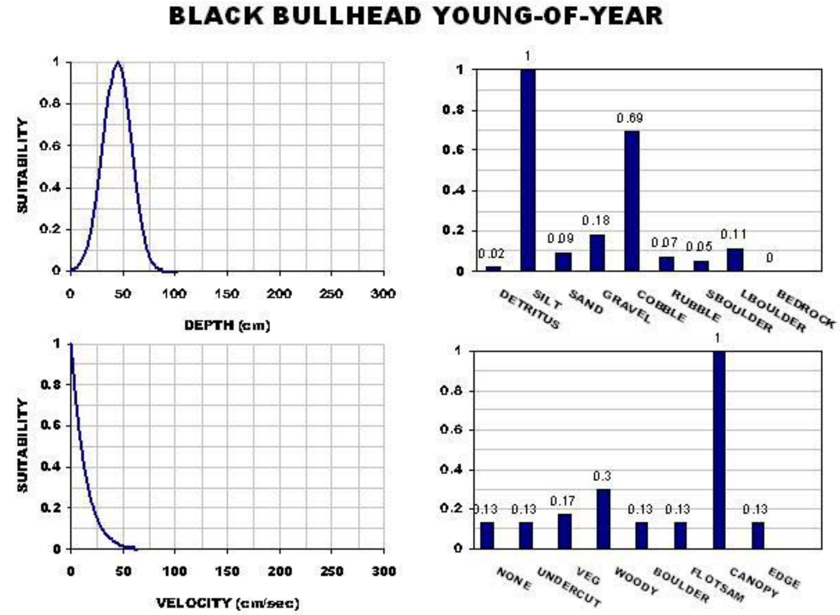

Figure 10. Habitat suitability curves and preference histograms for black bullhead young-of-year.

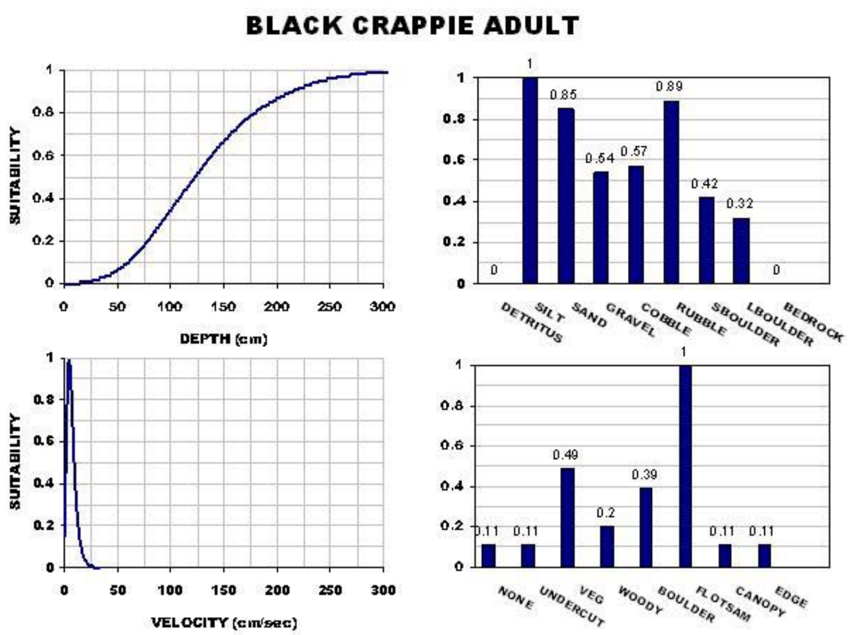

Figure 11. Habitat suitability curves and preference histograms for black crappie adult.

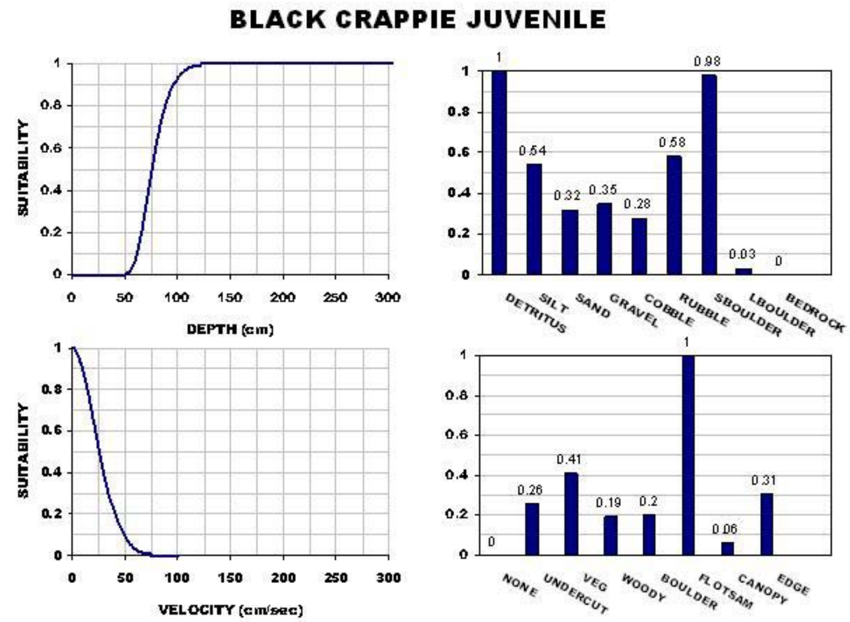

Figure 12. Habitat suitability curves and preference histograms for black crappie juvenile.

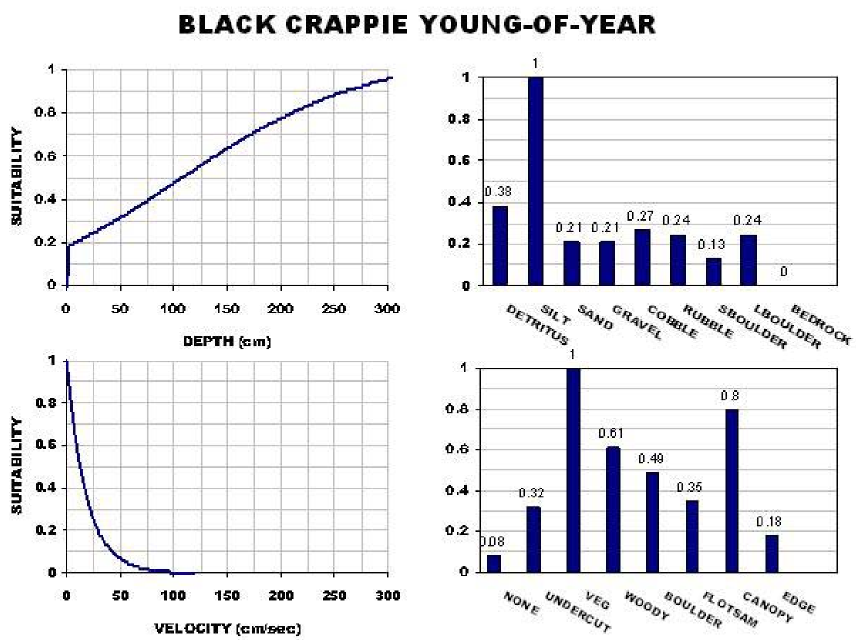

Figure 13. Habitat suitability curves and preference histograms for black crappie young-of-year.

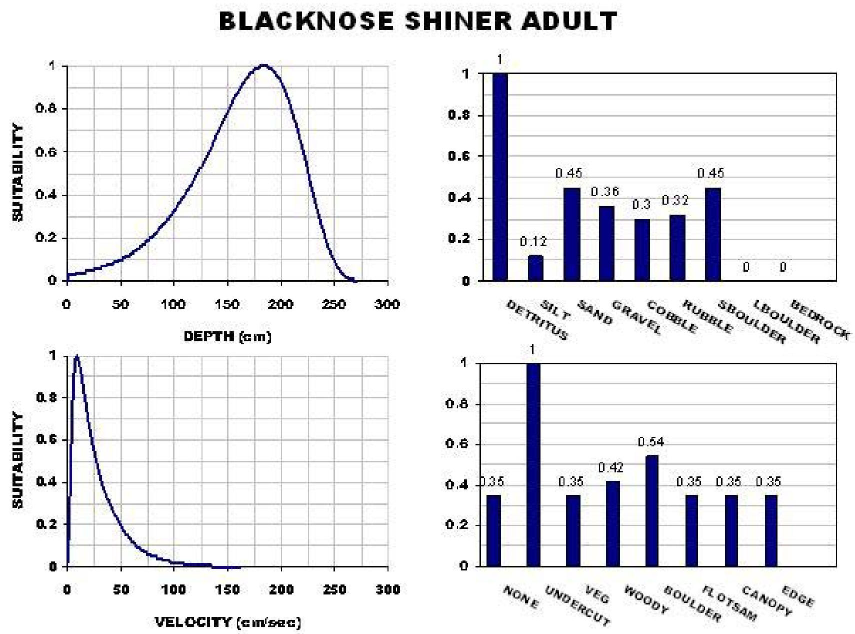

Figure 14. Habitat suitability curves and preference histograms for blacknose shiner adult.

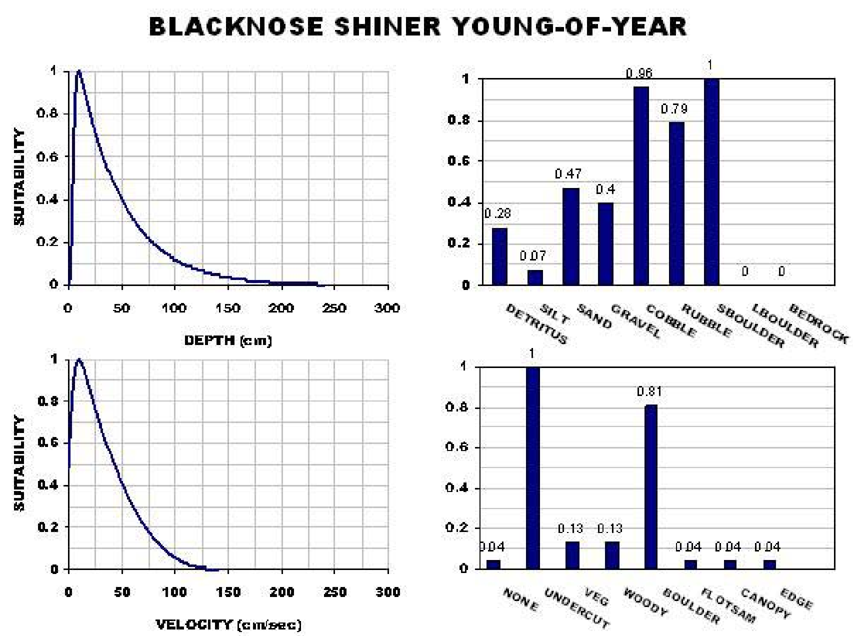

Figure 15. Habitat suitability curves and preference histograms for blacknose shiner young-of-year.

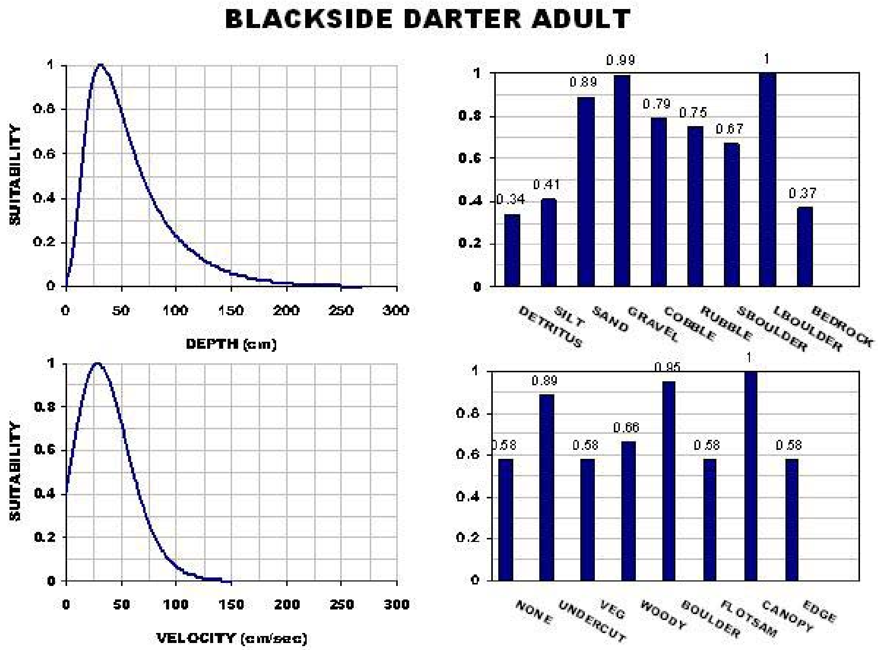

Figure 16. Habitat suitability curves and preference histograms for blackside darter adult.

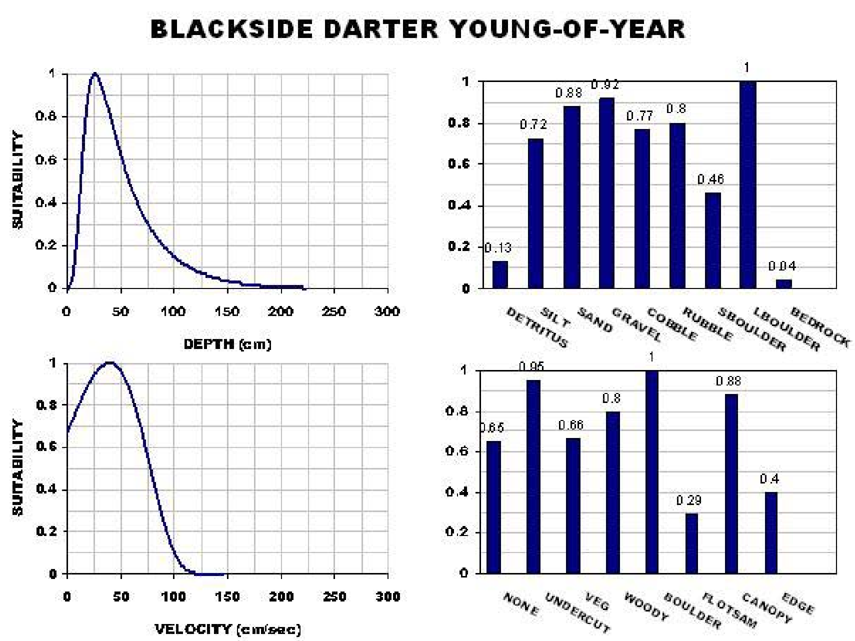

Figure 17. Habitat suitability curves and preference histograms for blackside darter young-of-year.

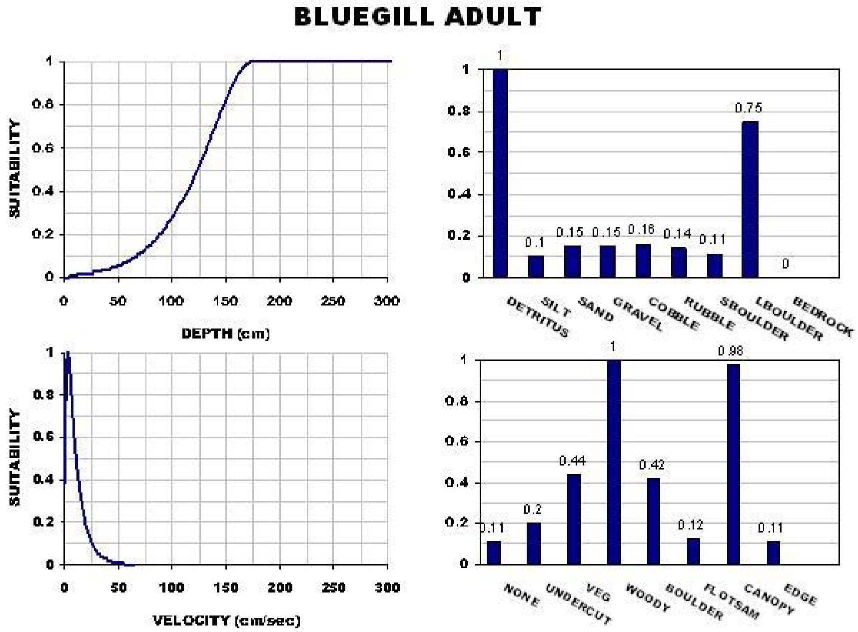

Figure 18. Habitat suitability curves and preference histograms for bluegill adult.

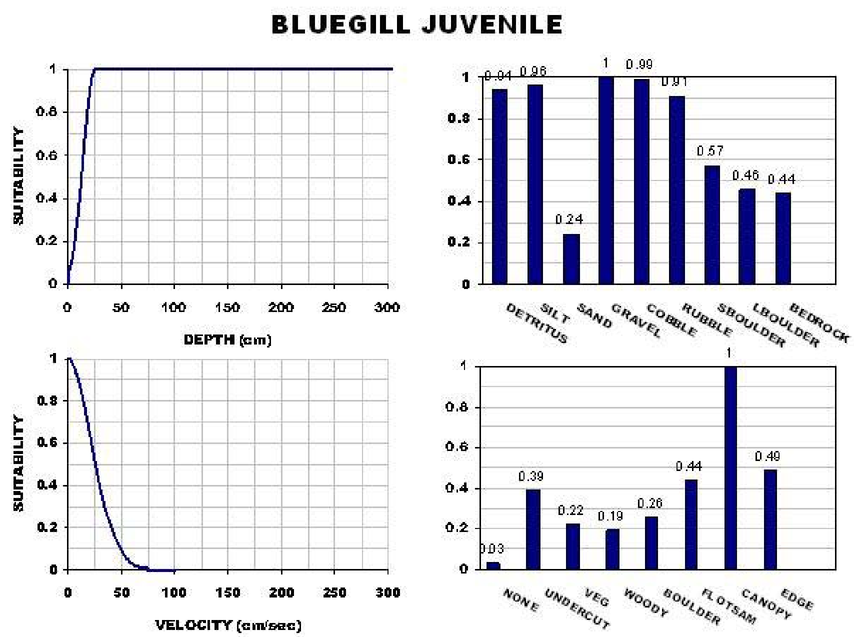

Figure 19. Habitat suitability curves and preference histograms for bluegill juvenile.

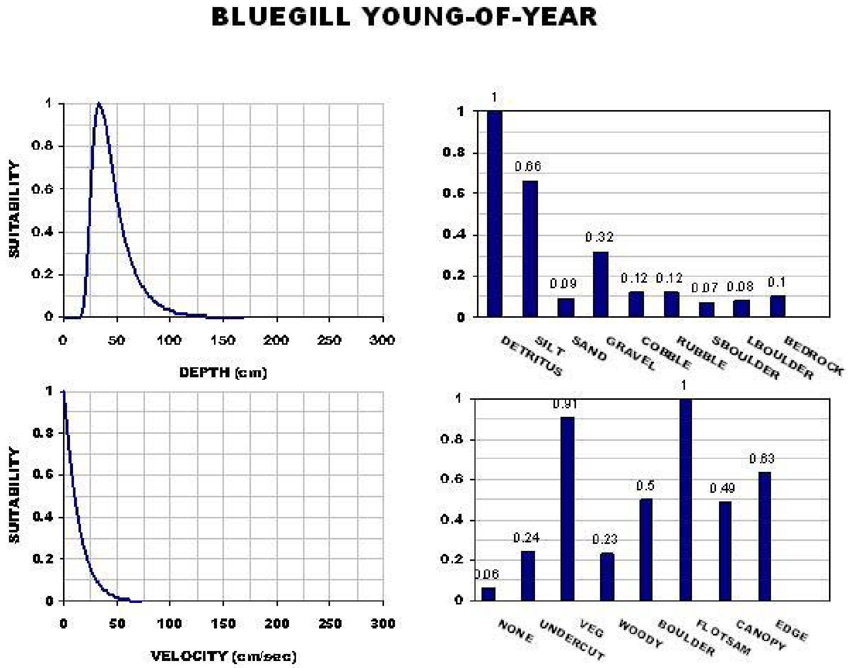

Figure 20. Habitat suitability curves and preference histograms for bluegill young-of-year.

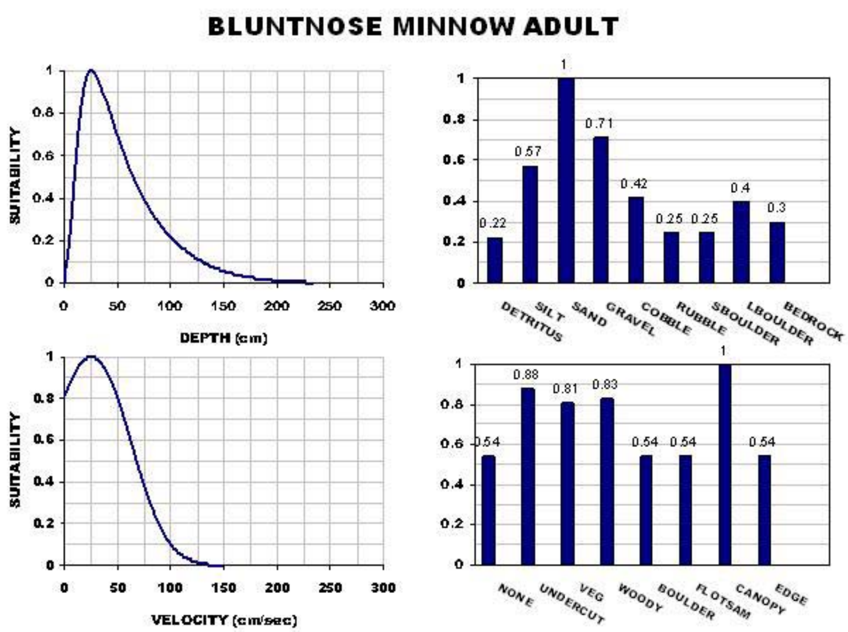

Figure 21. Habitat suitability curves and preference histograms for bluntnose minnow adult.

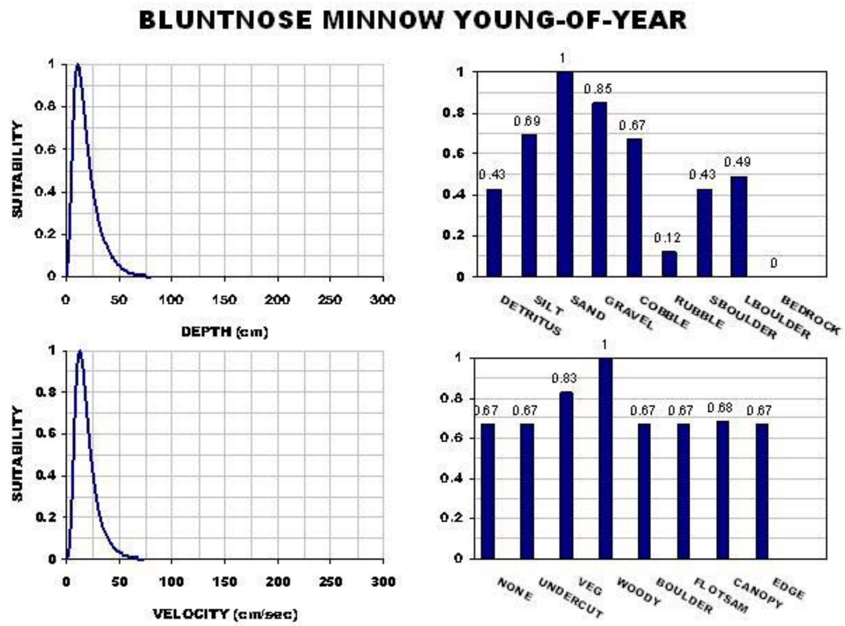

Figure 22. Habitat suitability curves and preference histograms for bluntnose minnow young-of-year.

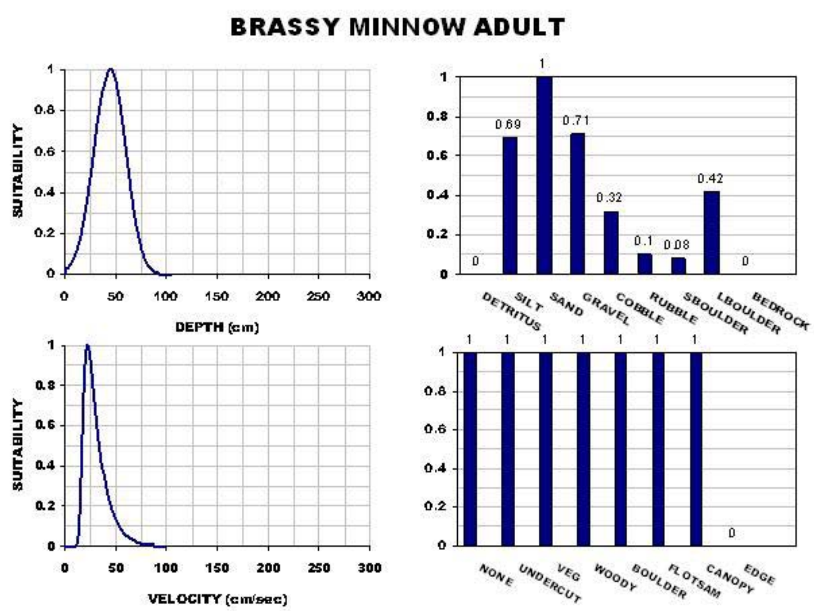

Figure 23. Habitat suitability curves and preference histograms for brassy minnow adult.

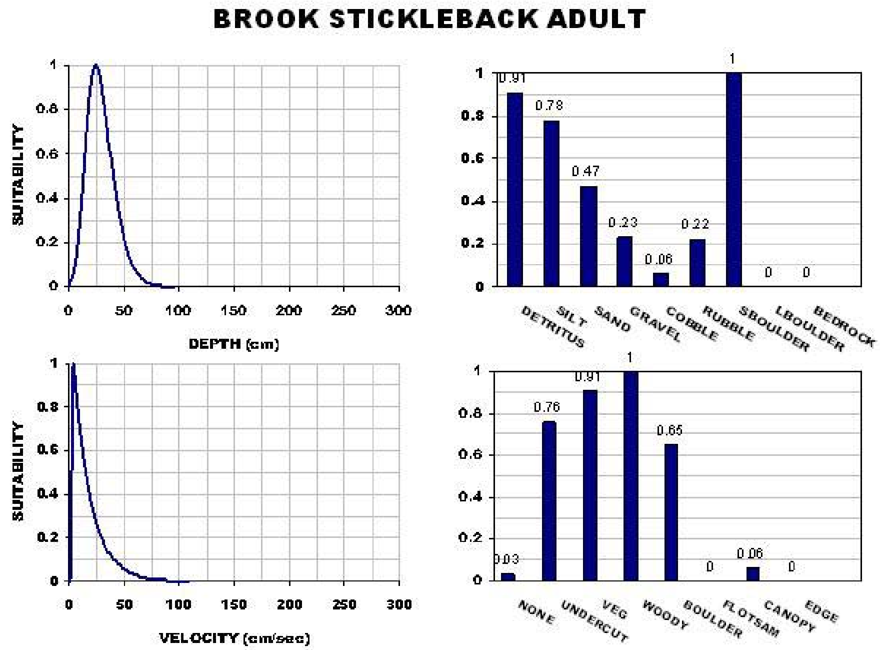

Figure 24. Habitat suitability curves and preference histograms for brook stickleback adult.

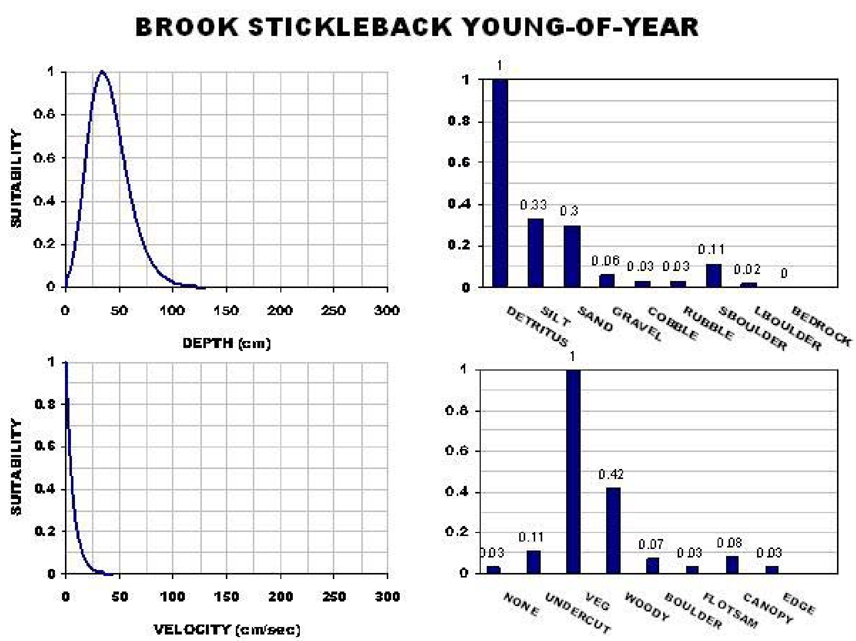

Figure 25. Habitat suitability curves and preference histograms for brook stickleback young-of-year.

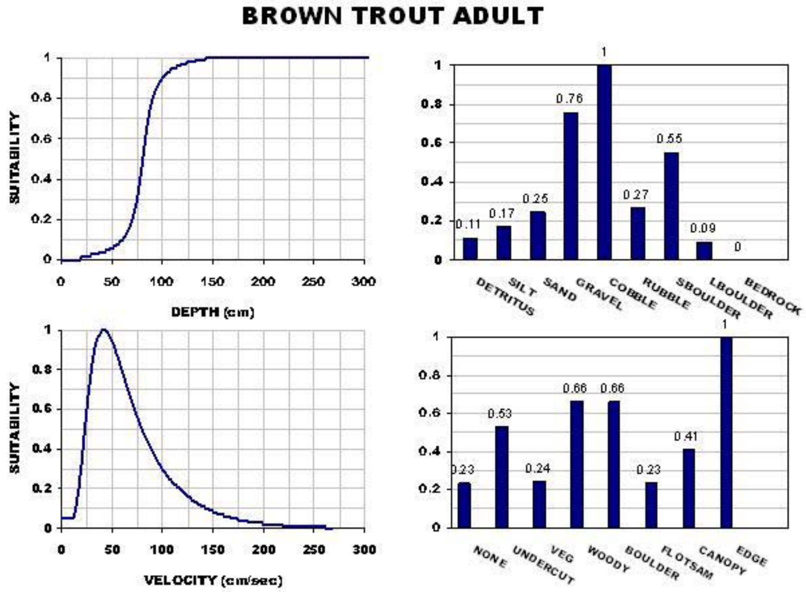

Figure 26. Habitat suitability curves and preference histograms for brown trout adult.

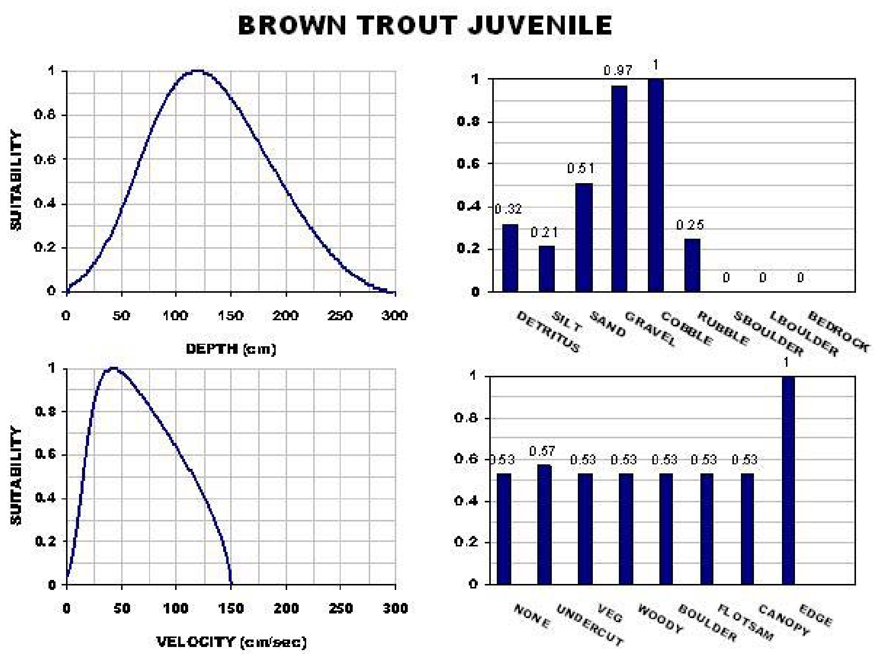

Figure 27. Habitat suitability curves and preference histograms for brown trout juvenile.

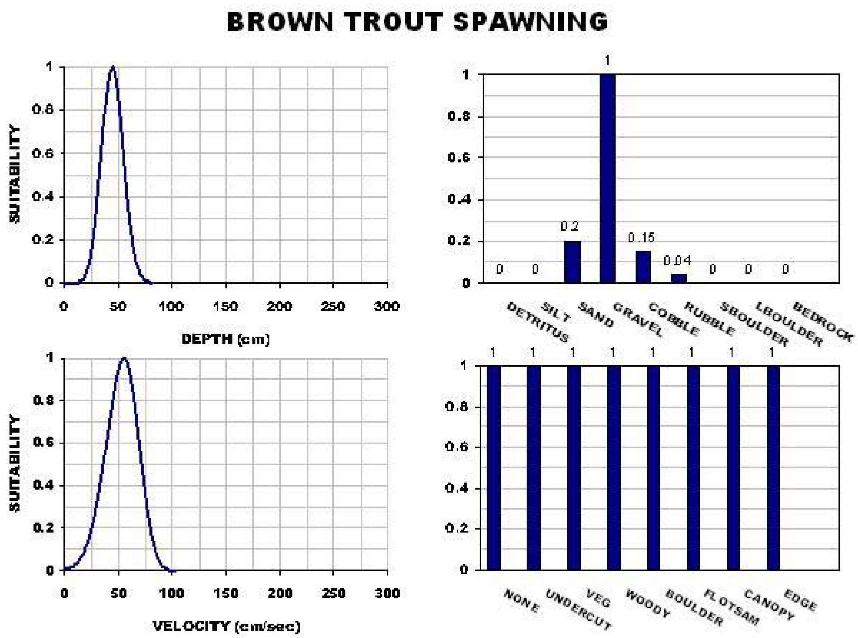

Figure 28. Habitat suitability curves and preference histograms for spawning brown trout.

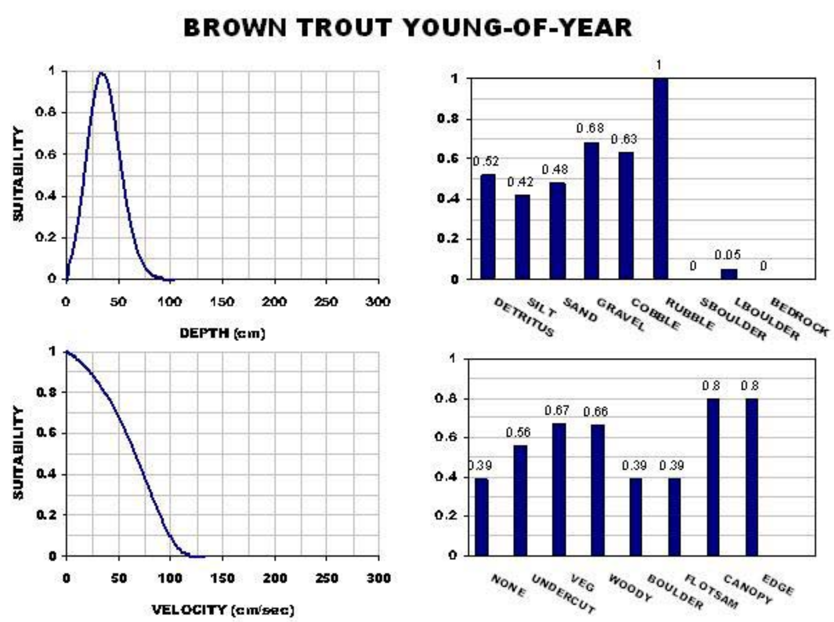

Figure 29. Habitat suitability curves and preference histograms for brown trout young-of-year.

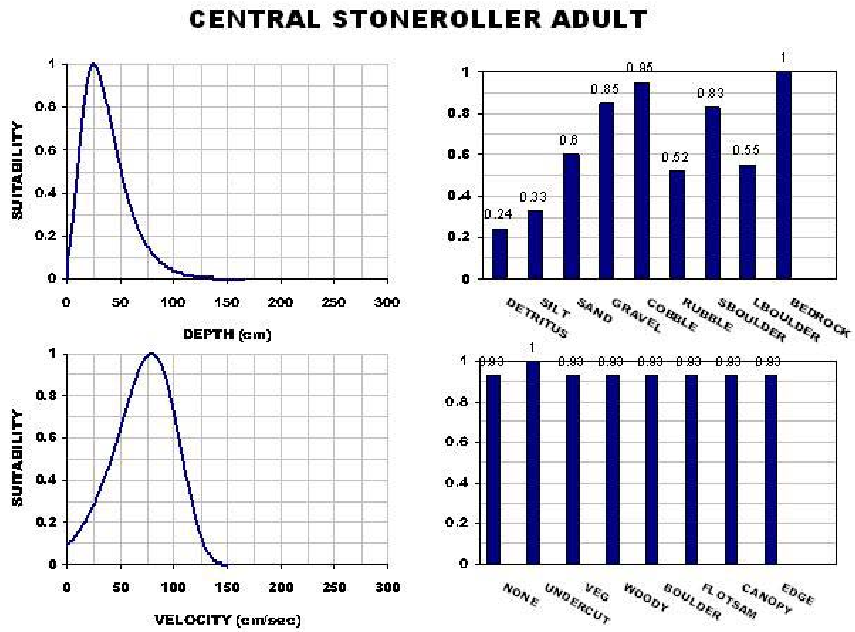

Figure 30. Habitat suitability curves and preference histograms for central stoneroller adult.

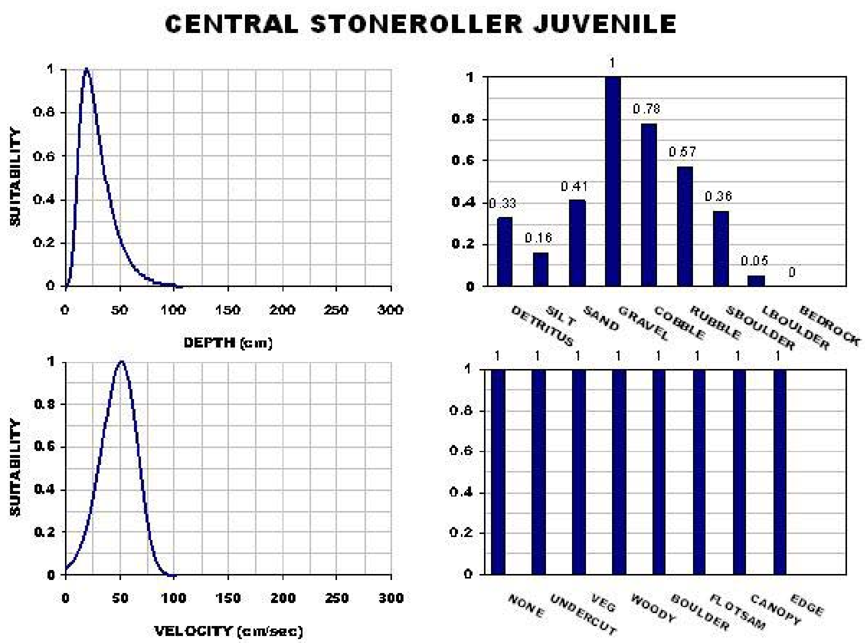

Figure 31. Habitat suitability curves and preference histograms for central stoneroller juvenile.

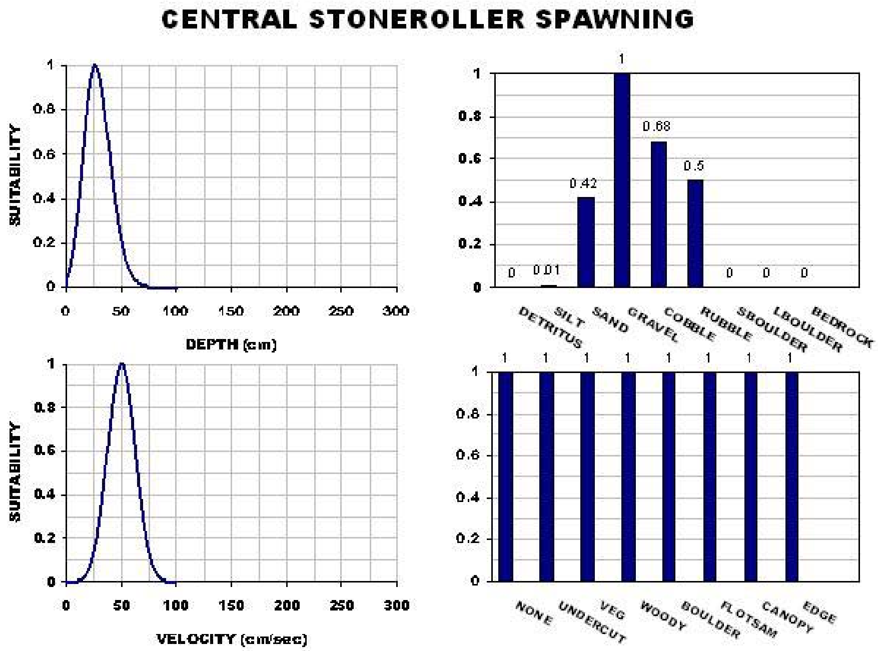

Figure 32. Habitat suitability curves and preference histograms for spawning central stoneroller.

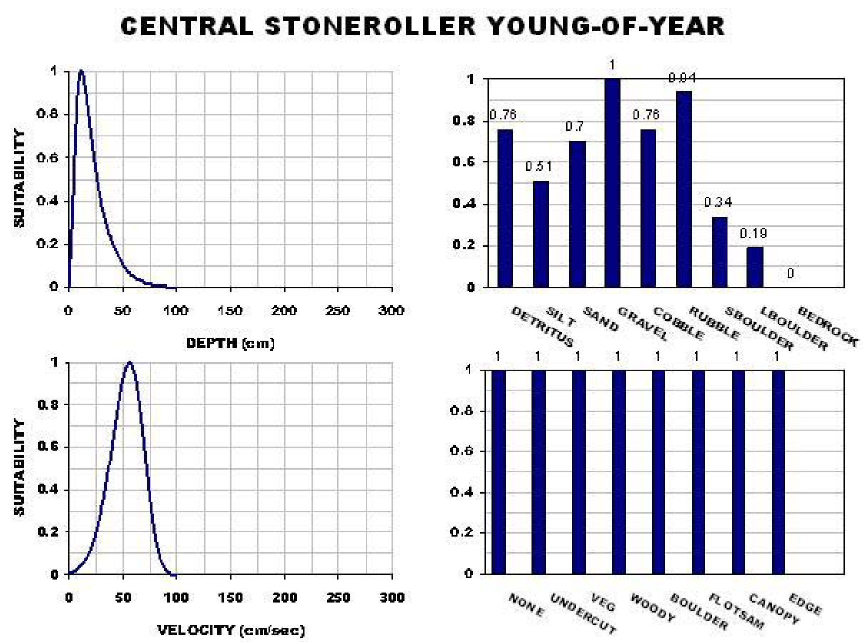

Figure 33. Habitat suitability curves and preference histograms for central stoneroller young-of-year.

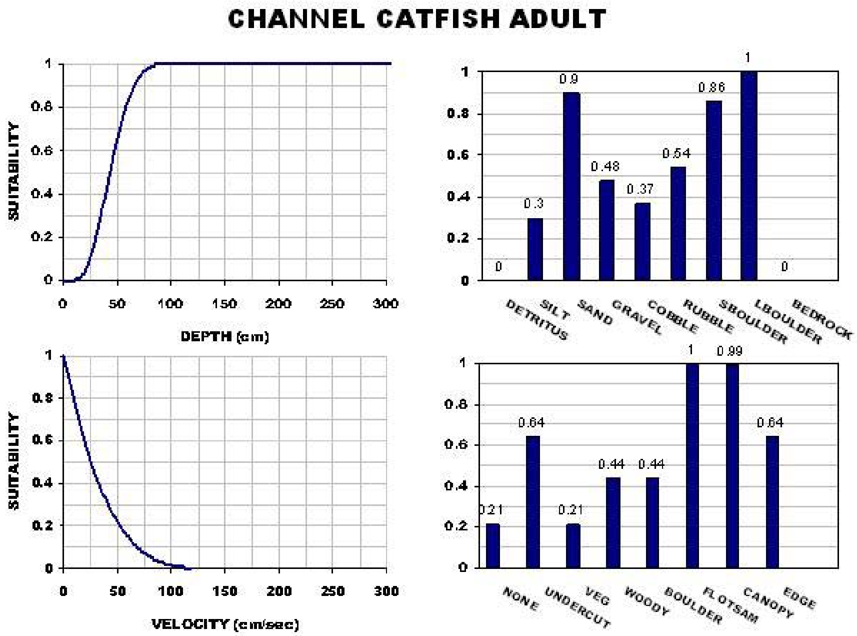

Figure 34. Habitat suitability curves and preference histograms for channel catfish adult.

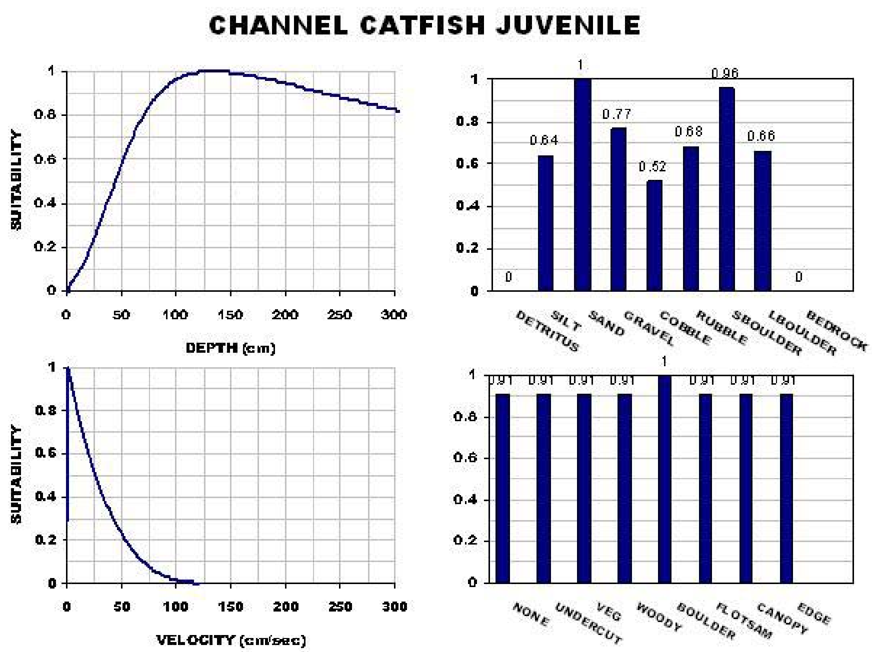

Figure 35. Habitat suitability curves and preference histograms for channel catfish juvenile.

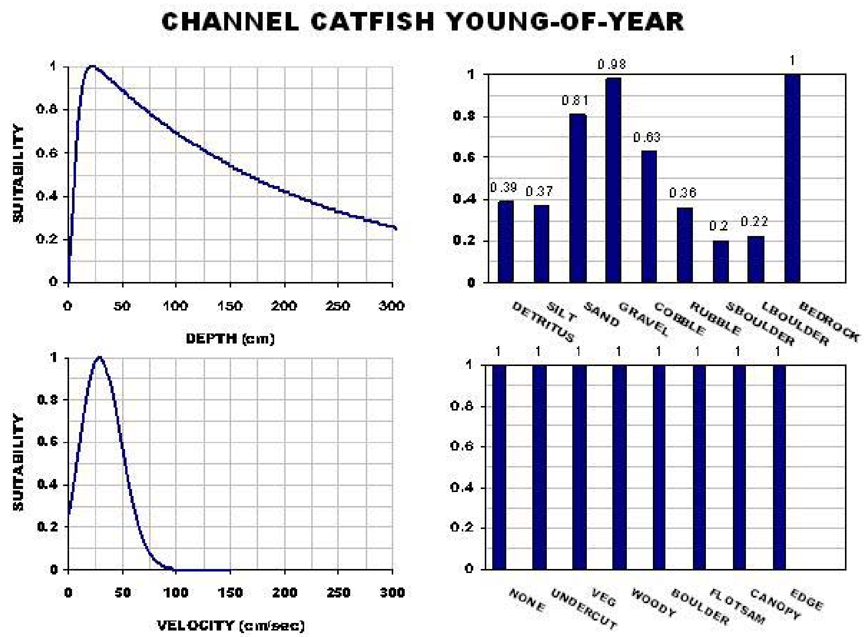

Figure 36. Habitat suitability curves and preference histograms for channel catfish young-of-year.

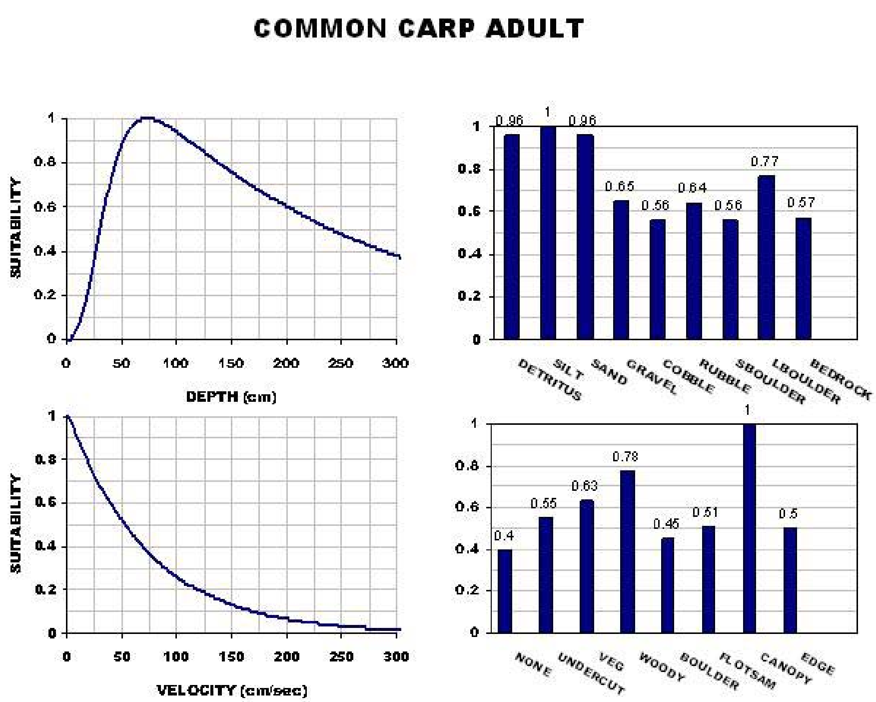

Figure 37. Habitat suitability curves and preference histograms for common carp adult.

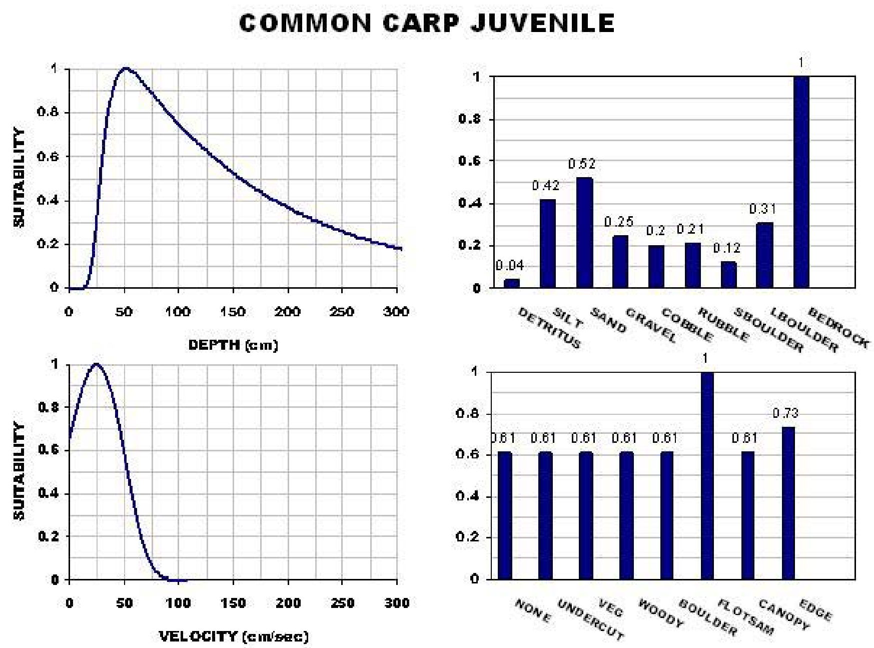

Figure 38. Habitat suitability curves and preference histograms for common carp juvenile.

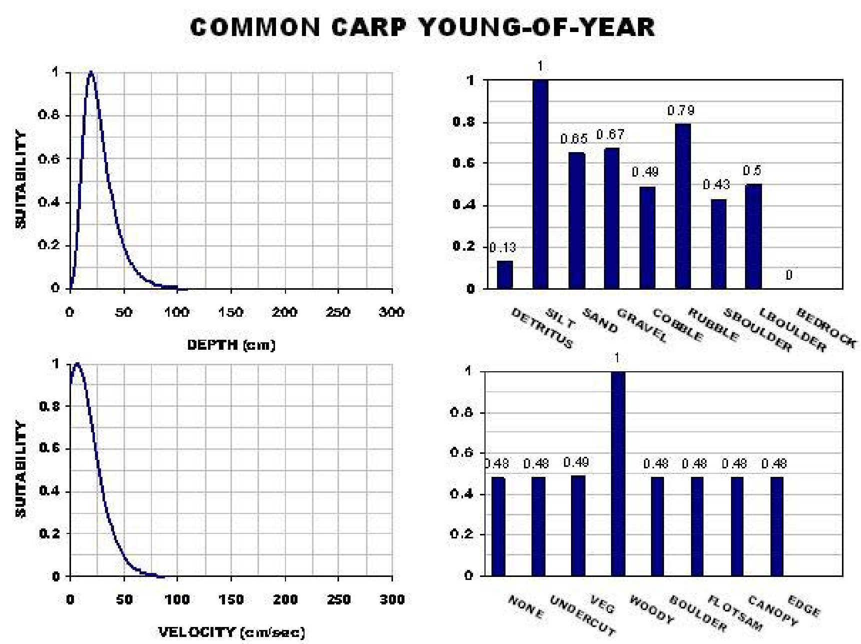

Figure 39. Habitat suitability curves and preference histograms for common carp young-of-year.

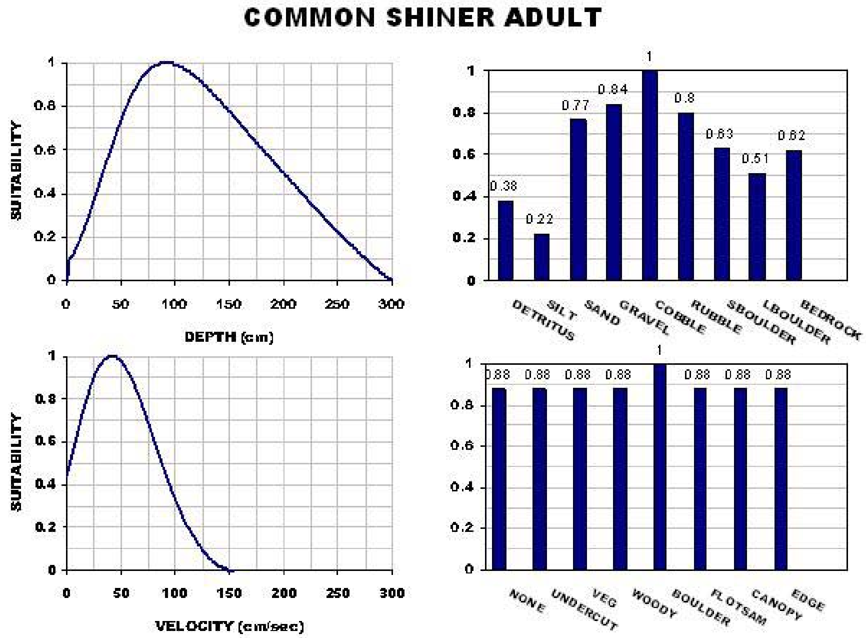

Figure 40. Habitat suitability curves and preference histograms for common shiner adult.

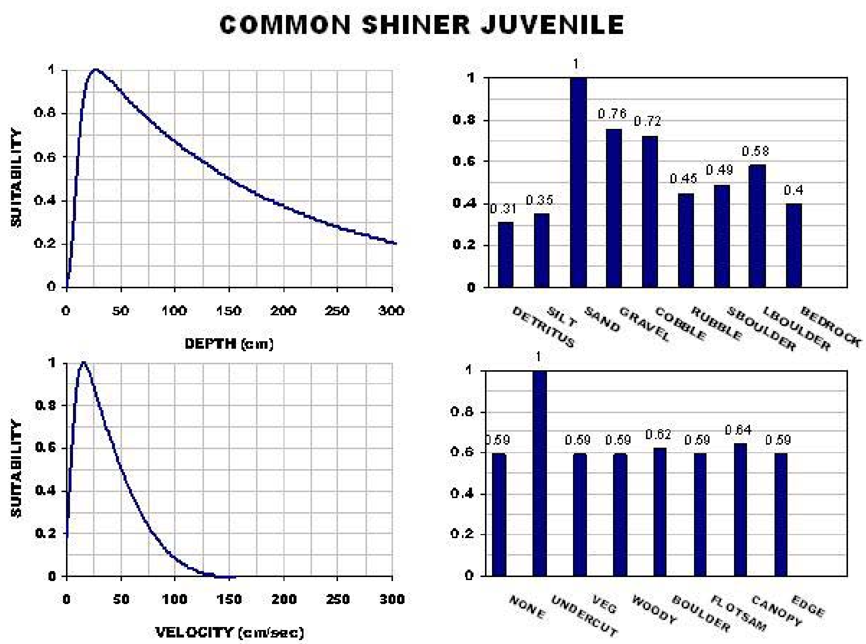

Figure 41. Habitat suitability curves and preference histograms for common shiner juvenile.

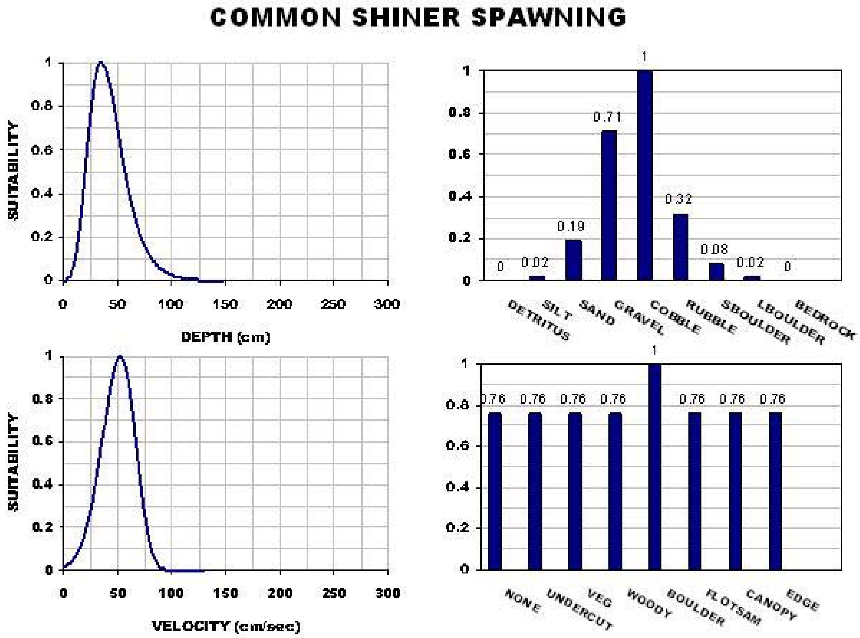

Figure 42. Habitat suitability curves and preference histograms for spawning common shiner.

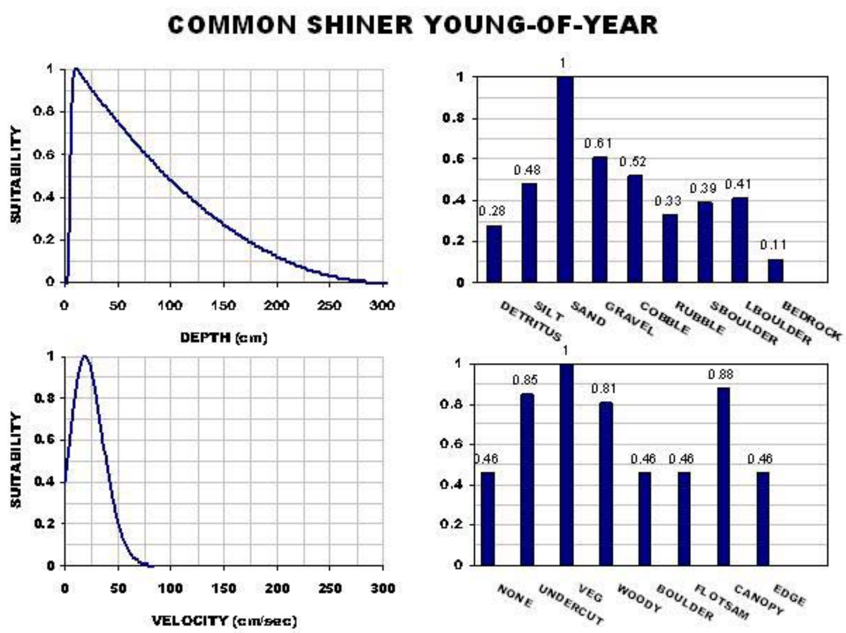

Figure 43. Habitat suitability curves and preference histograms for common shiner young-of-year.

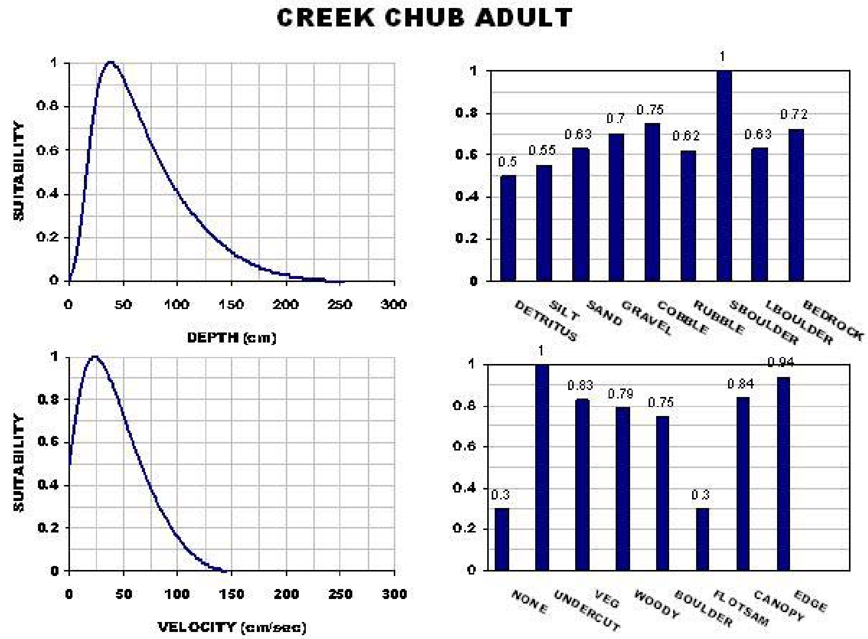

Figure 44. Habitat suitability curves and preference histograms for creek chub adult.

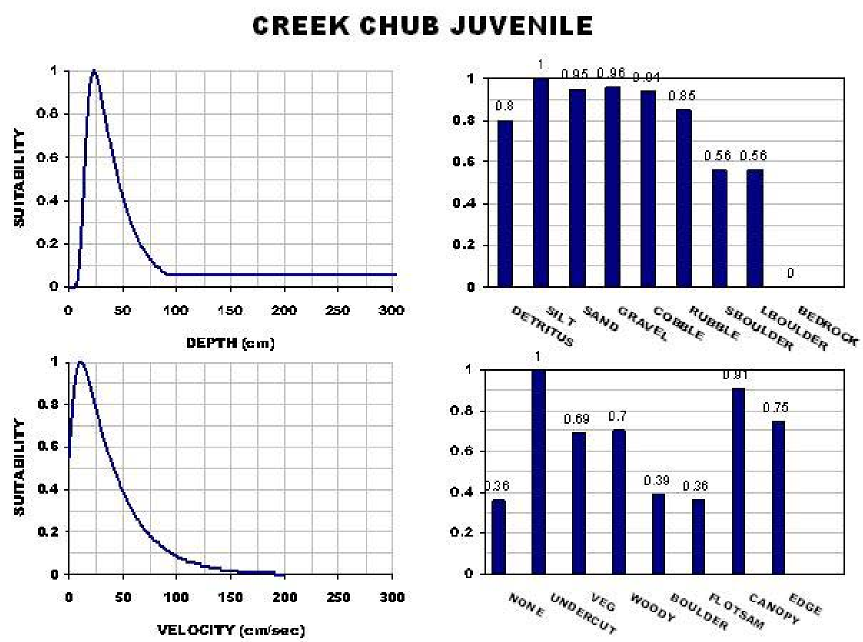

Figure 45. Habitat suitability curves and preference histograms for creek chub juvenile.

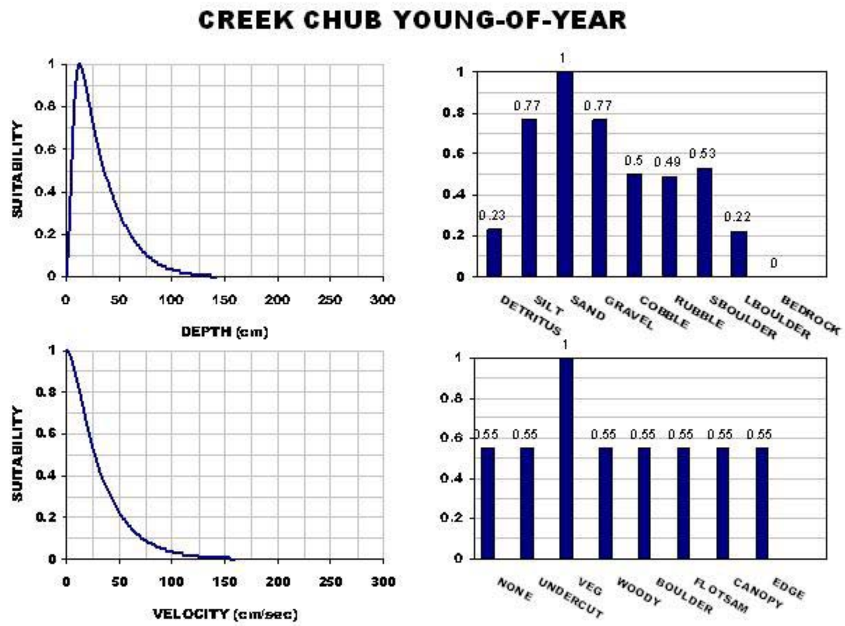

Figure 46. Habitat suitability curves and preference histograms for creek chub young-of-year.

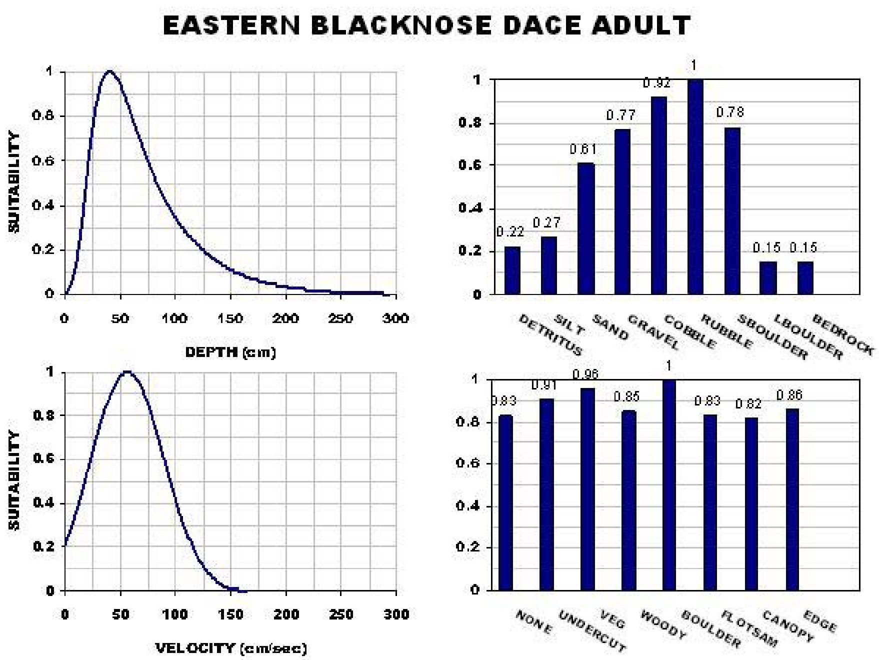

Figure 47. Habitat suitability curves and preference histograms for eastern blacknose dace adult.

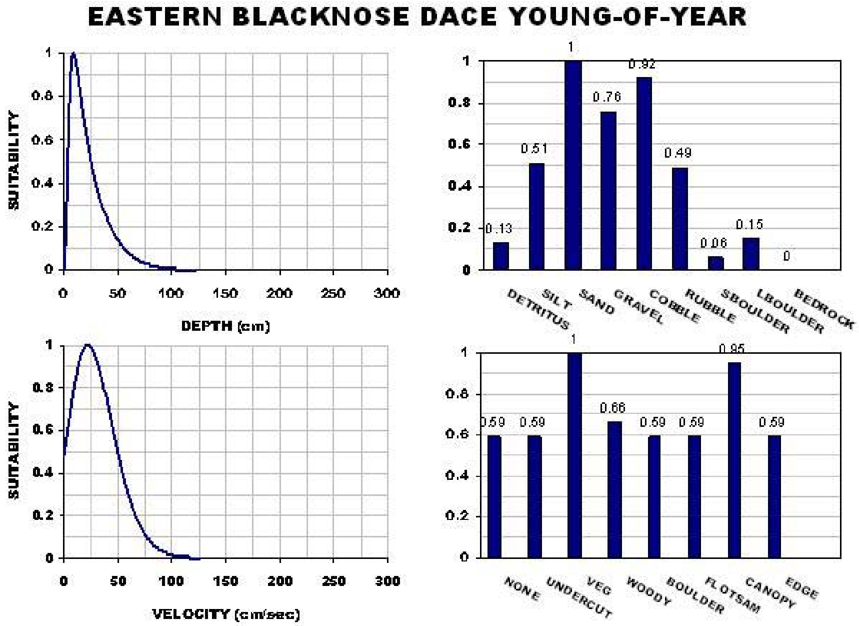

Figure 48. Habitat suitability curves and preference histograms for eastern blacknose dace young-of-year.

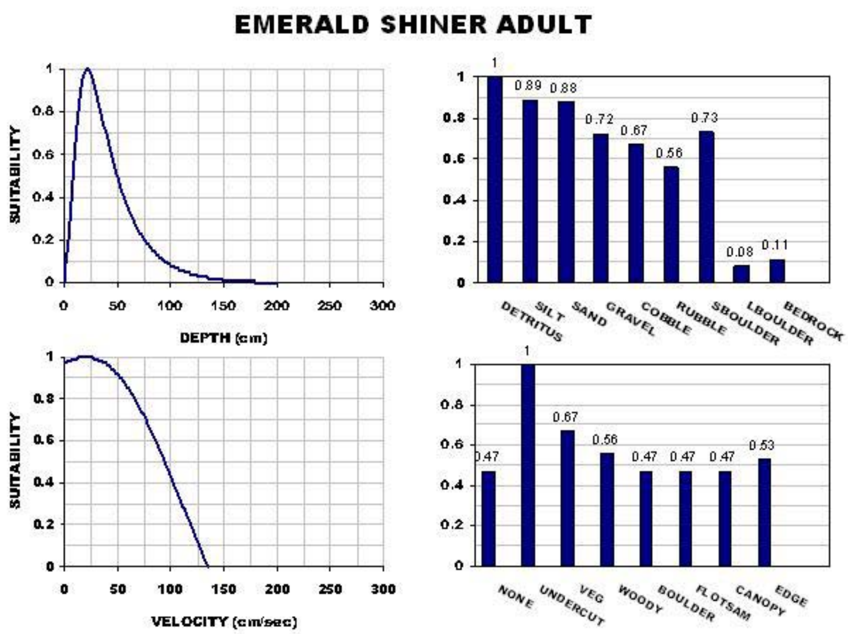

Figure 49. Habitat suitability curves and preference histograms for emerald shiner adult.

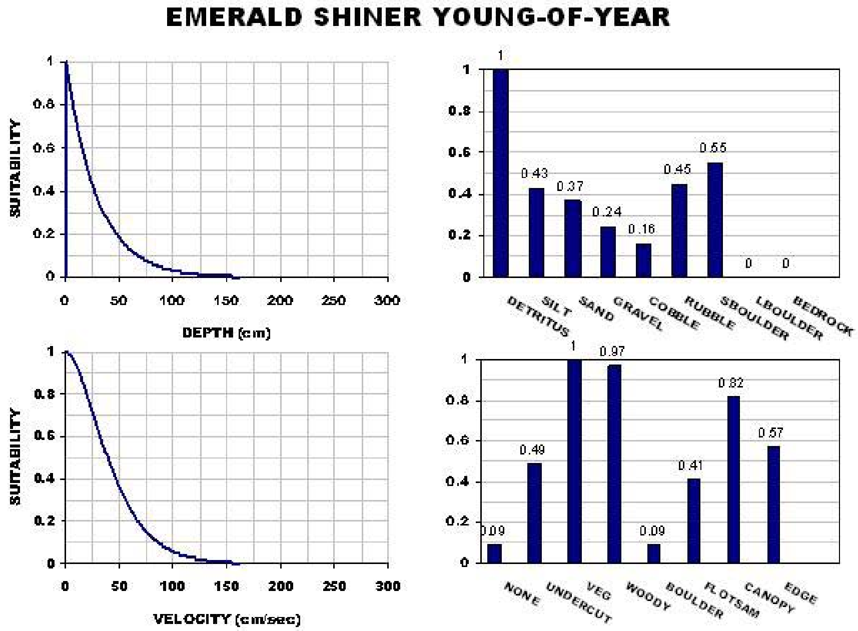

Figure 50. Habitat suitability curves and preference histograms for emerald shiner young-of-year.

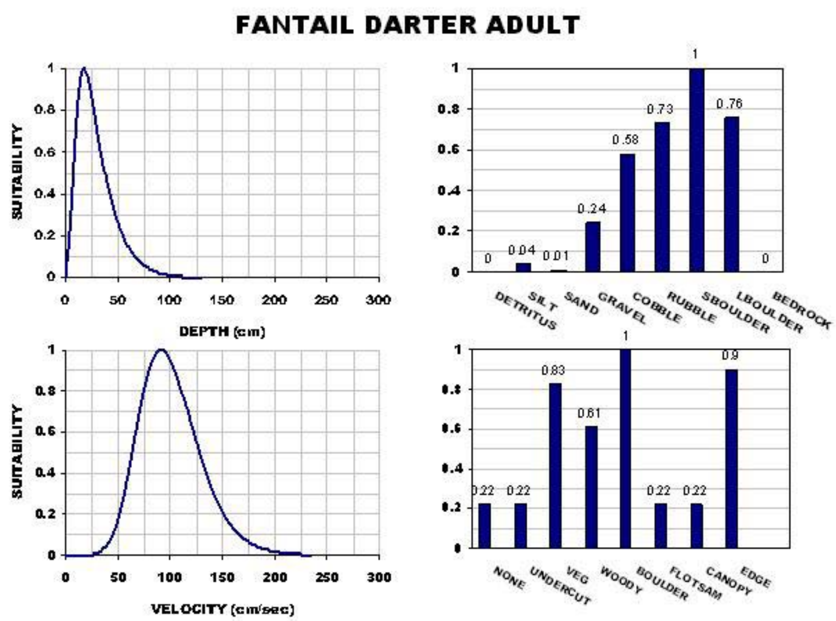

Figure 51. Habitat suitability curves and preference histograms for fantail darter adult.

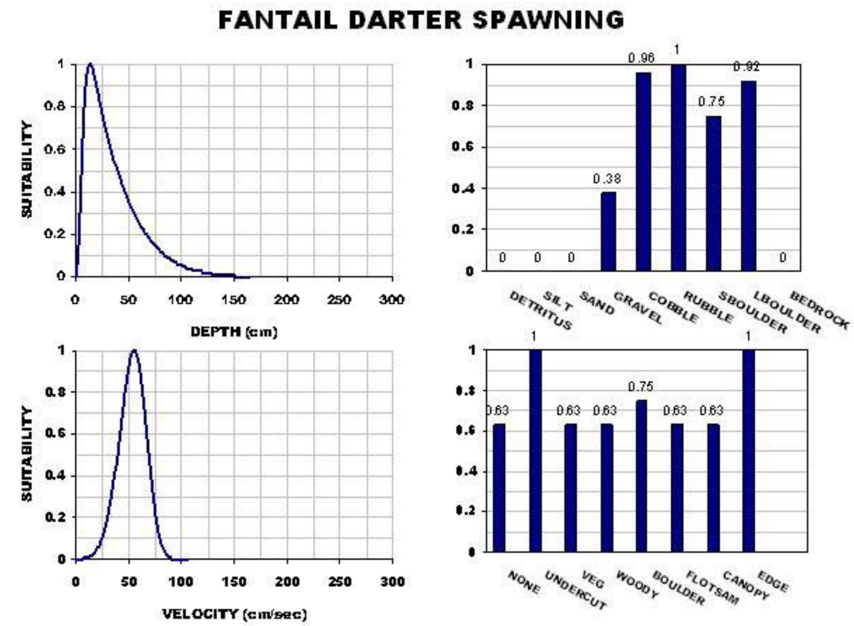

Figure 52. Habitat suitability curves and preference histograms for spawning fantail darter.

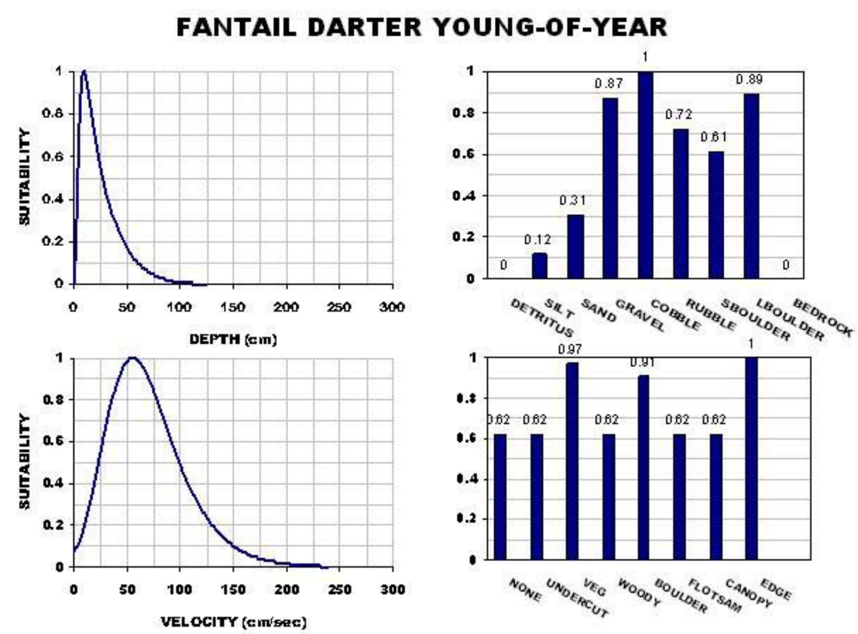

Figure 53. Habitat suitability curves and preference histograms for fantail darter young-of-year.

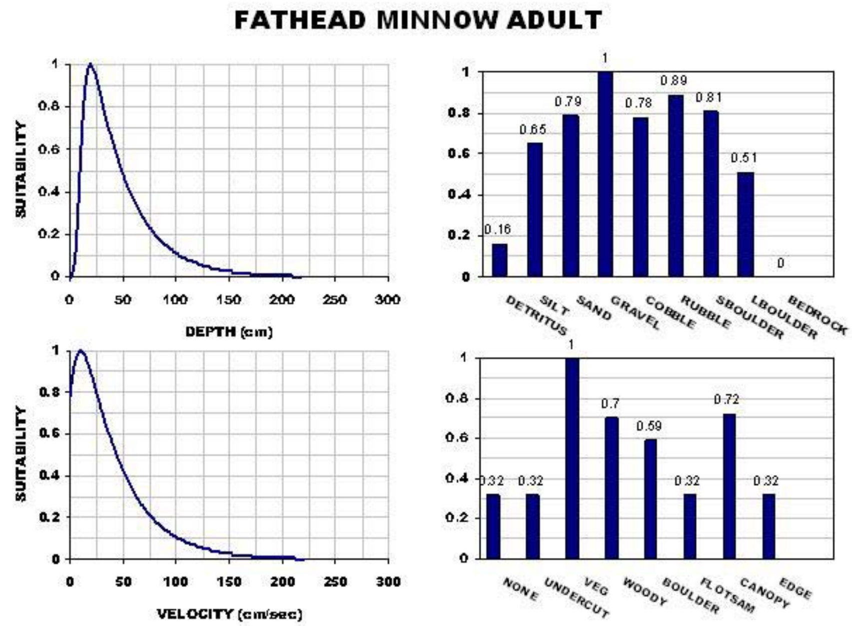

Figure 54. Habitat suitability curves and preference histograms for fathead minnow adult.

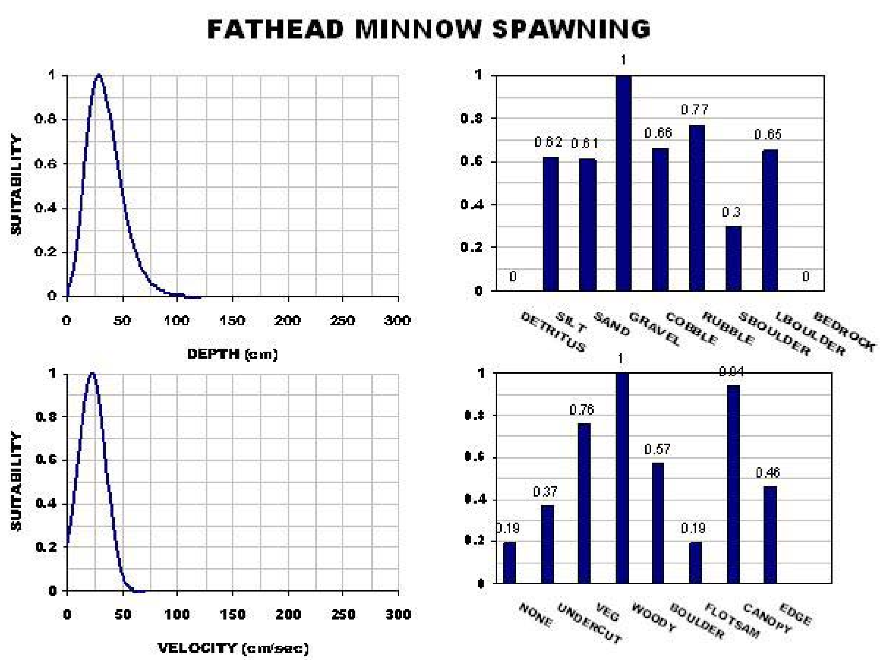

Figure 55. Habitat suitability curves and preference histograms for spawning fathead minnow.

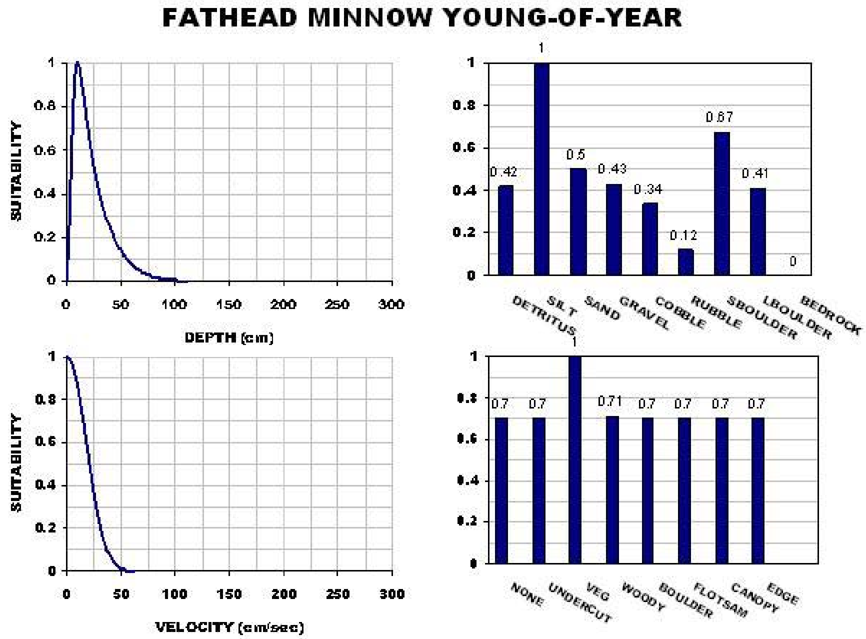

Figure 56. Habitat suitability curves and preference histograms for fathead minnow young-of-year.

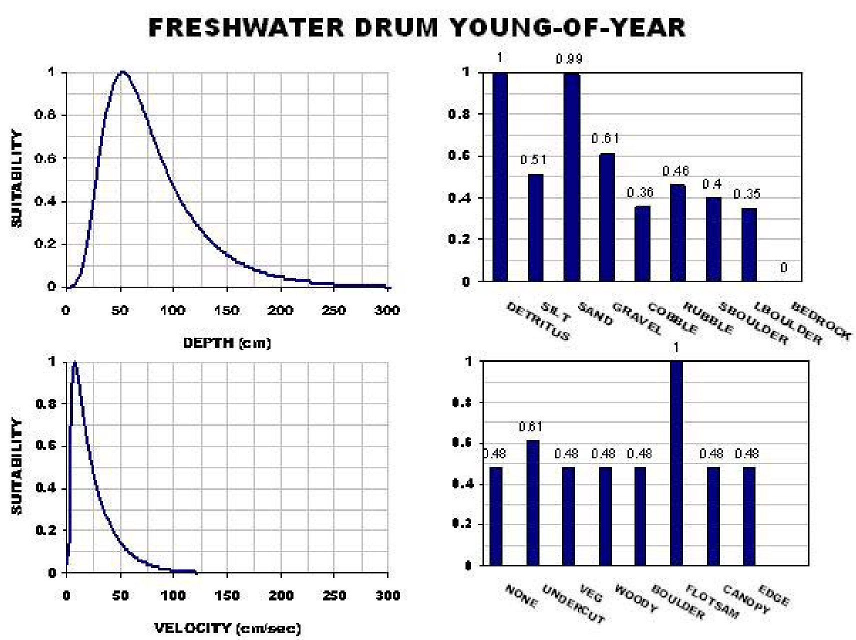

Figure 57. Habitat suitability curves and preference histograms for freshwater drum young-of-year.

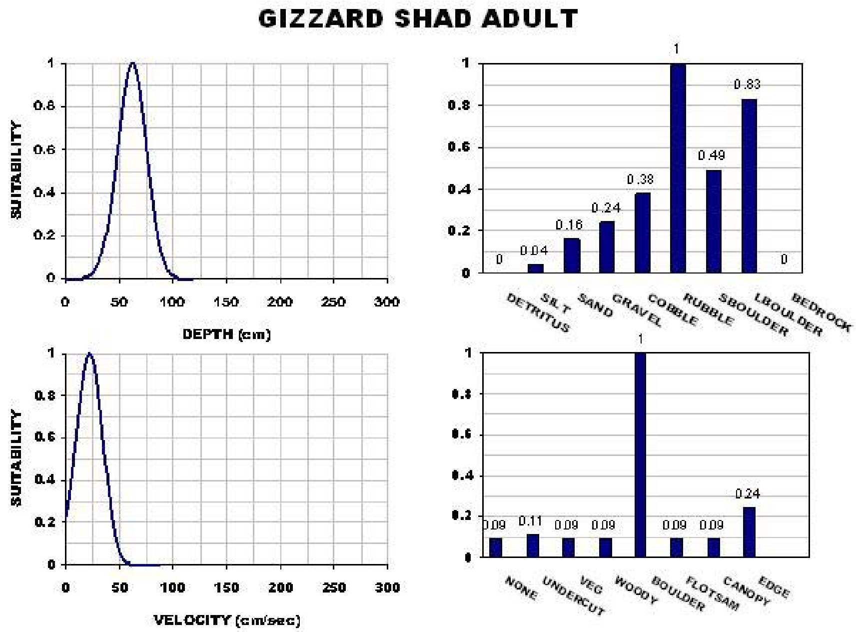

Figure 58. Habitat suitability curves and preference histograms for gizzard shad adult.

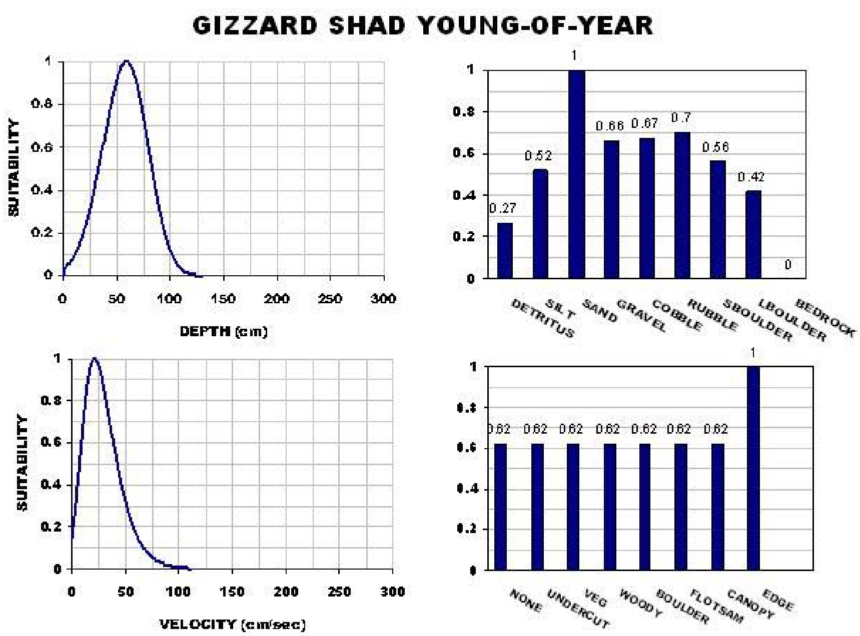

Figure 59. Habitat suitability curves and preference histograms for gizzard shad young-of-year.

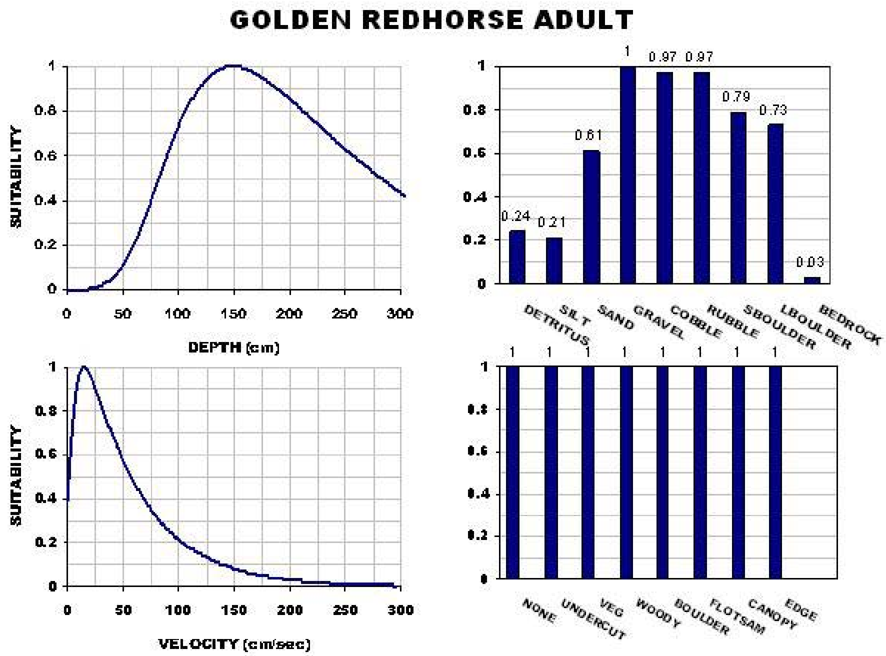

Figure 60. Habitat suitability curves and preference histograms for golden redhorse adult.

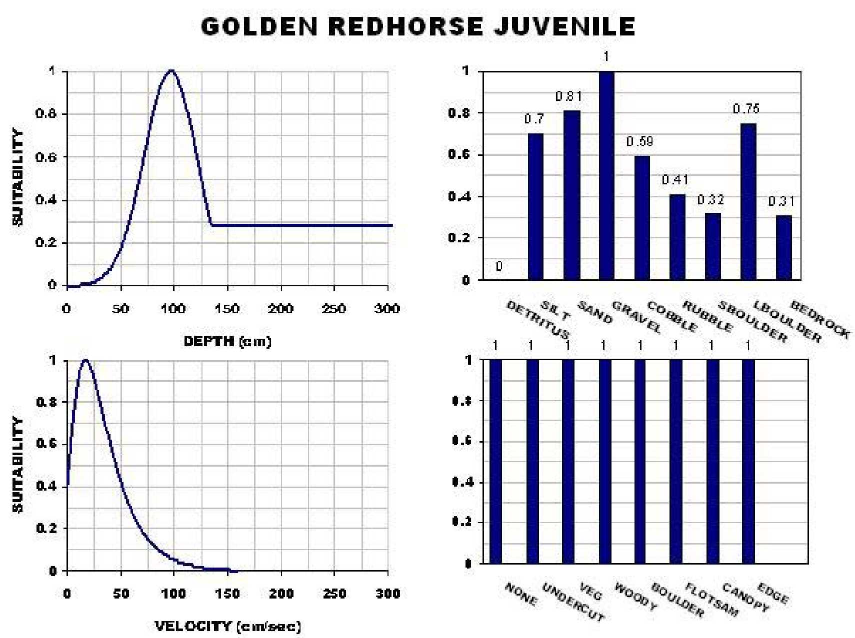

Figure 61. Habitat suitability curves and preference histograms for golden redhorse juvenile.

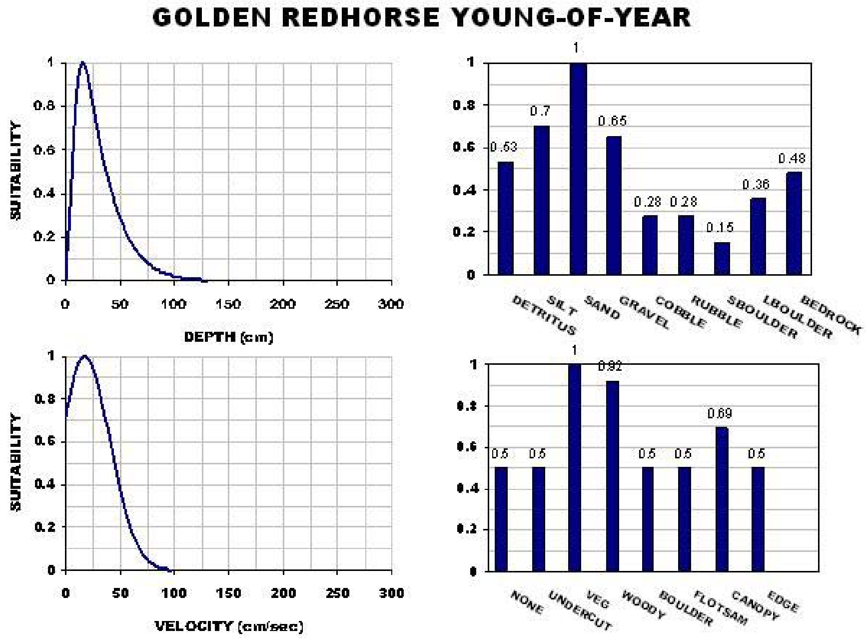

Figure 62 Habitat suitability curves and preference histograms for golden redhorse young-of-year.

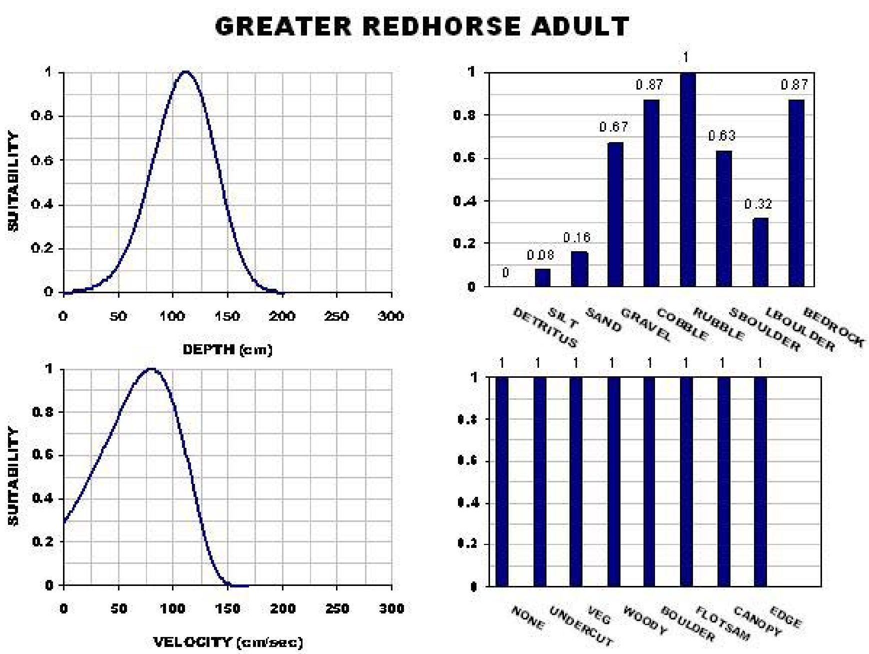

Figure 63. Habitat suitability curves and preference histograms for greater redhorse adult.

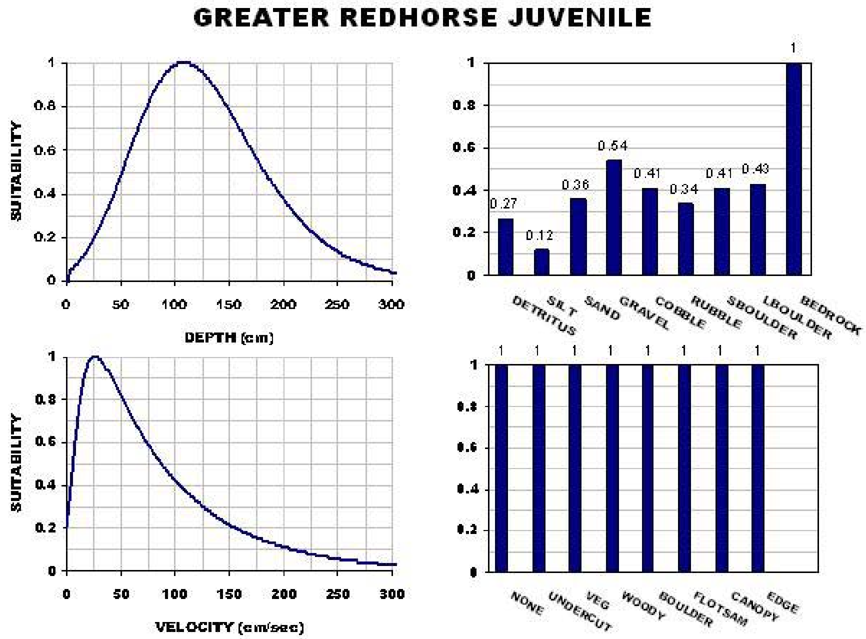

Figure 64 Habitat suitability curves and preference histograms for greater redhorse juvenile.

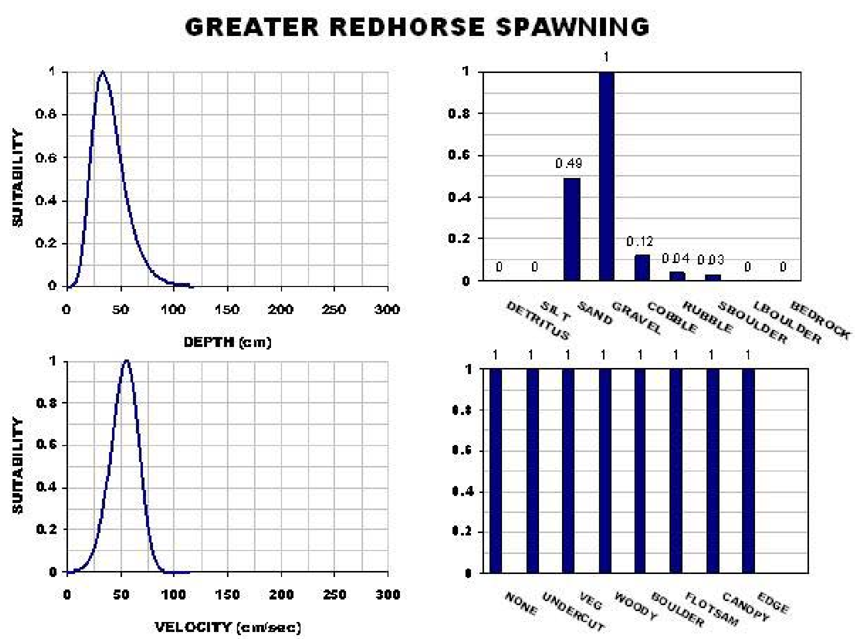

Figure 65. Habitat suitability curves and preference histograms for spawning greater redhorse.

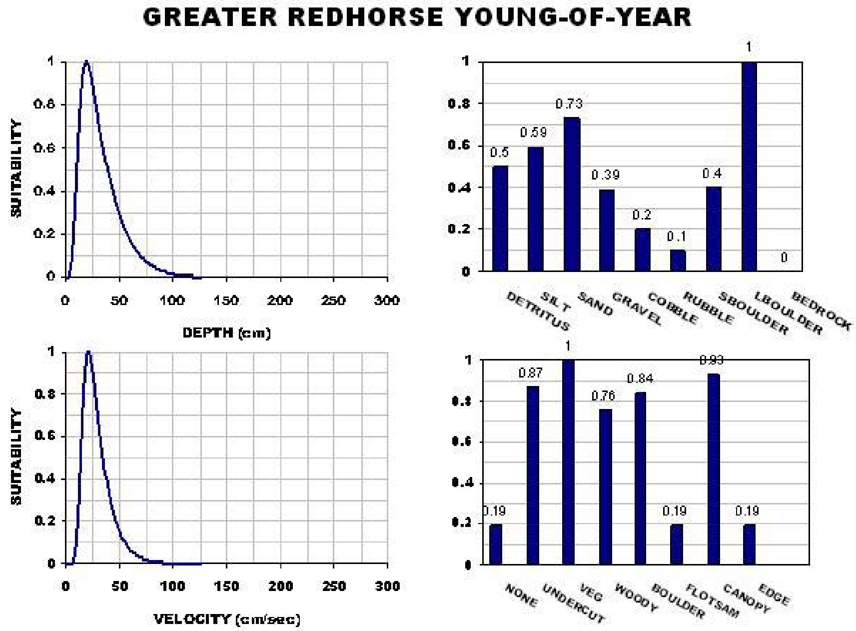

Figure 66. Habitat suitability curves and preference histograms for greater redhorse young-of-year.

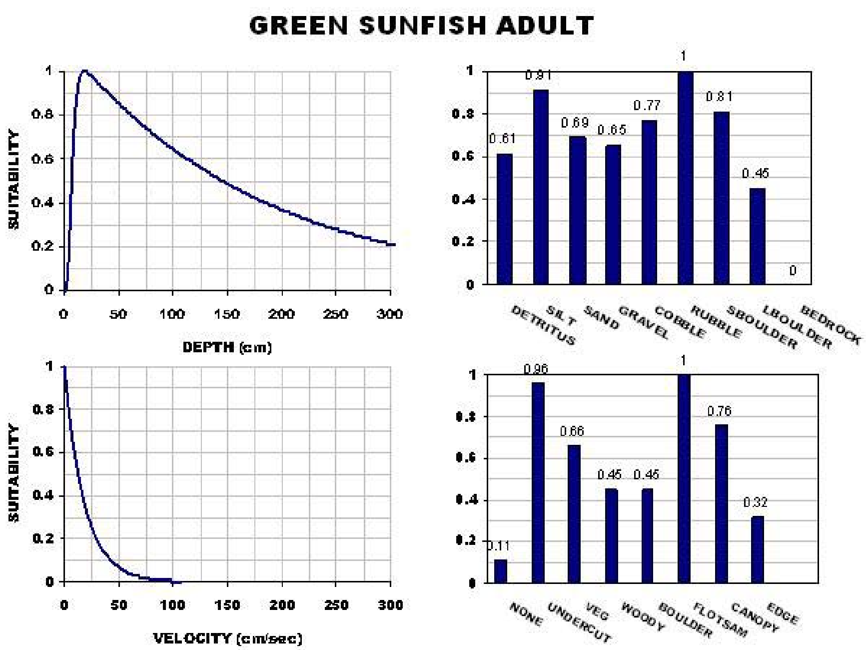

Figure 67. Habitat suitability curves and preference histograms for green sunfish adult.

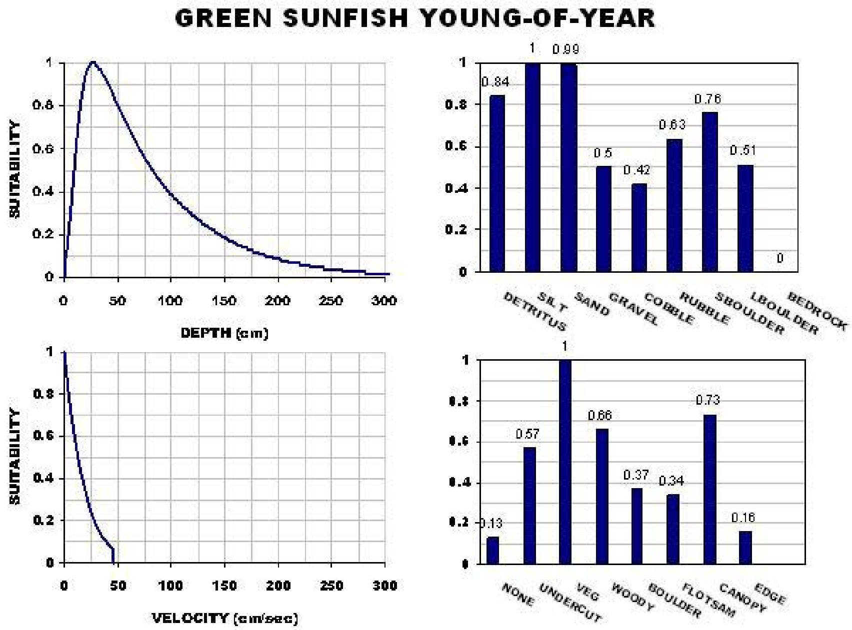

Figure 68. Habitat suitability curves and preference histograms for green sunfish young-of-year.

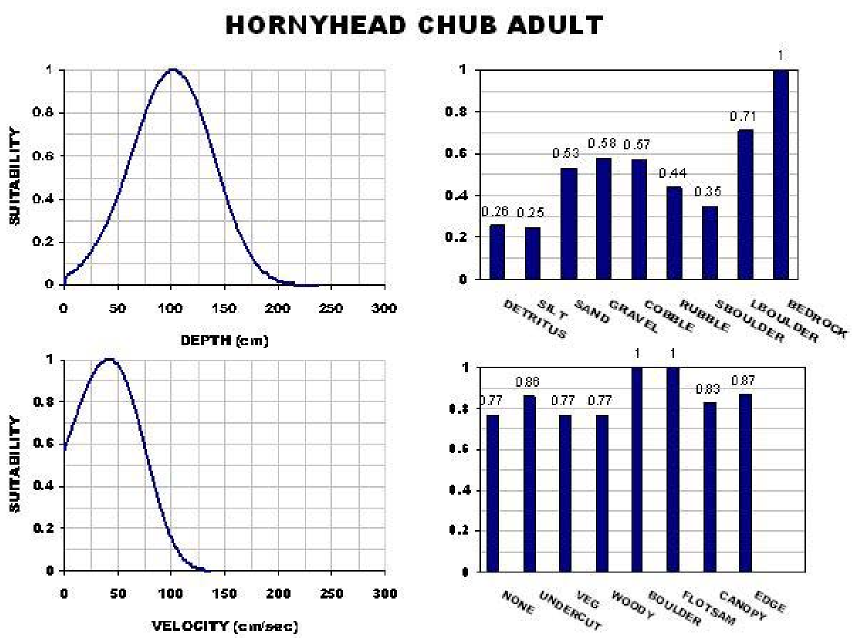

Figure 69. Habitat suitability curves and preference histograms for hornyhead chub adult.

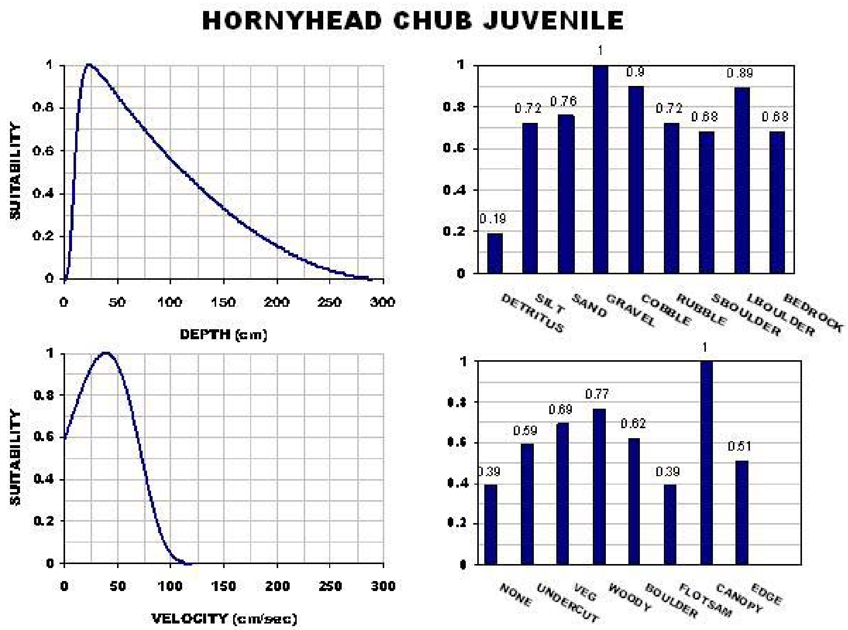

Figure 70. Habitat suitability curves and preference histograms for hornyhead chub juvenile.

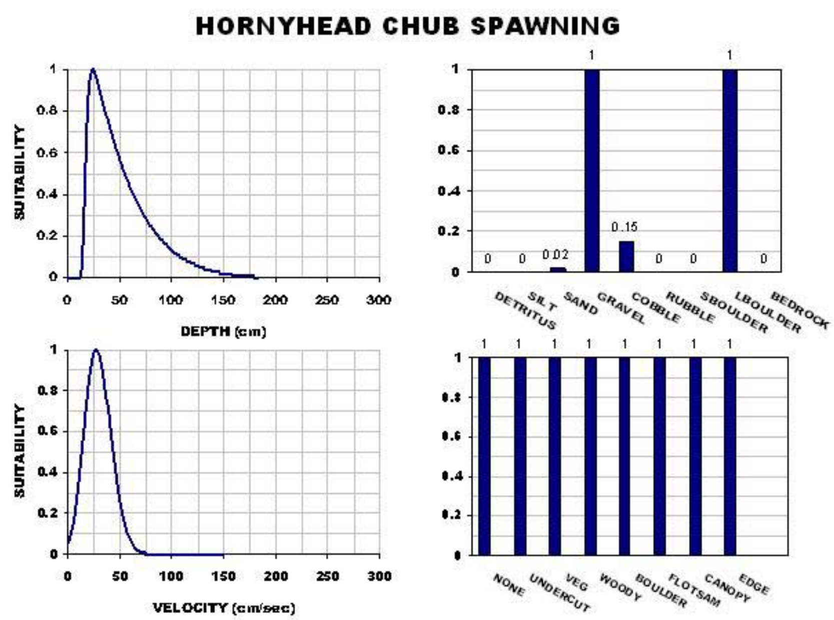

Figure 71. Habitat suitability curves and preference histograms for spawning hornyhead chub.

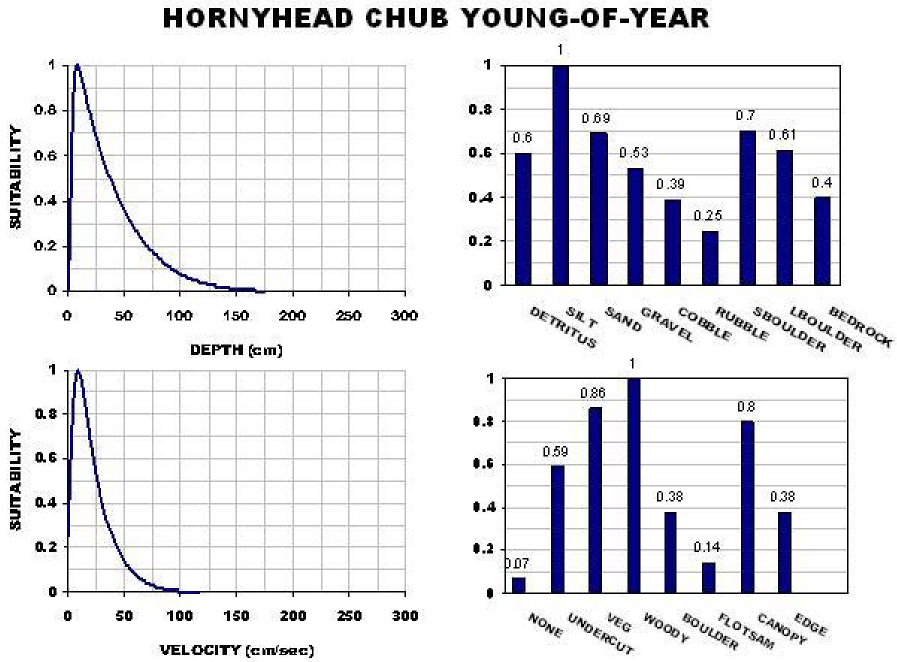

Figure 72. Habitat suitability curves and preference histograms for hornyhead chub young-of-year.

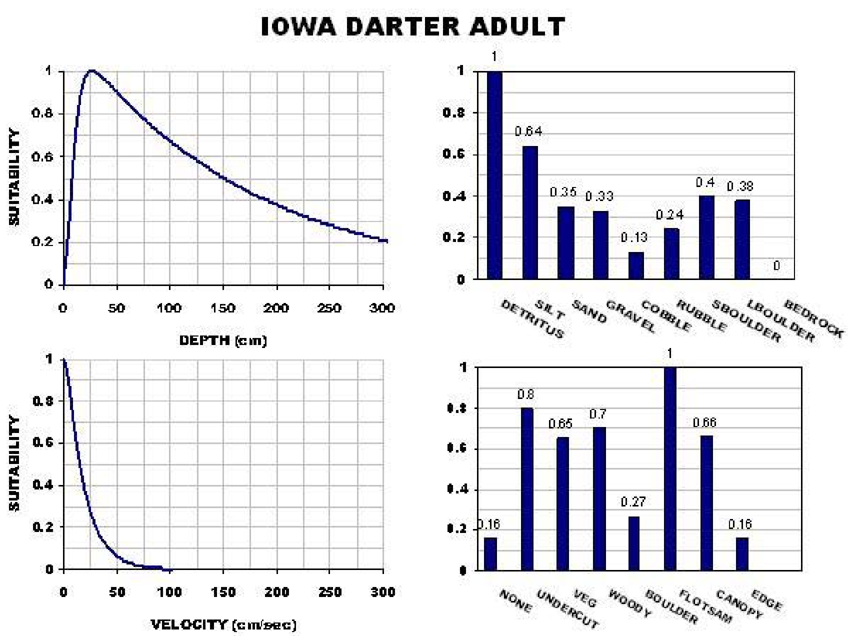

Figure 73. Habitat suitability curves and preference histograms for Iowa darter adult.

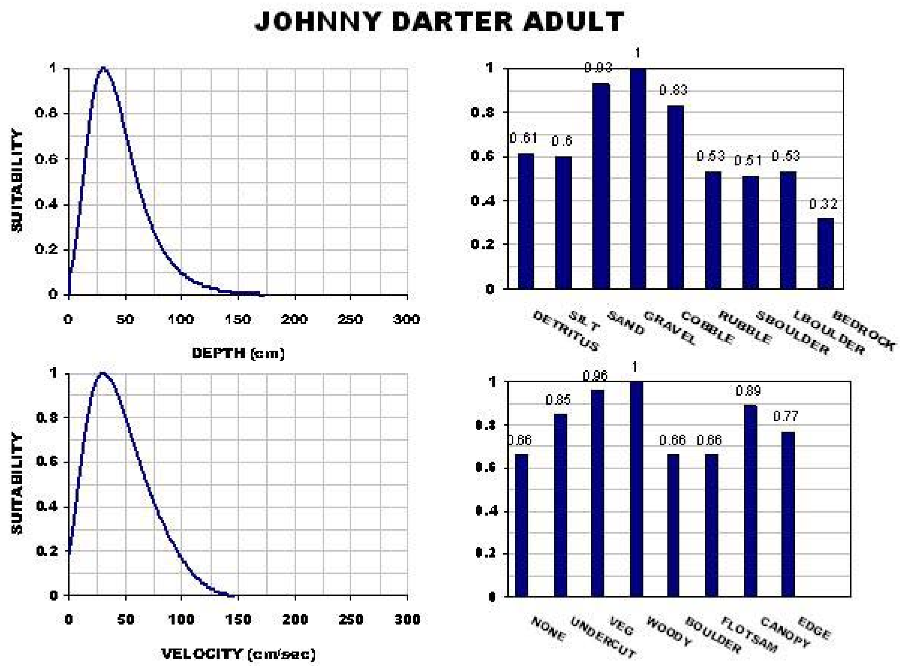

Figure 74. Habitat suitability curves and preference histograms for johnny darter adult.

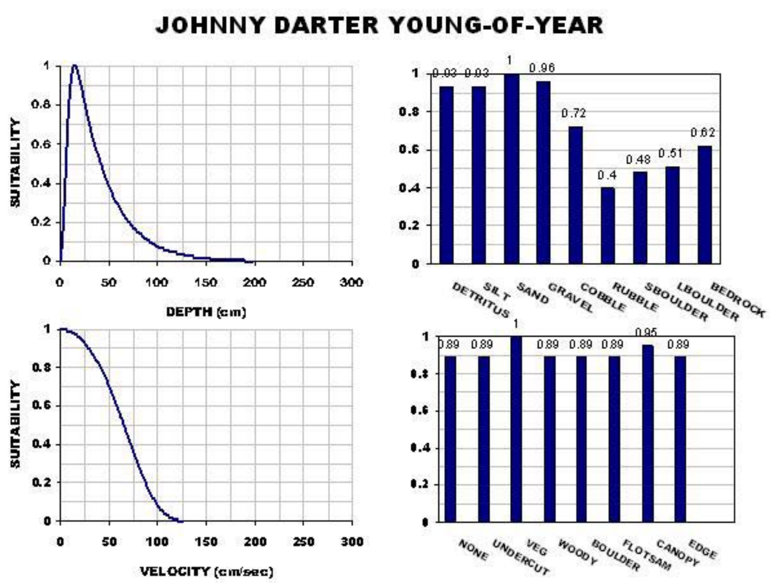

Figure 75. Habitat suitability curves and preference histograms for johnny darter young-of-year.

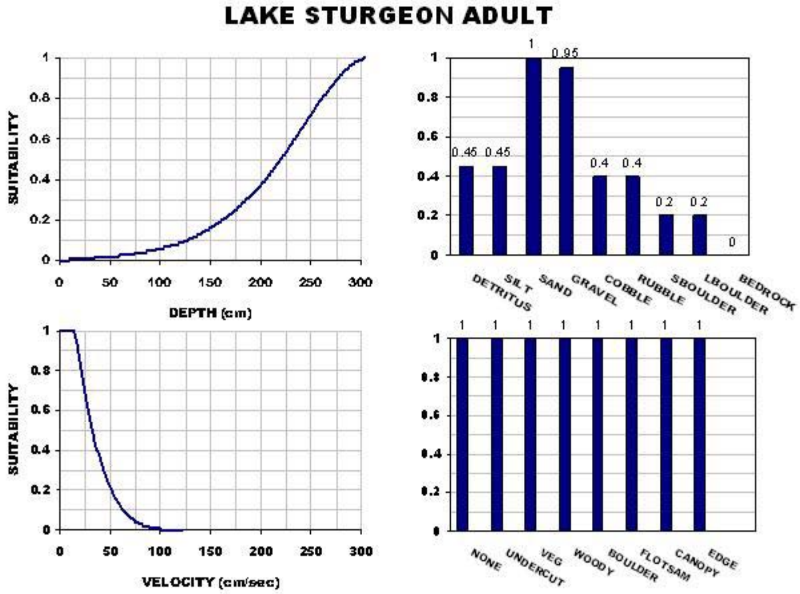

Figure 76. Habitat suitability curves and preference histograms for lake sturgeon adult. Adult lake sturgeon criteria are included here but were developed by Morse et al. (1997) from radiotelemetry observations on the Kettle River.

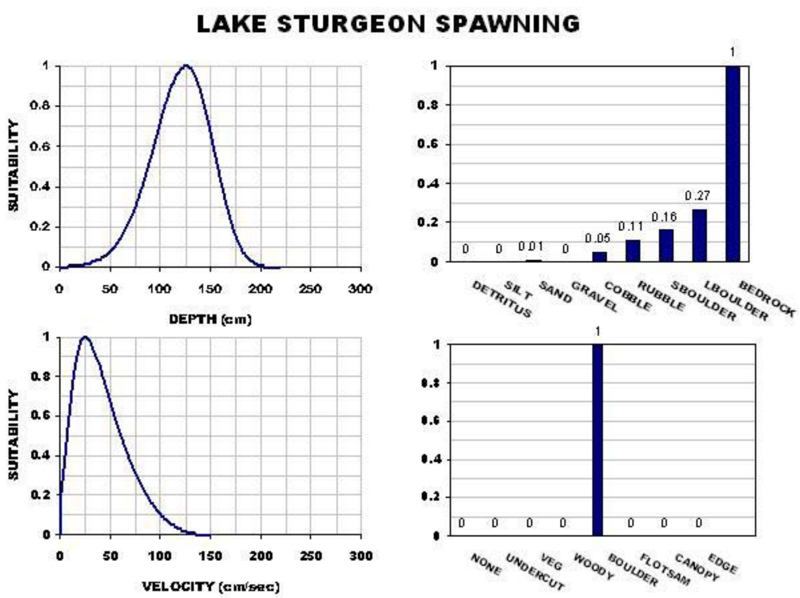

Figure 77. Habitat suitability curves and preference histograms for spawning lake sturgeon.

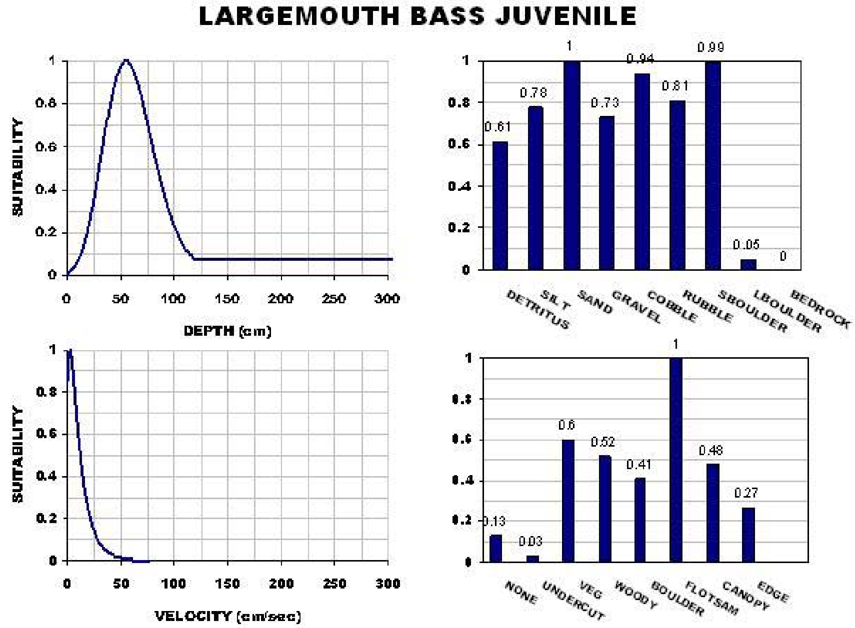

Figure 78. Habitat suitability curves and preference histograms for largemouth bass juvenile.

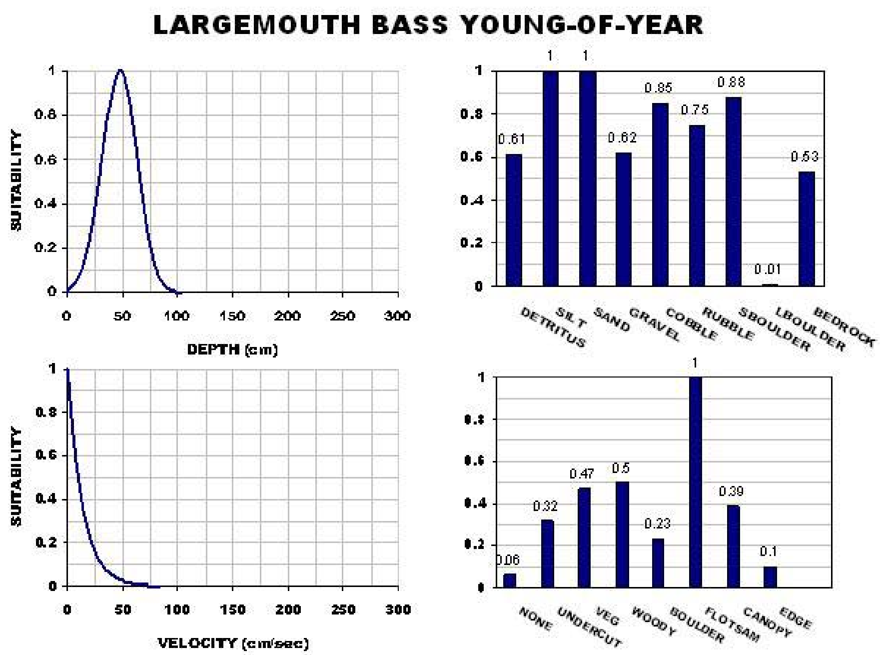

Figure 79. Habitat suitability curves and preference histograms for largemouth bass young-of-year.

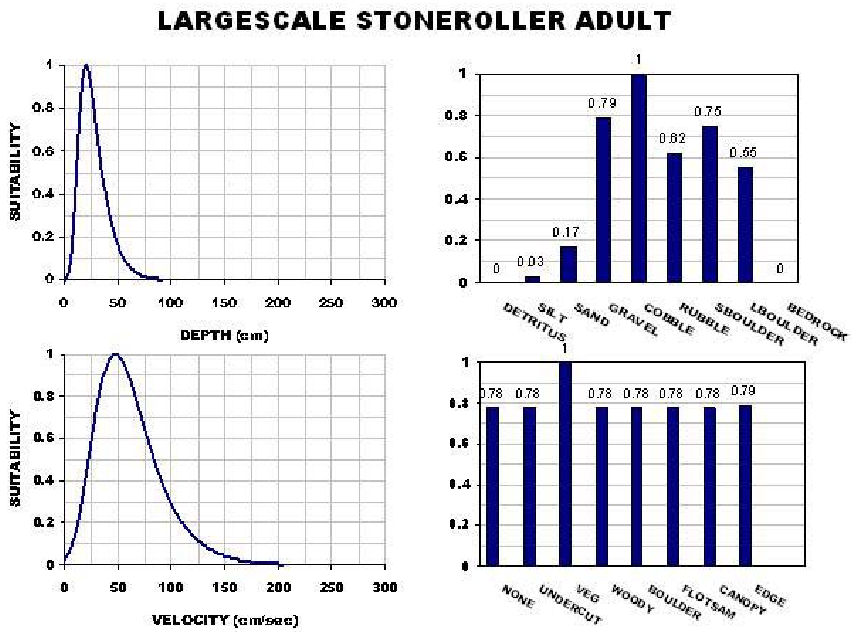

Figure 80. Habitat suitability curves and preference histograms for largescale stoneroller adult.

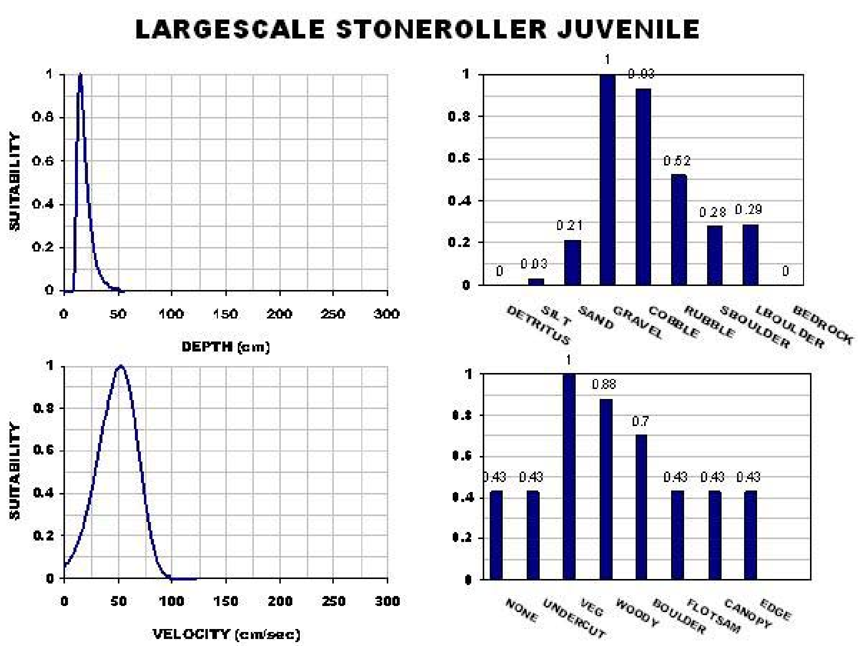

Figure 81. Habitat suitability curves and preference histograms for largescale stoneroller juvenile.

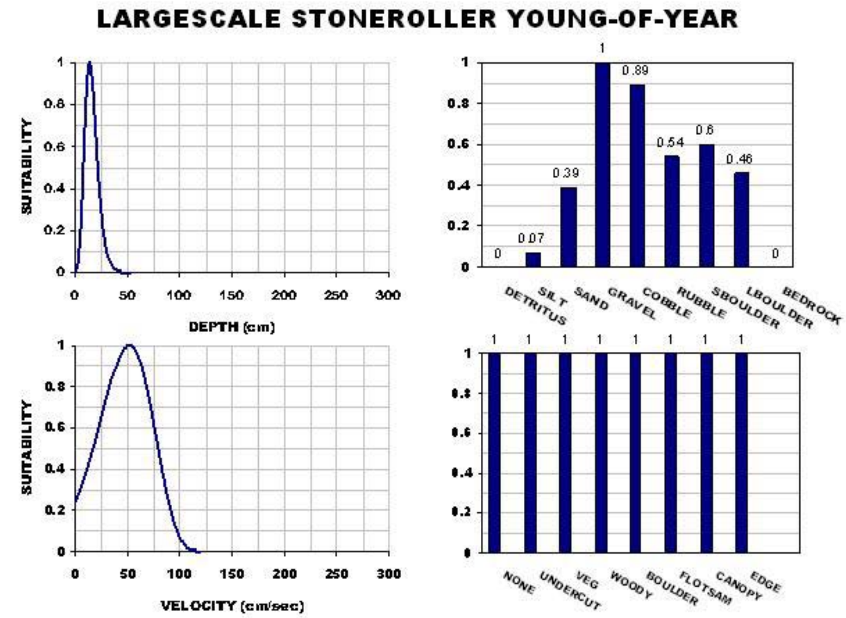

Figure 82. Habitat suitability curves and preference histograms for largescale stoneroller young-of-year.

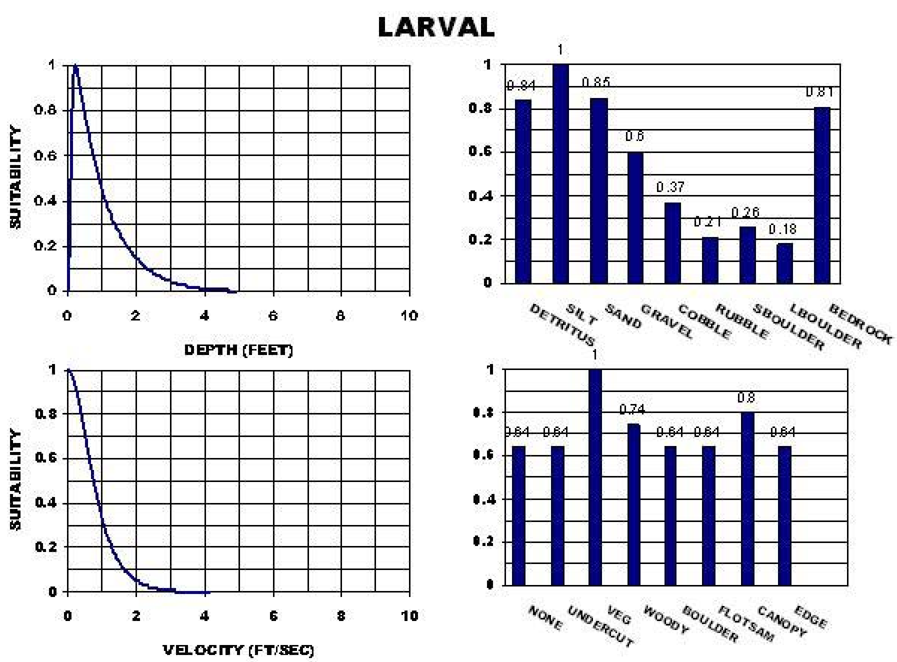

Figure 83. Habitat suitability curves and preference histograms for larval fish.

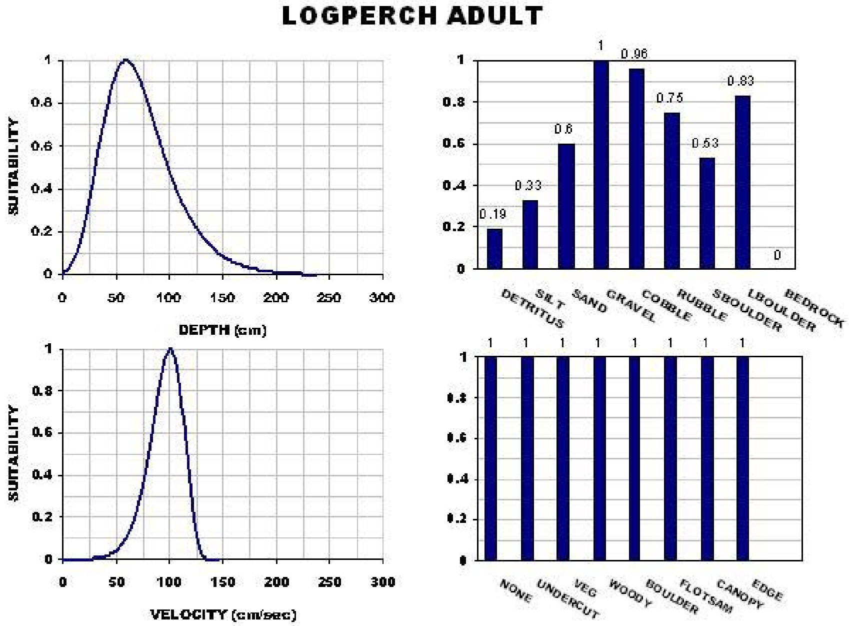

Figure 84. Habitat suitability curves and preference histograms for logperch adult.

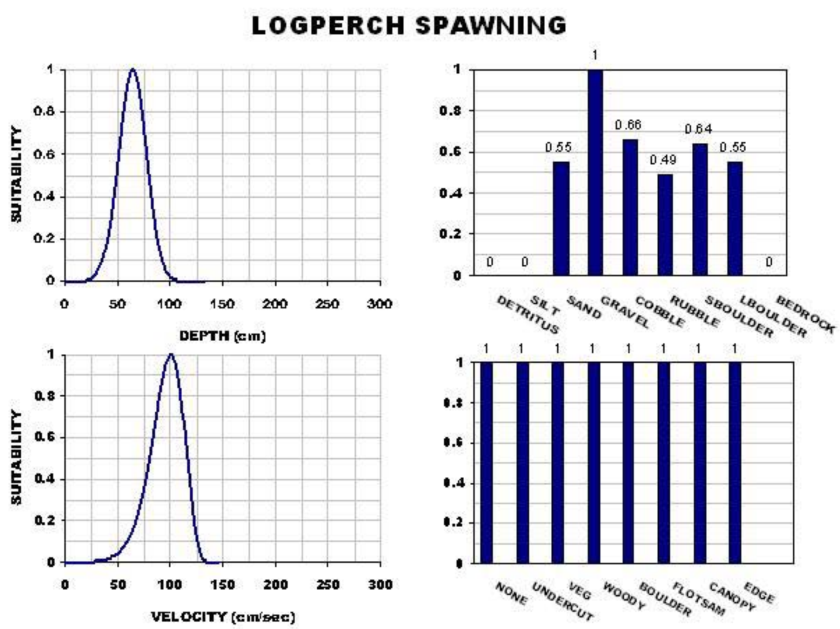

Figure 85. Habitat suitability curves and preference histograms for spawning logperch.

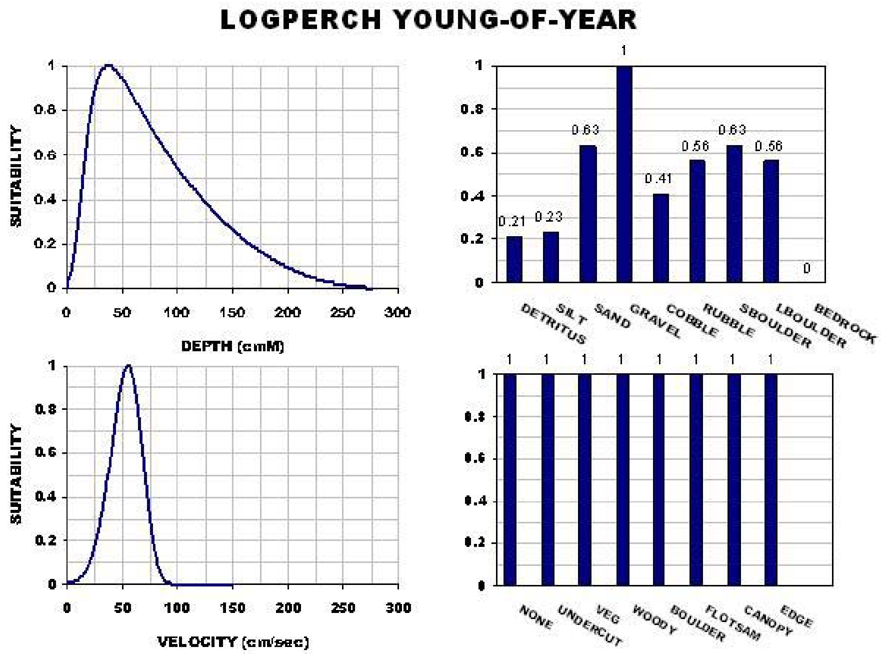

Figure 86. Habitat suitability curves and preference histograms for logperch young-of-year.

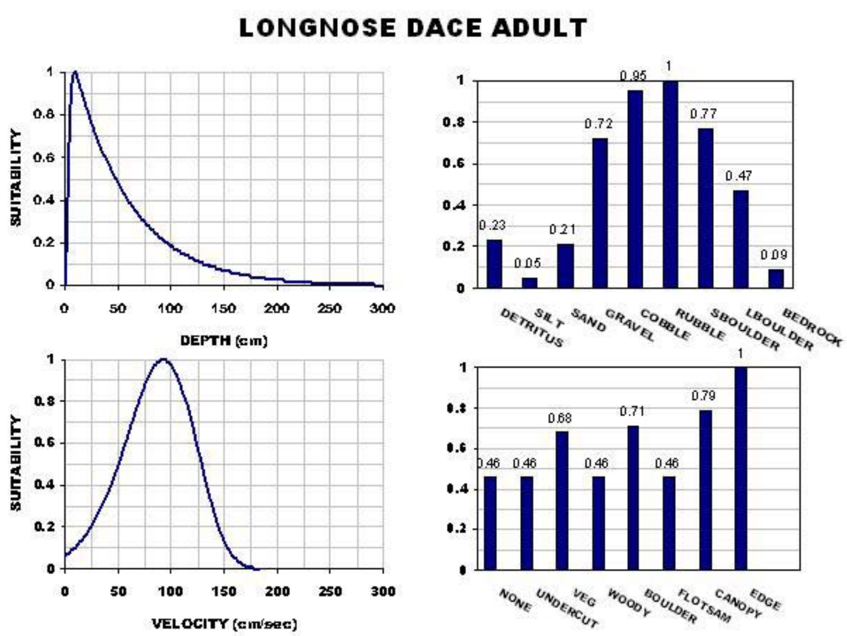

Figure 87. Habitat suitability curves and preference histograms for longnose dace adult.

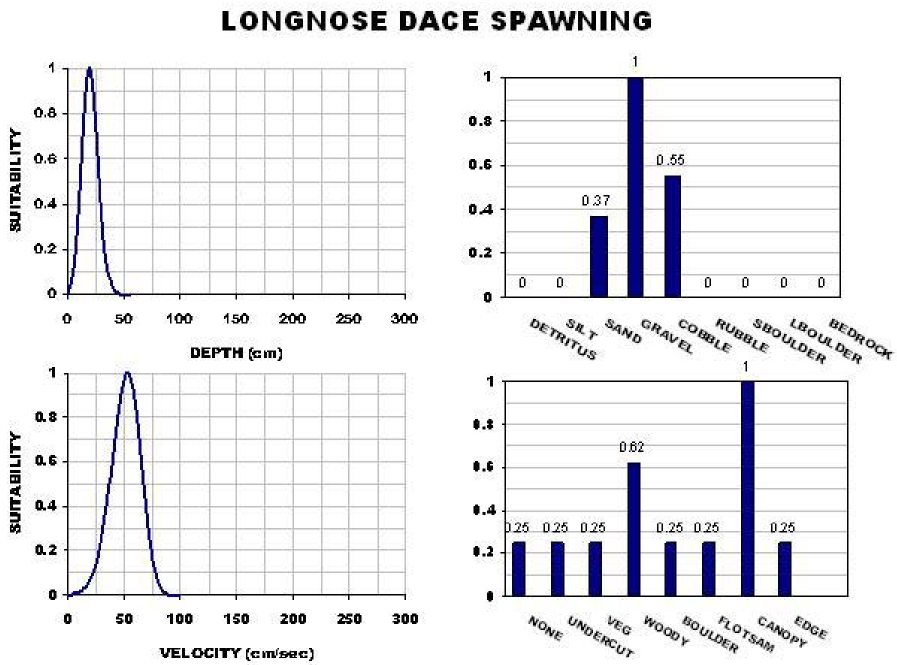

Figure 88. Habitat suitability curves and preference histograms for spawning longnose dace.

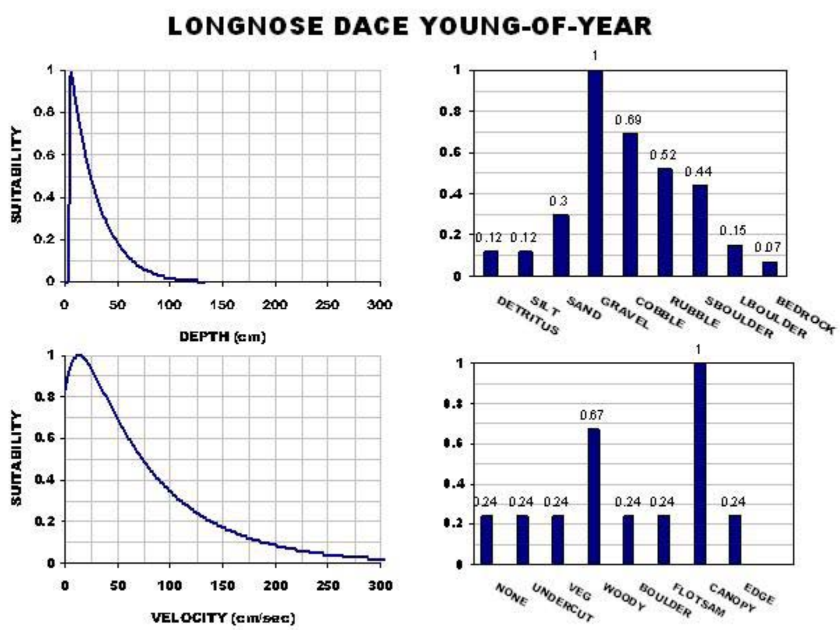

Figure 89. Habitat suitability curves and preference histograms for longnose dace young-of-year.

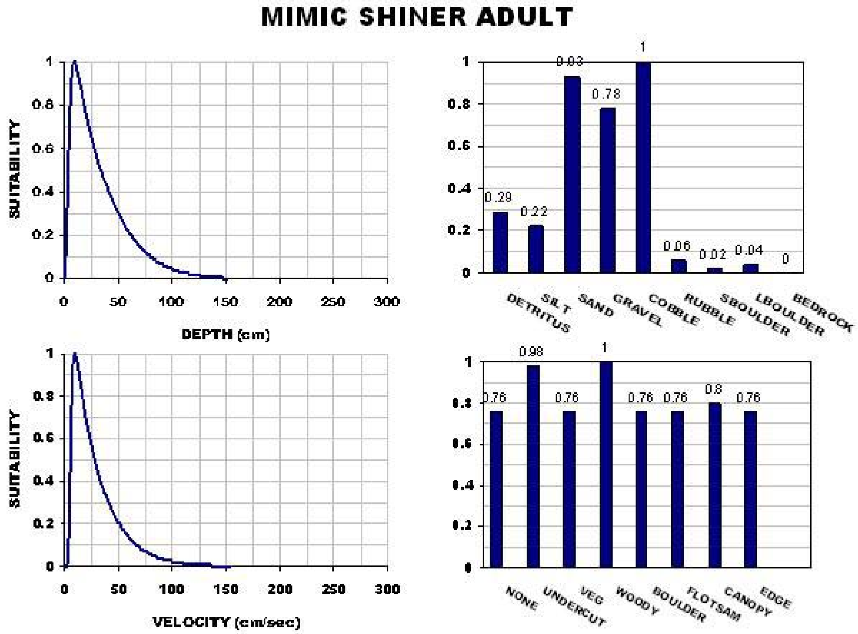

Figure 90. Habitat suitability curves and preference histograms for mimic shiner adult.

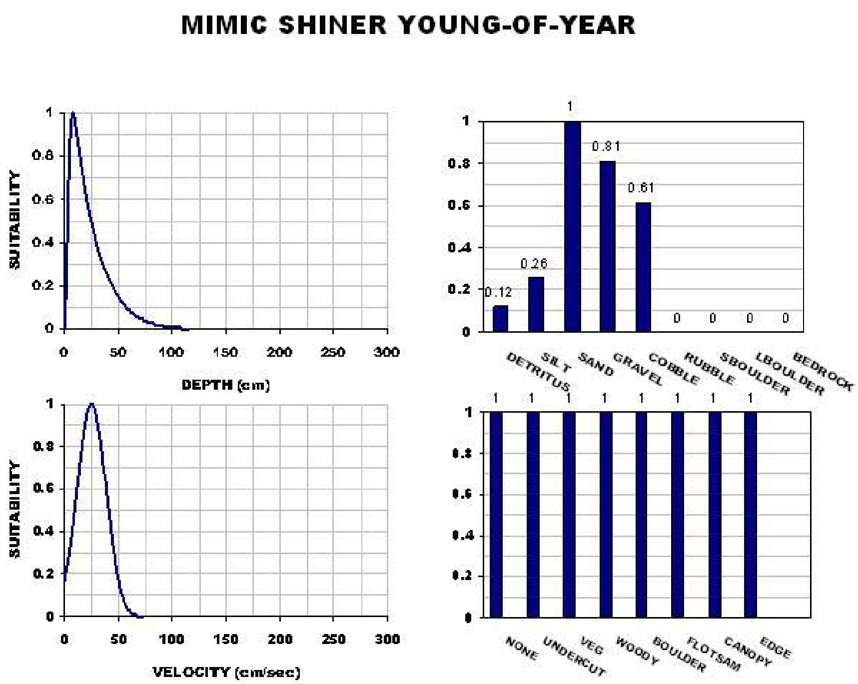

Figure 91. Habitat suitability curves and preference histograms for mimic shiner young-of-year.

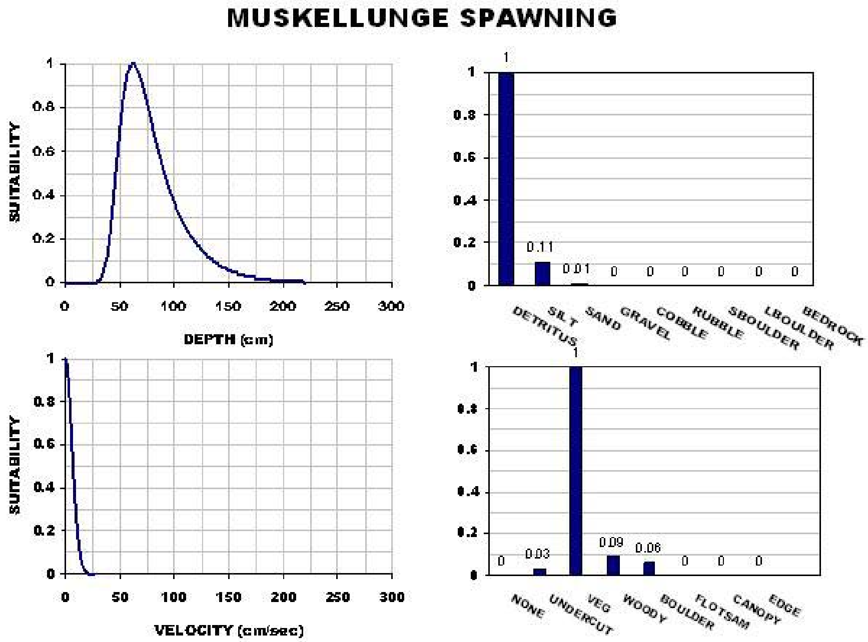

Figure 92. Habitat suitability curves and preference histograms for spawning muskellunge.

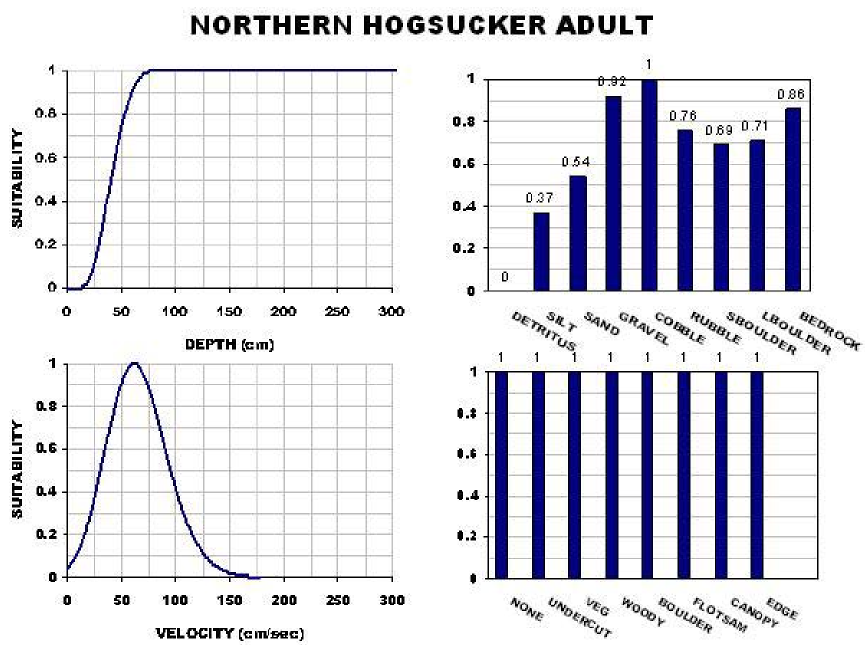

Figure 93. Habitat suitability curves and preference histograms for northern hogsucker adult.

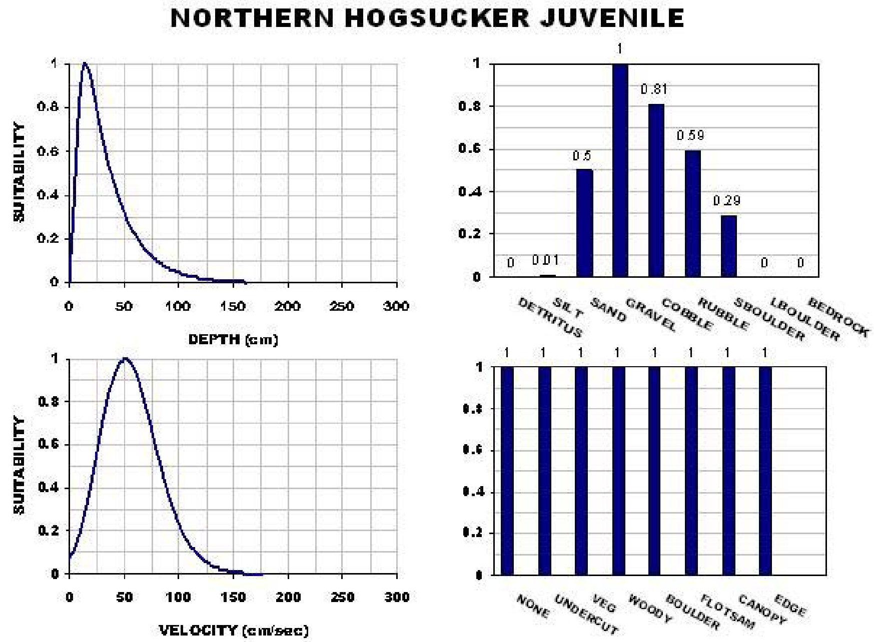

Figure 94. Habitat suitability curves and preference histograms for northern hogsucker juvenile.

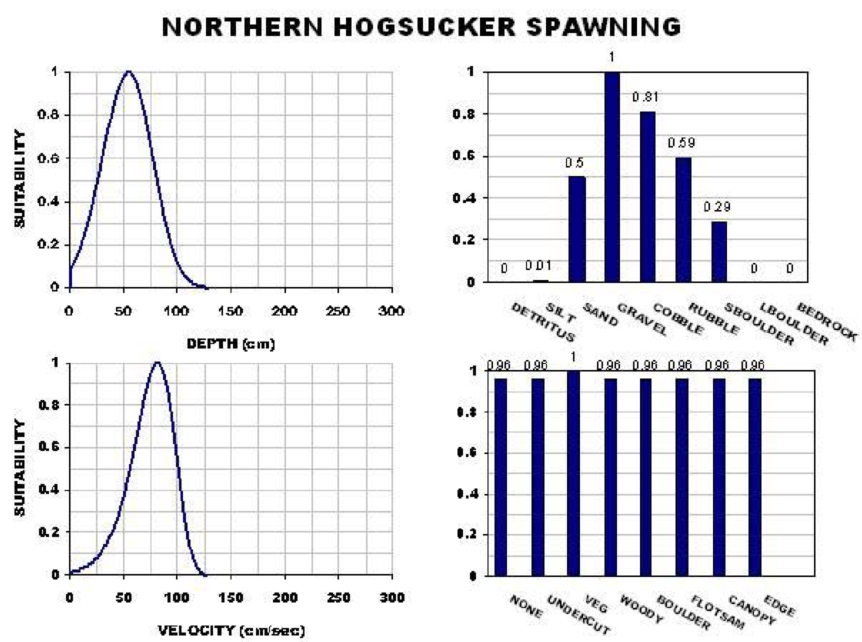

Figure 95. Habitat suitability curves and preference histograms for spawning northern hogsucker.

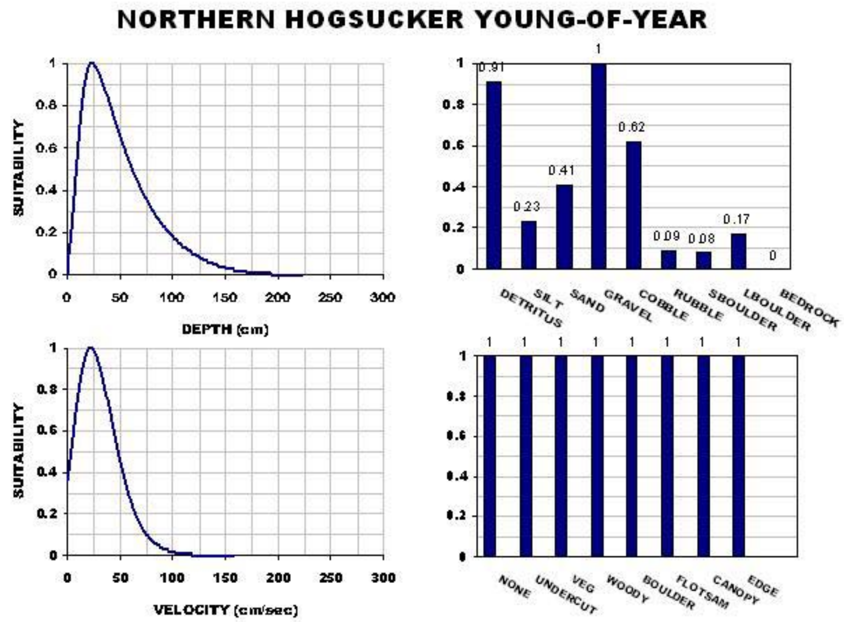

Figure 96. Habitat suitability curves and preference histograms for northern hogsucker young-of-year.

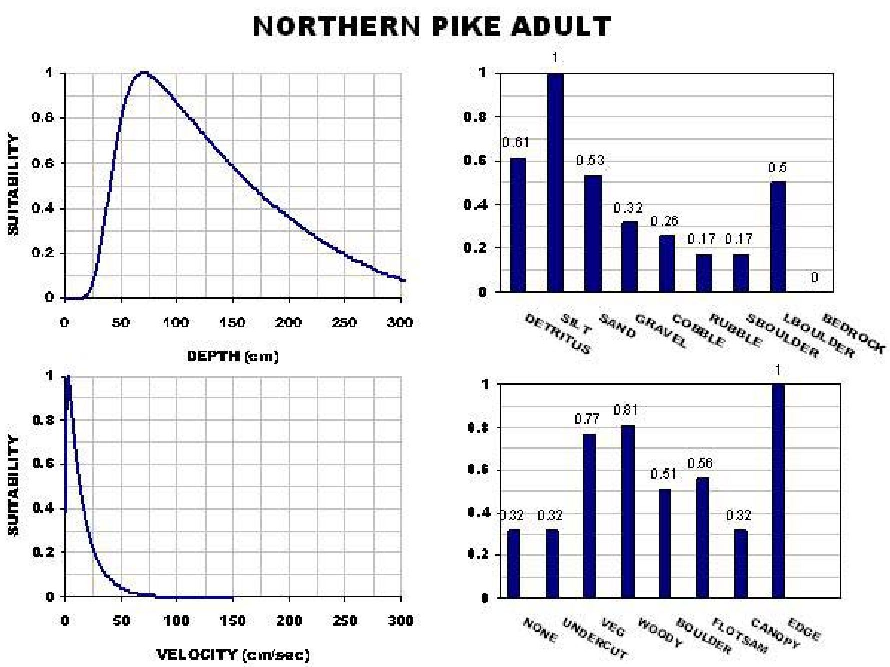

Figure 97. Habitat suitability curves and preference histograms for northern pike adult.

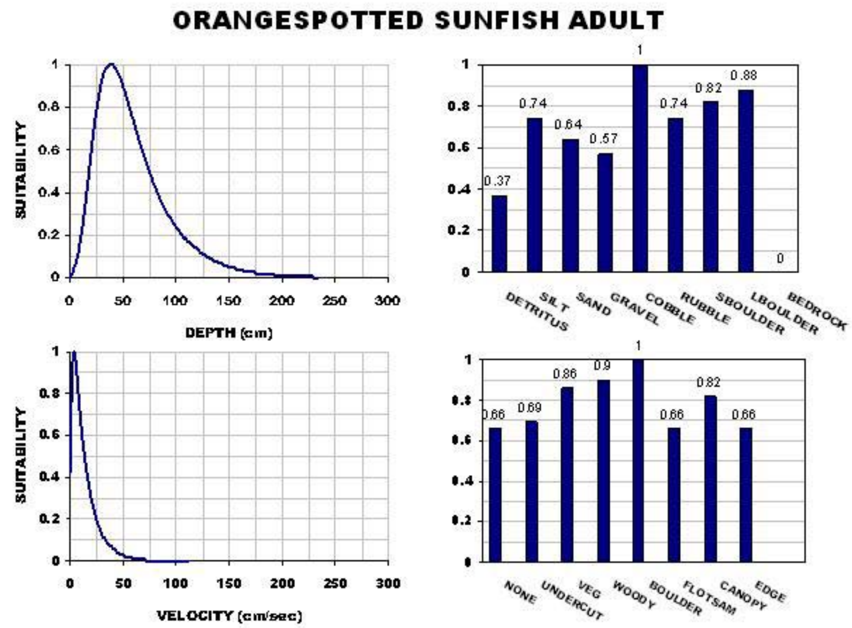

Figure 98. Habitat suitability curves and preference histograms for orangespotted sunfish adult.

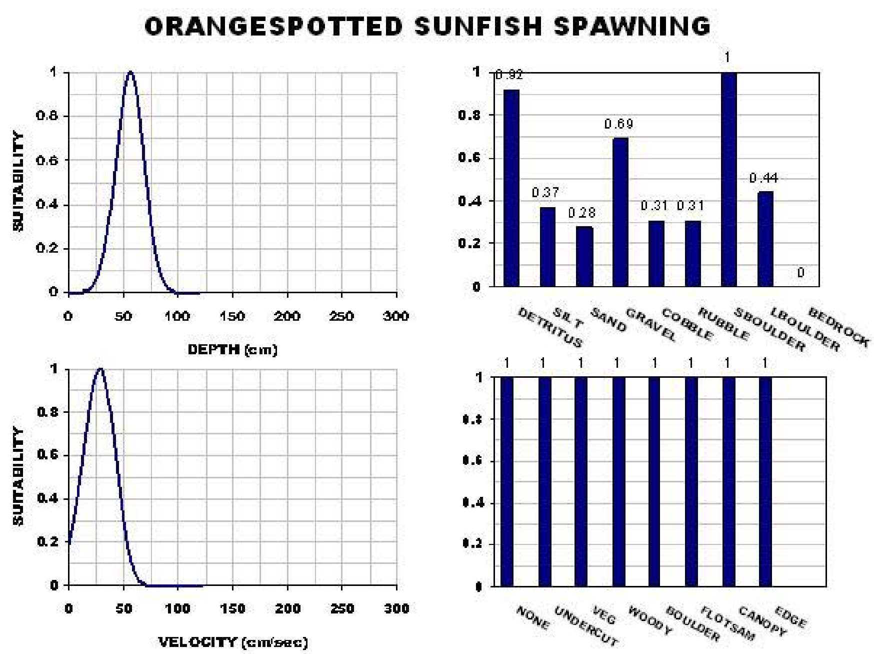

Figure 99. Habitat suitability curves and preference histograms for spawning orangespotted sunfish.

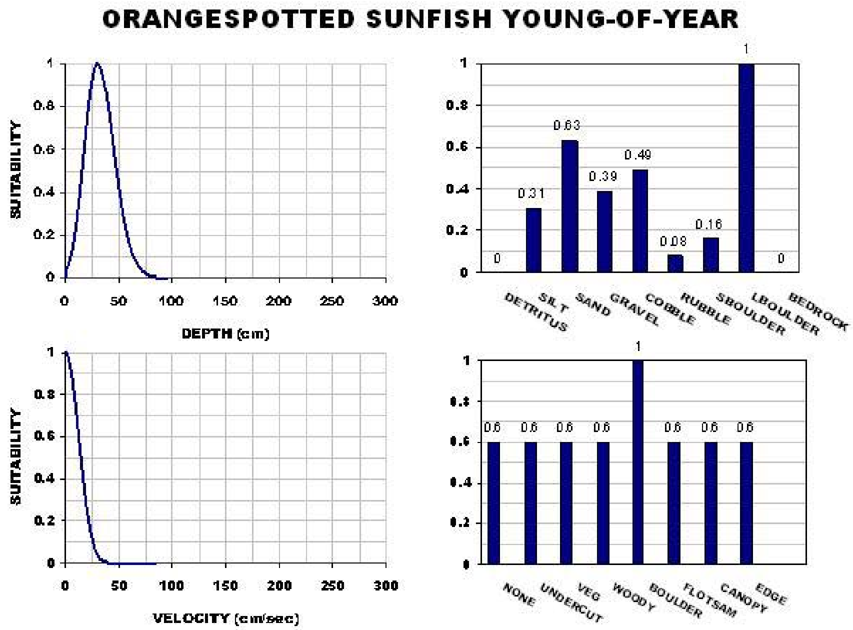

Figure 100. Habitat suitability curves and preference histograms for orangespotted sunfish young-of-year.

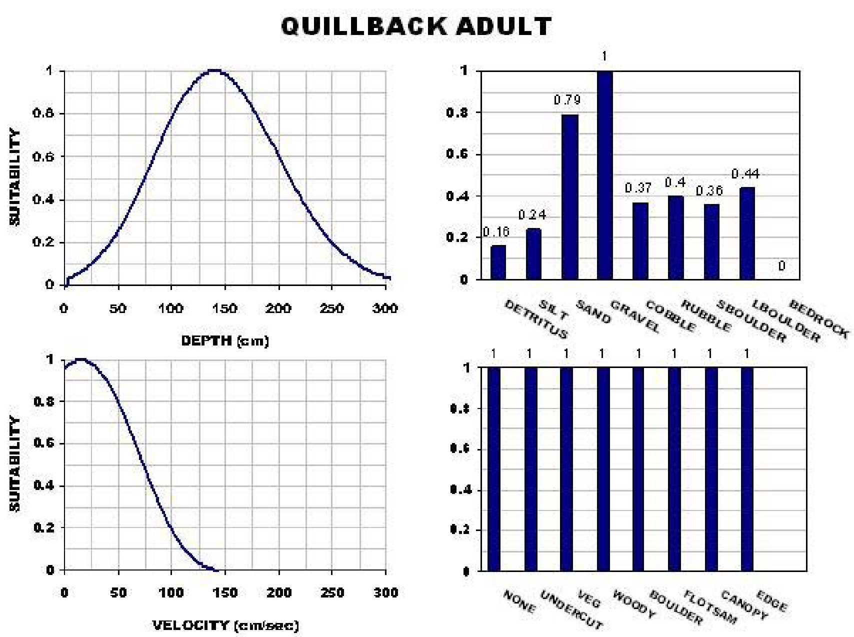

Figure 101. Habitat suitability curves and preference histograms for quillback carpsucker adult.

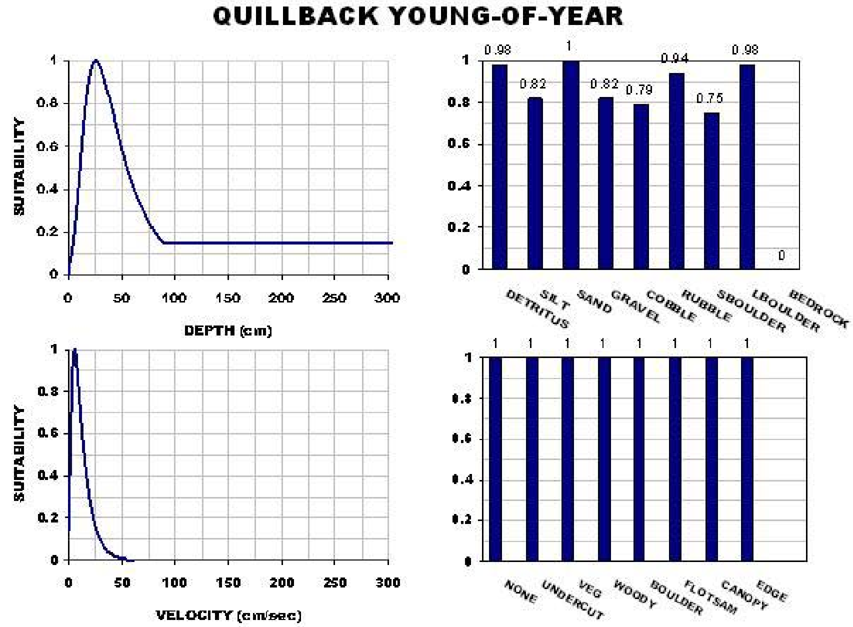

Figure 102. Habitat suitability curves and preference histograms for quillback carpsucker young-of-year.

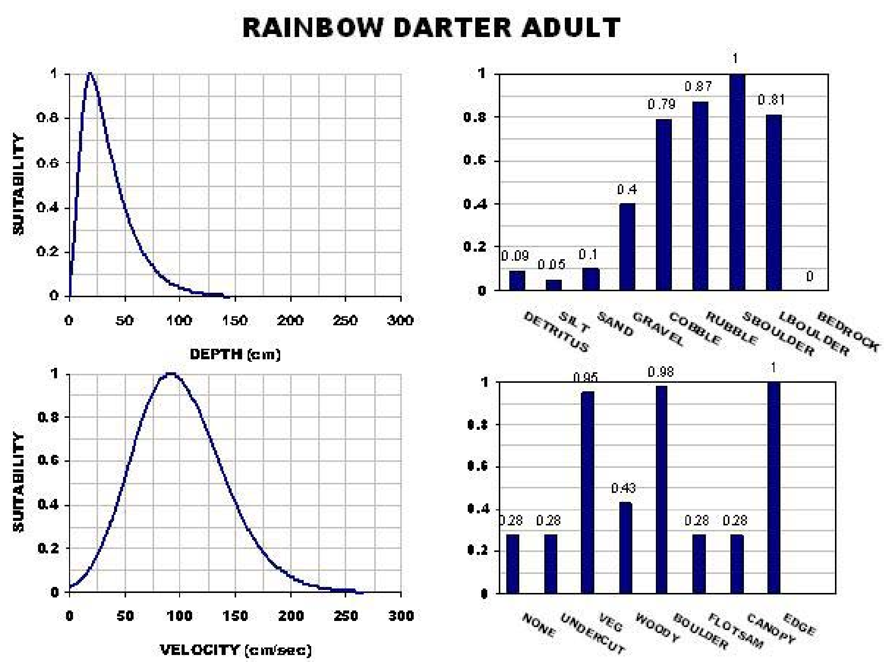

Figure 103. Habitat suitability curves and preference histograms for rainbow darter adult.

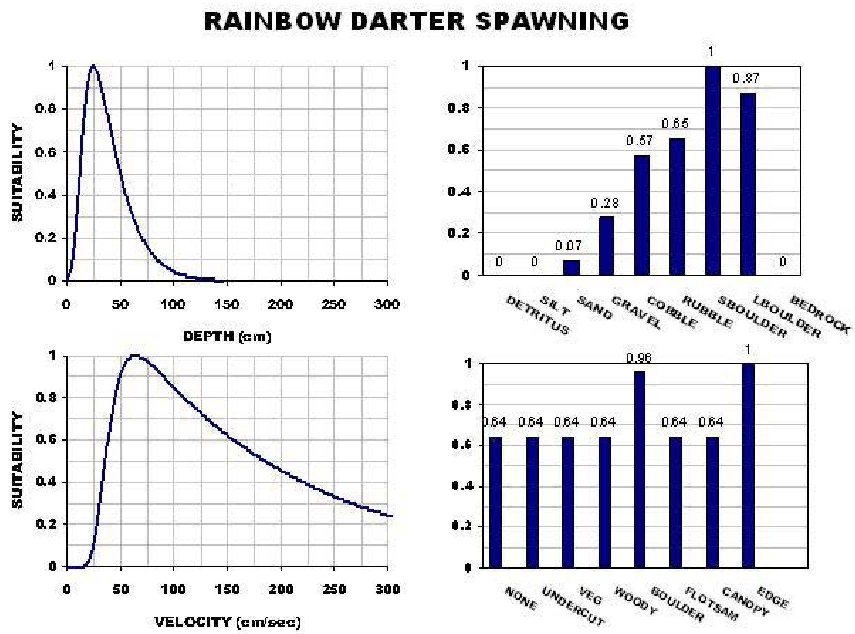

Figure 104. Habitat suitability curves and preference histograms for spawning rainbow darter.

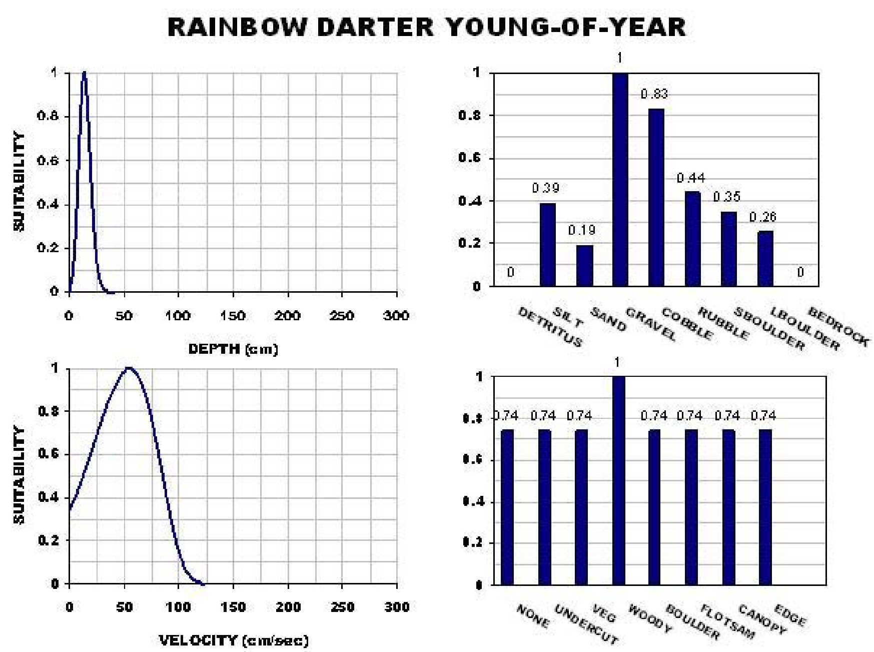

Figure 105. Habitat suitability curves and preference histograms for rainbow darter young-of-year.

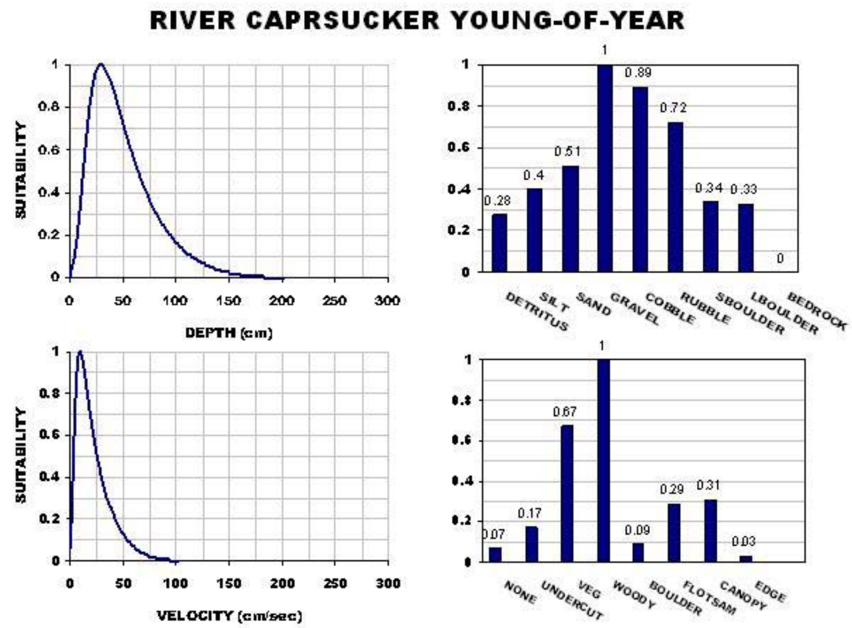

Figure 106. Habitat suitability curves and preference histograms for river carpsucker young-of-year.

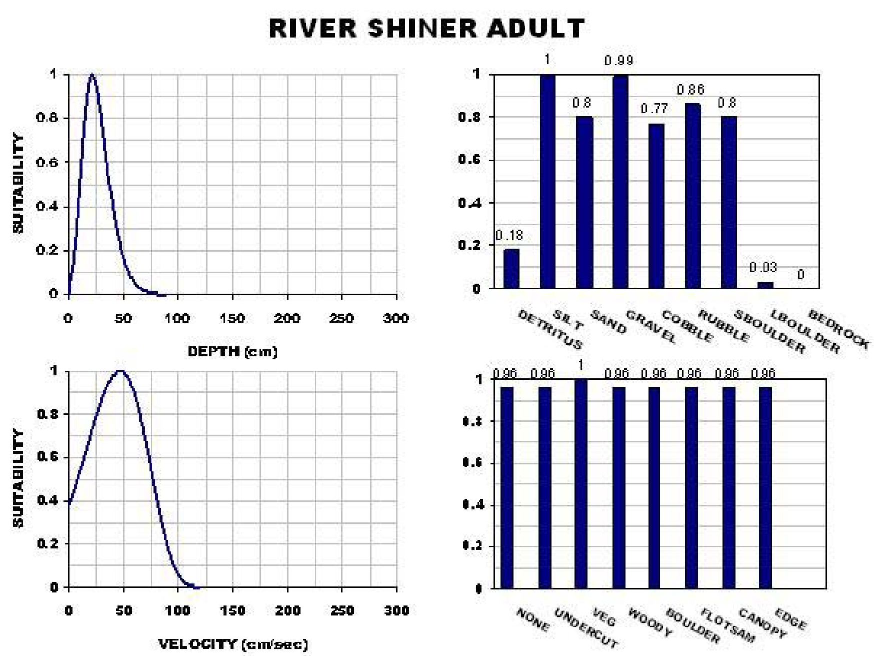

Figure 107. Habitat suitability curves and preference histograms for river shiner adult.

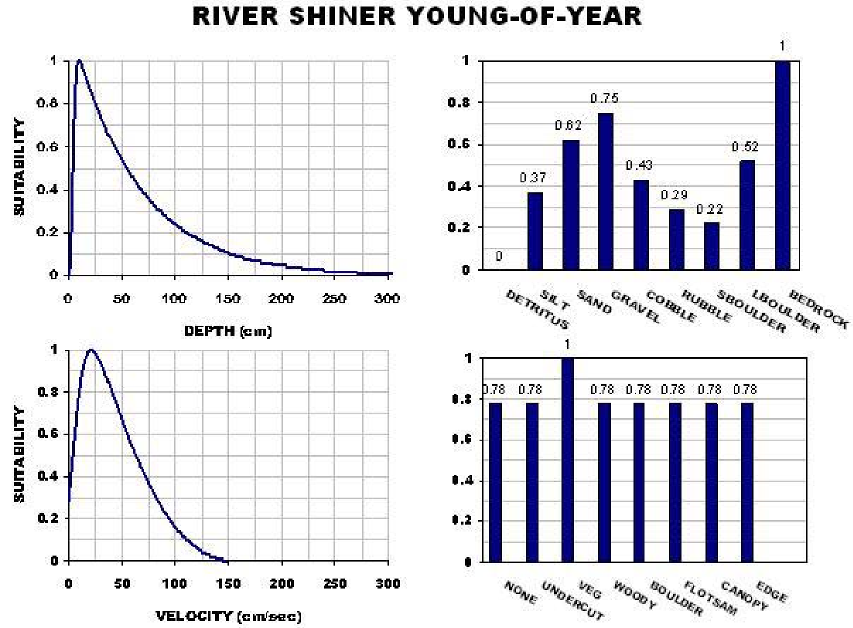

Figure 108. Habitat suitability curves and preference histograms for river shiner young-of-year.

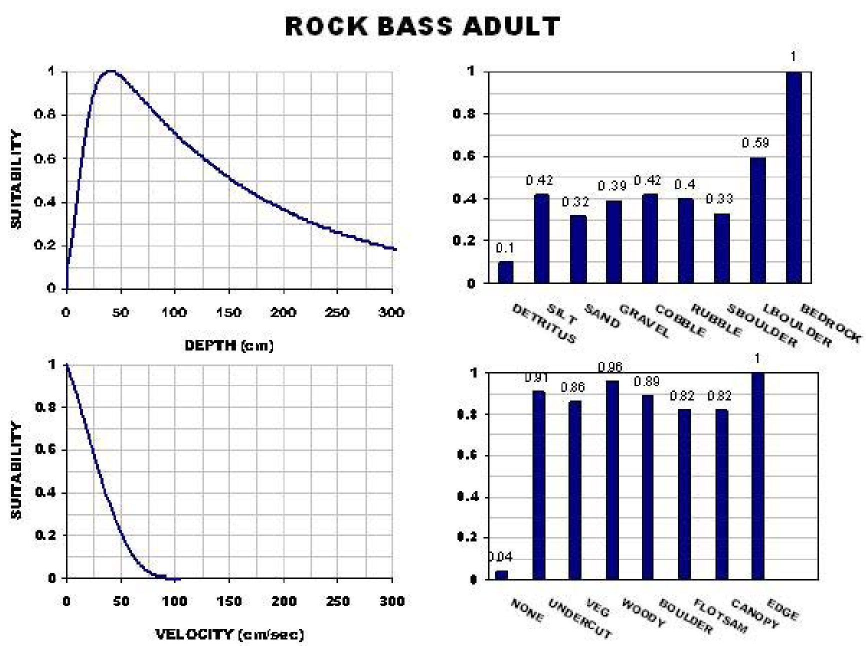

Figure 109. Habitat suitability curves and preference histograms for rock bass adult.

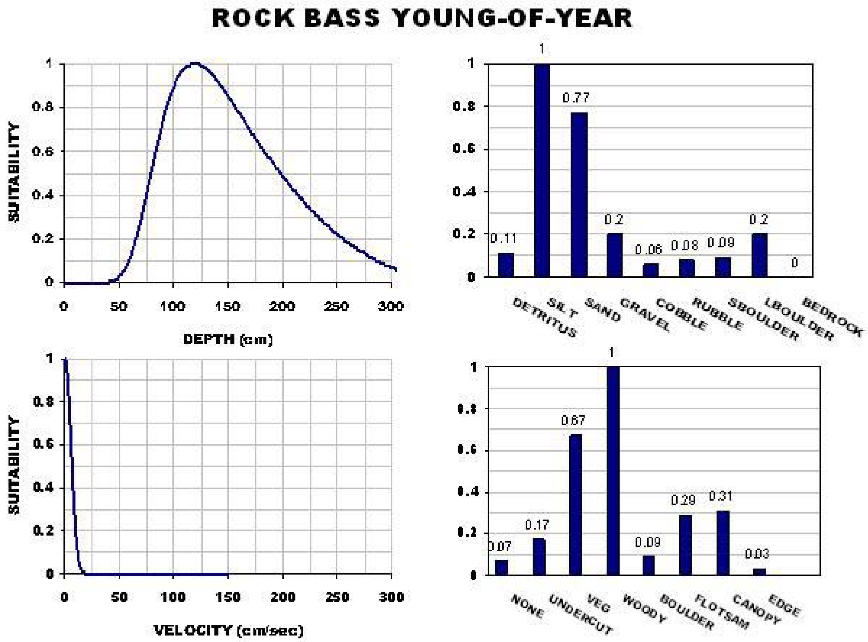

Figure 110. Habitat suitability curves and preference histograms for rock bass young-of-year.

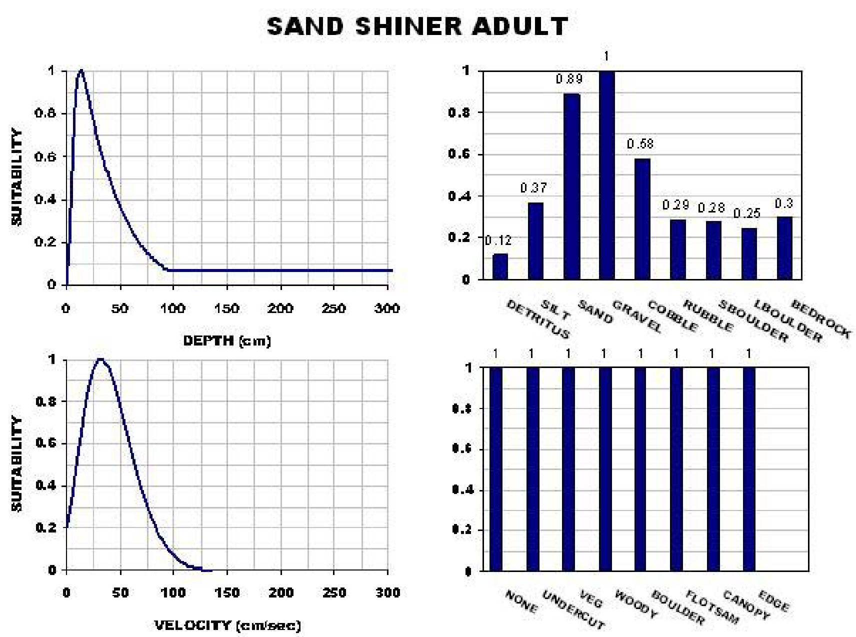

Figure 111. Habitat suitability curves and preference histograms for sand shiner adult.

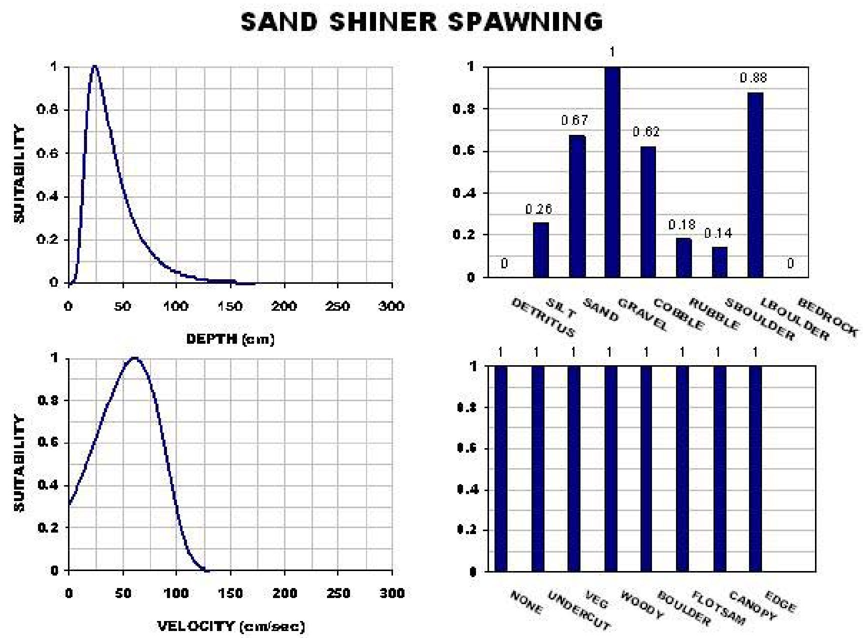

Figure 112. Habitat suitability curves and preference histograms for spawning sand shiner.

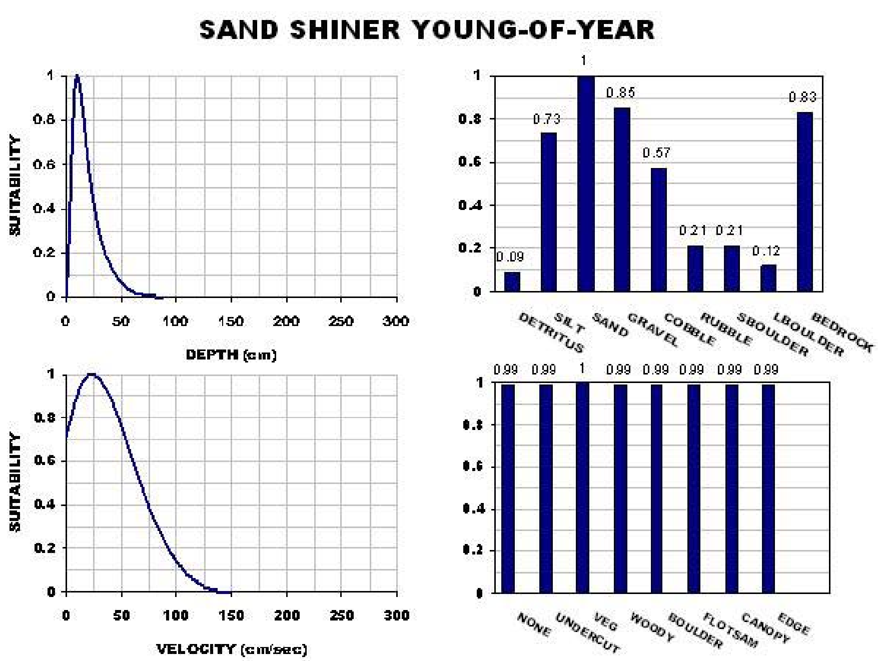

Figure 113. Habitat suitability curves and preference histograms for sand shiner young-of-year.

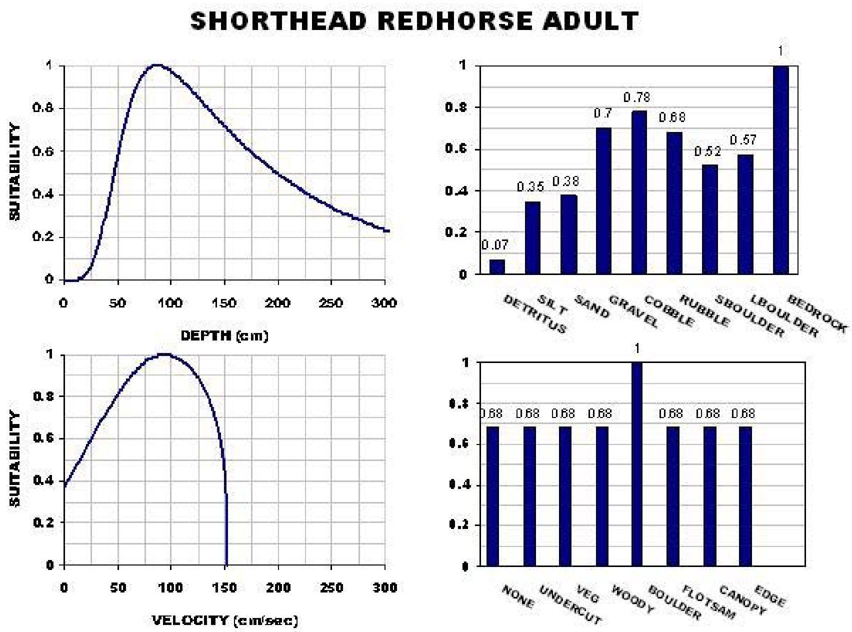

Figure 114. Habitat suitability curves and preference histograms for shorthead redhorse adult.

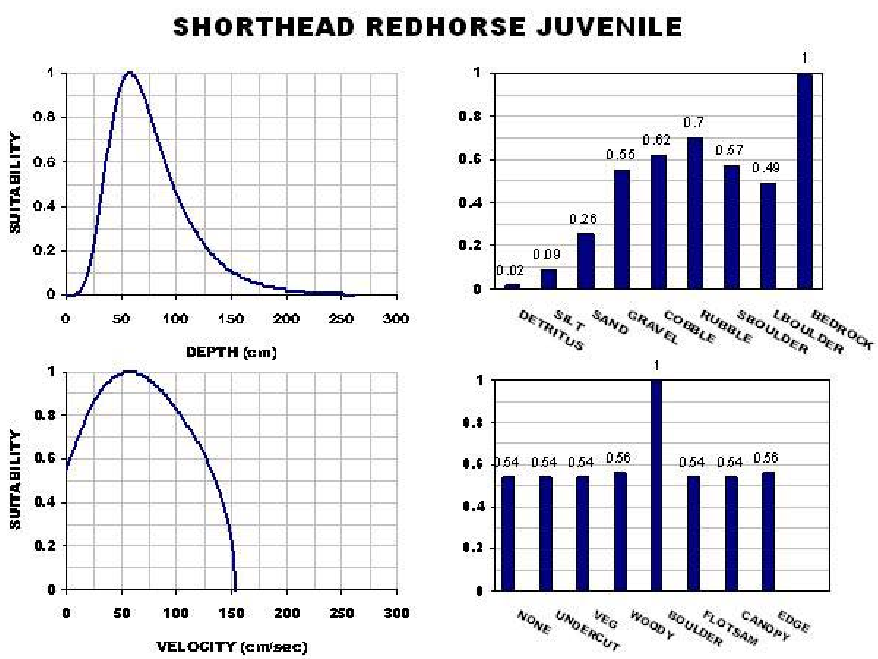

Figure 115. Habitat suitability curves and preference histograms for shorthead redhorse juvenile.

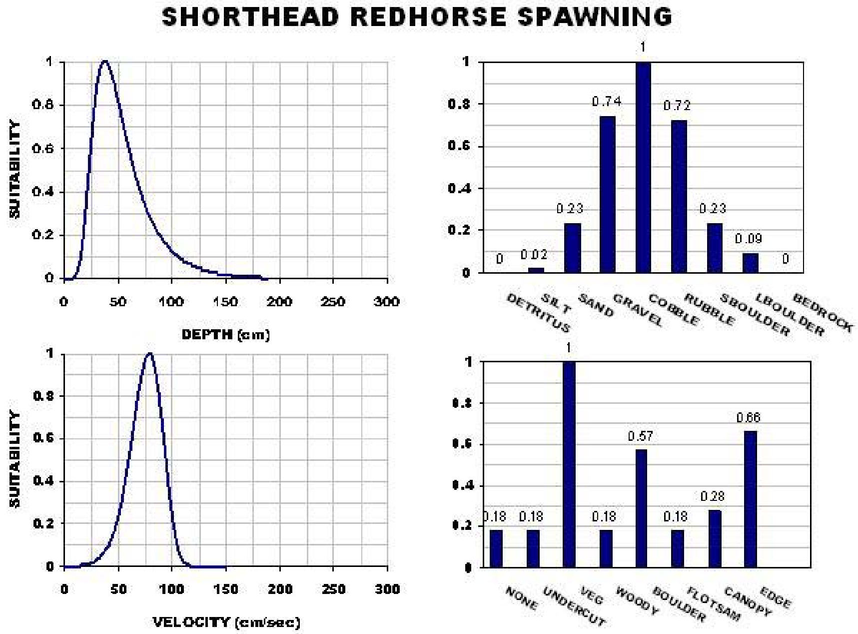

Figure 116. Habitat suitability curves and preference histograms for spawning shorthead redhorse.

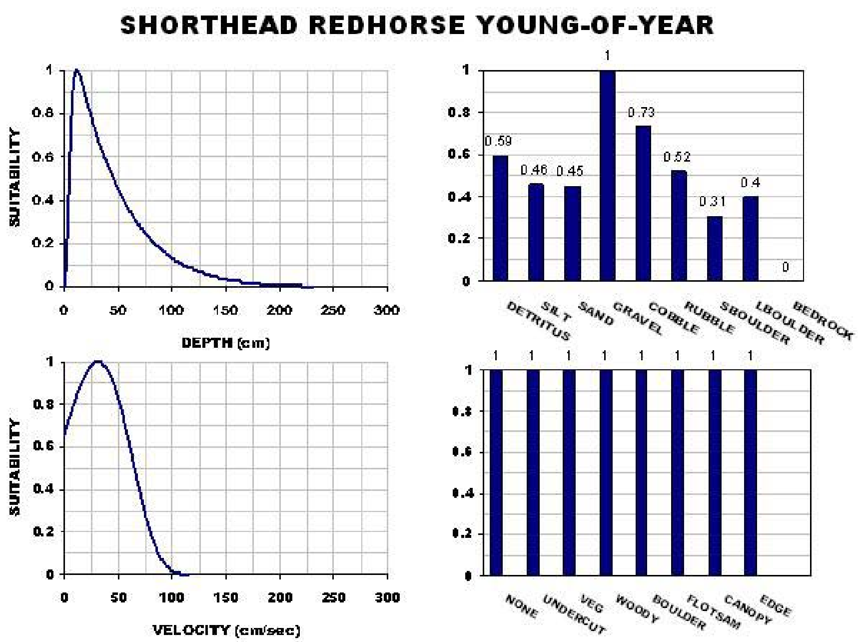

Figure 117. Habitat suitability curves and preference histograms for shorthead redhorse young-of-year.

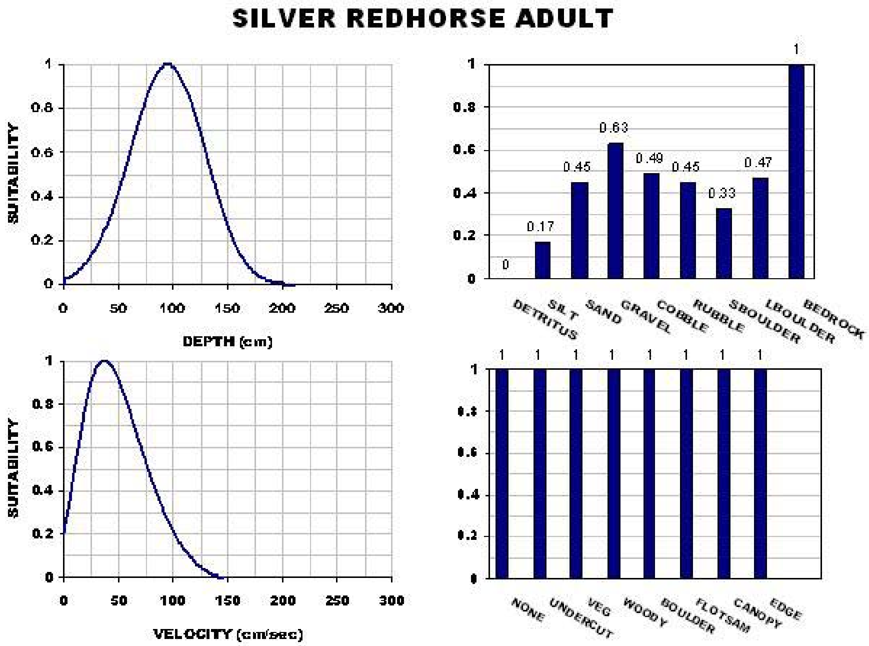

Figure 118. Habitat suitability curves and preference histograms for silver redhorse adult.

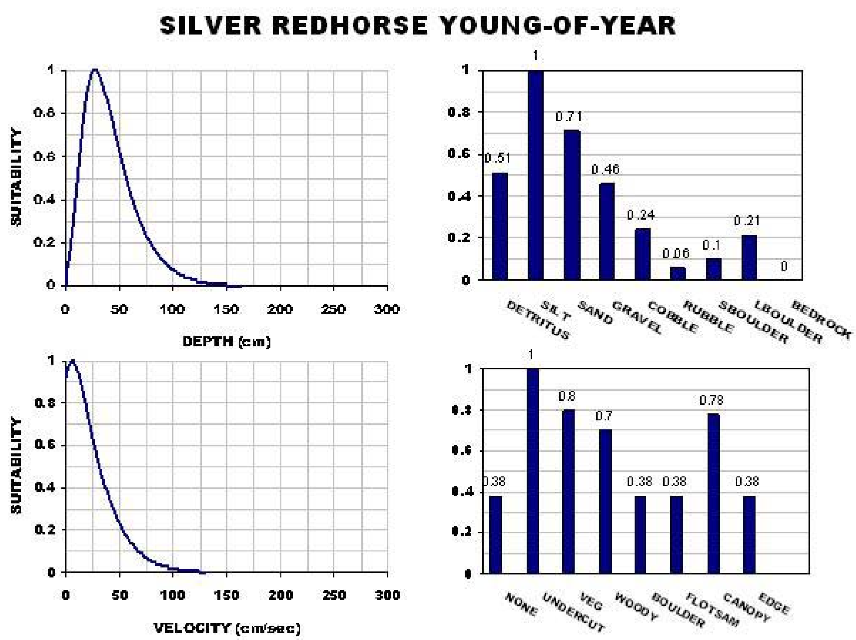

Figure 119. Habitat suitability curves and preference histograms for silver redhorse young-of-year.

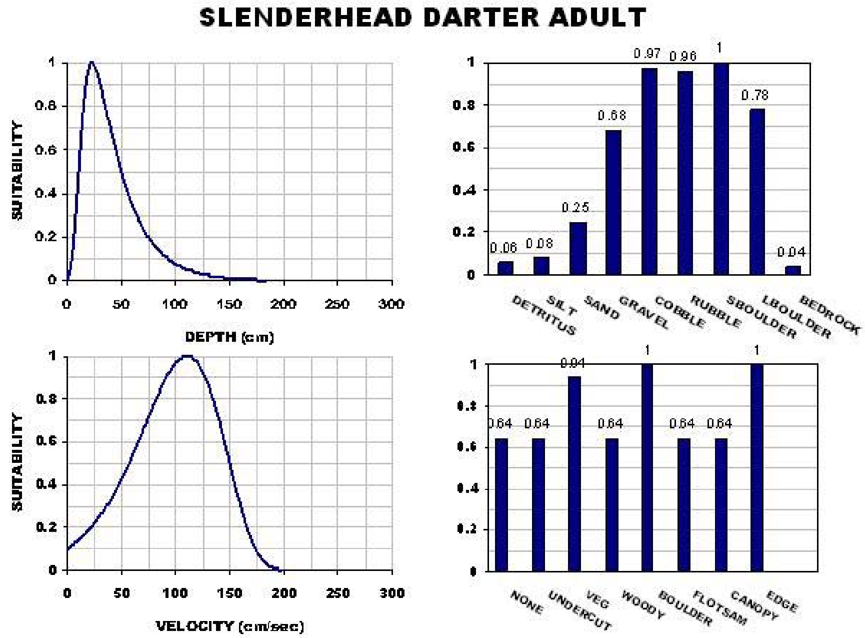

Figure 120. Habitat suitability curves and preference histograms for slenderhead darter adult.

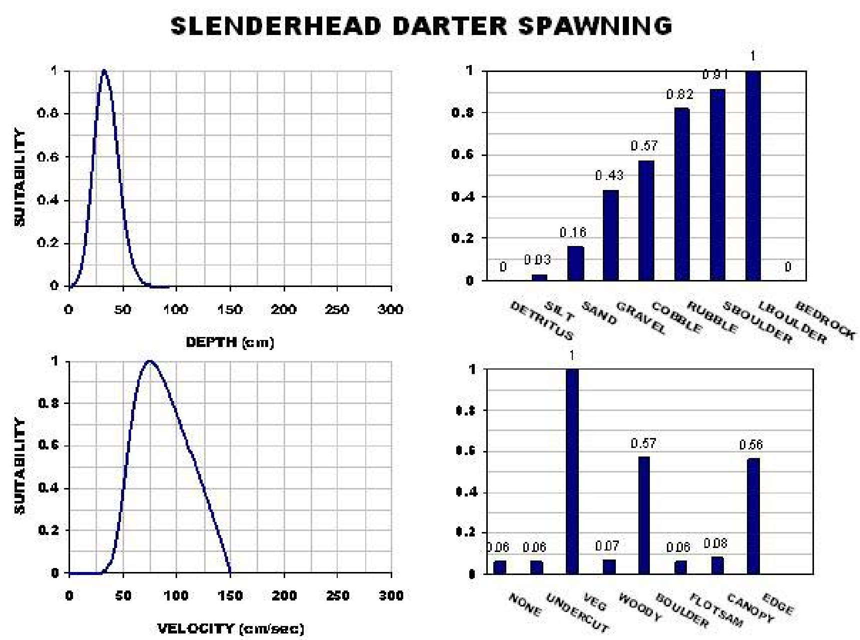

Figure 121. Habitat suitability curves and preference histograms for spawning slenderhead darter.

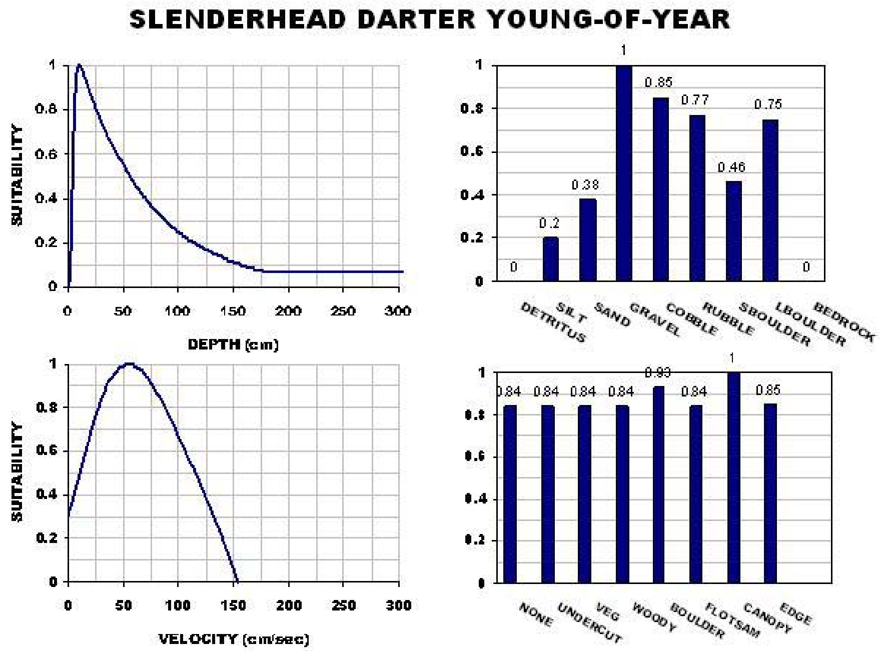

Figure 122. Habitat suitability curves and preference histograms for slenderhead darter young-of-year.

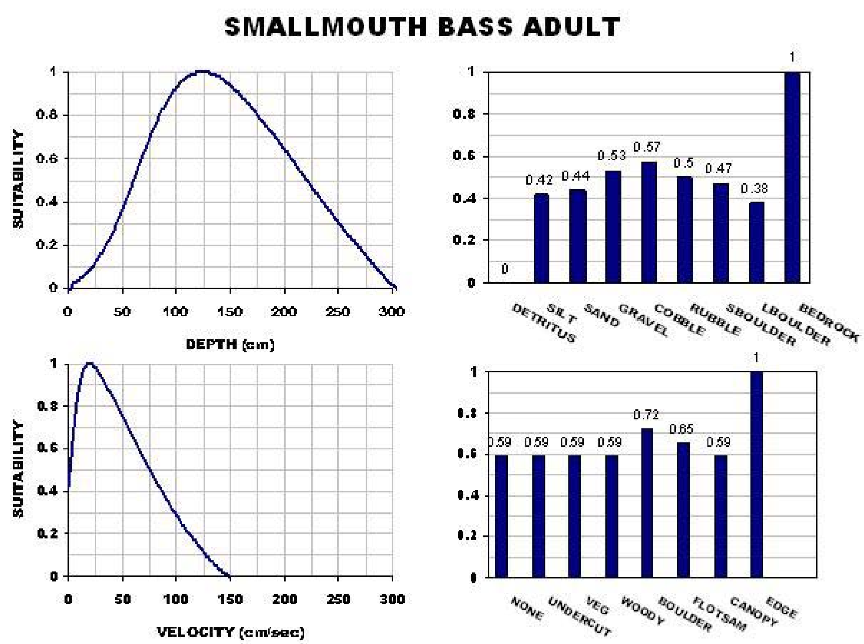

Figure 123. Habitat suitability curves and preference histograms for smallmouth bass adult.

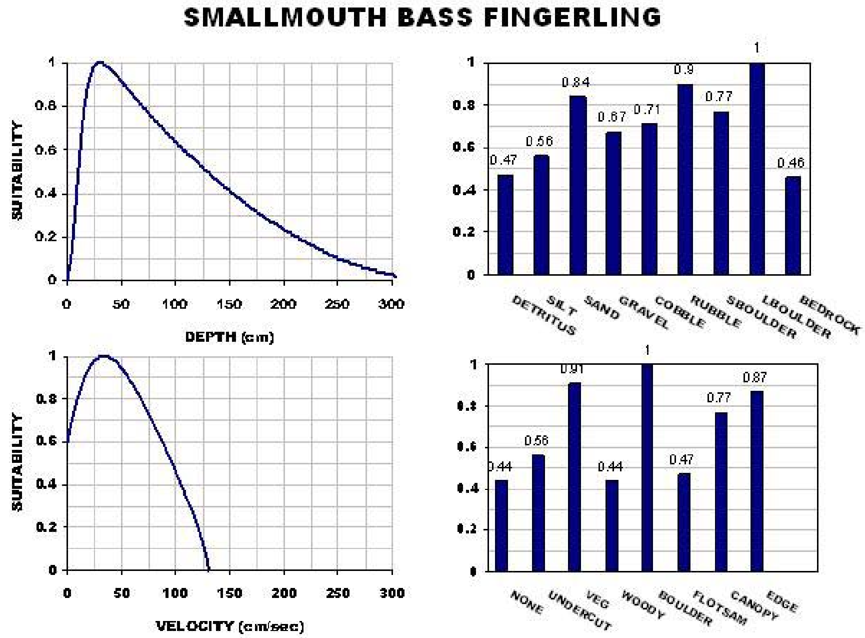

Figure 124. Habitat suitability curves and preference histograms for smallmouth bass fingerling.

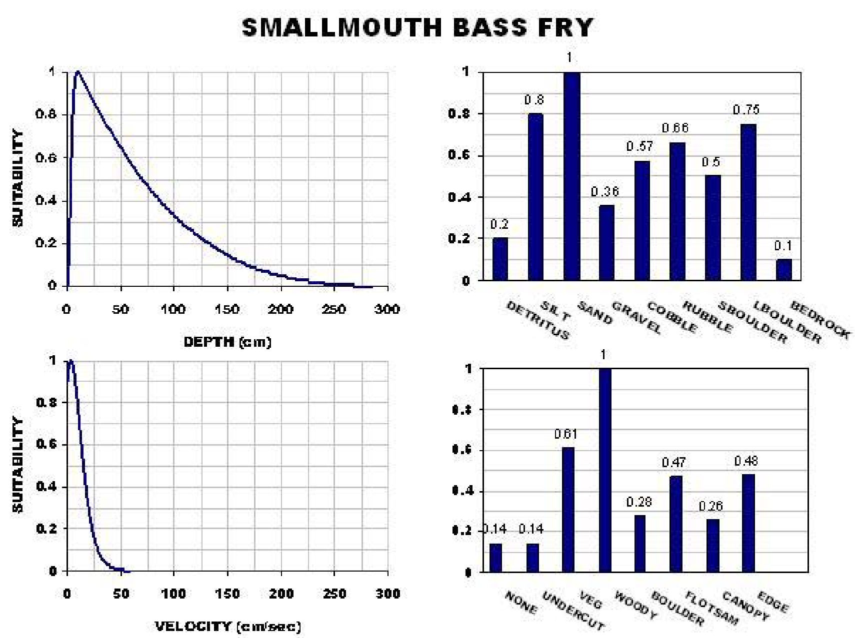

Figure 125. Habitat suitability curves and preference histograms for smallmouth bass fry.

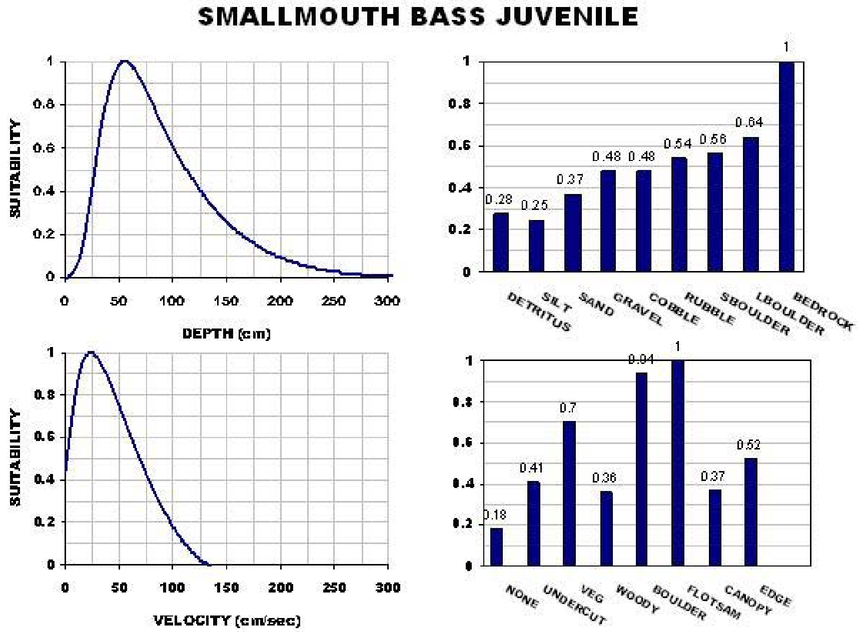

Figure 126. Habitat suitability curves and preference histograms for smallmouth bass juvenile.

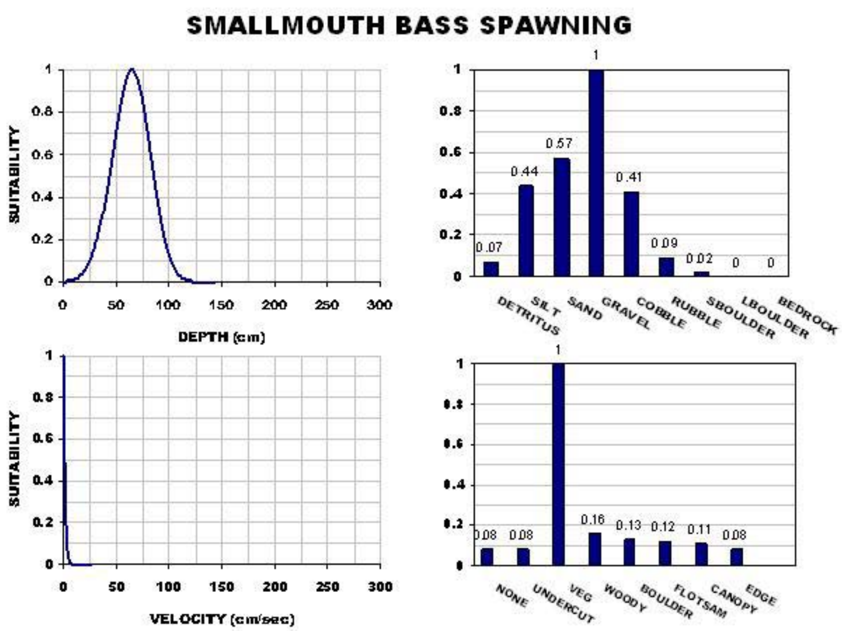

Figure 127. Habitat suitability curves and preference histograms for spawning smallmouth bass.

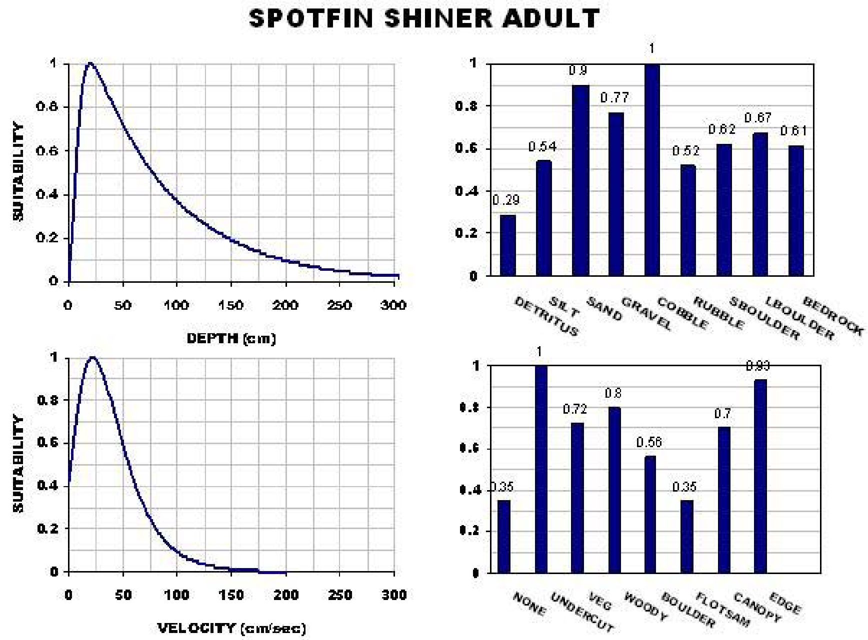

Figure 128. Habitat suitability curves and preference histograms for spotfin shiner adult.

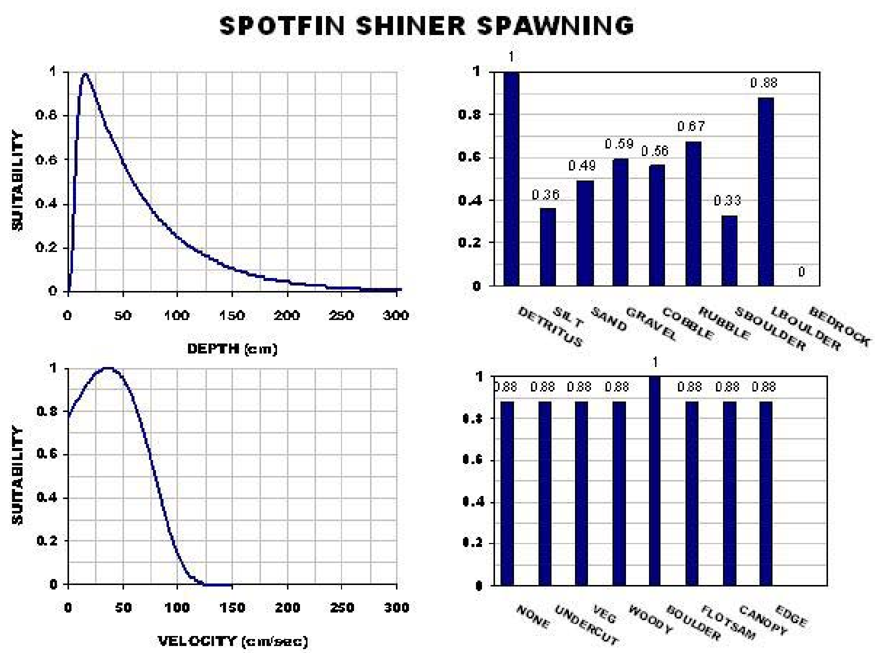

Figure 129. Habitat suitability curves and preference histograms for spawning spotfin shiner.

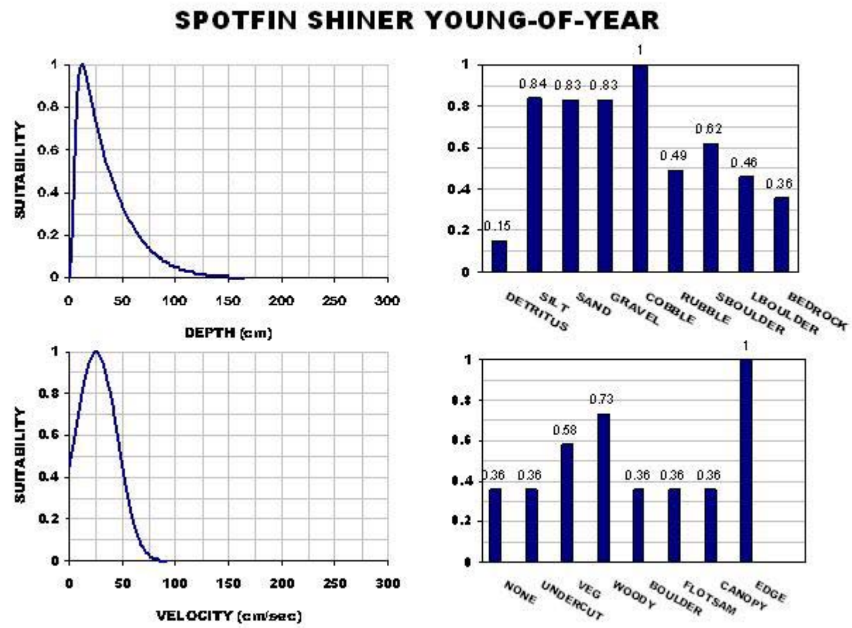

Figure 130. Habitat suitability curves and preference histograms for spotfin shiner young-of-year.

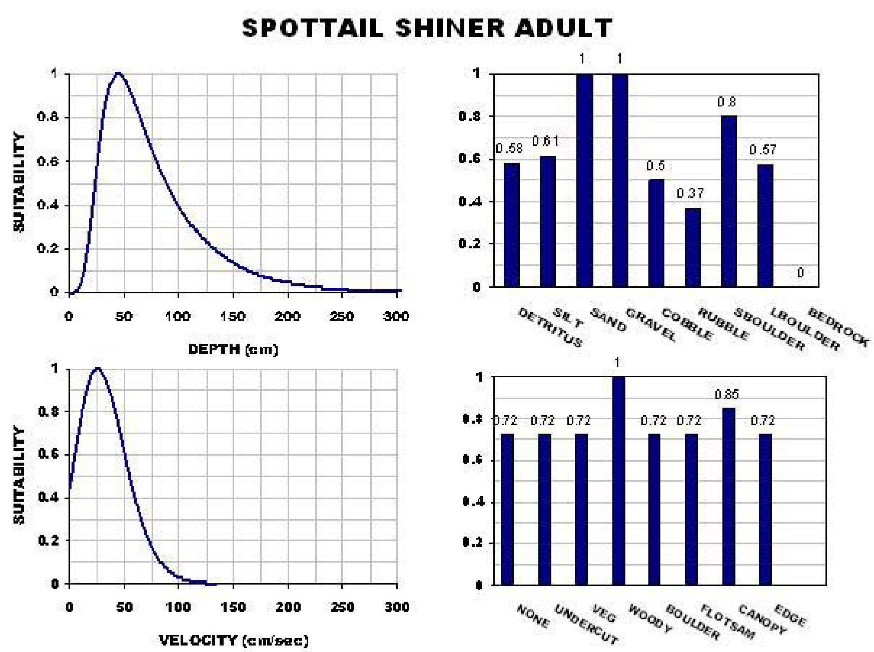

Figure 131. Habitat suitability curves and preference histograms for spottail shiner adult.

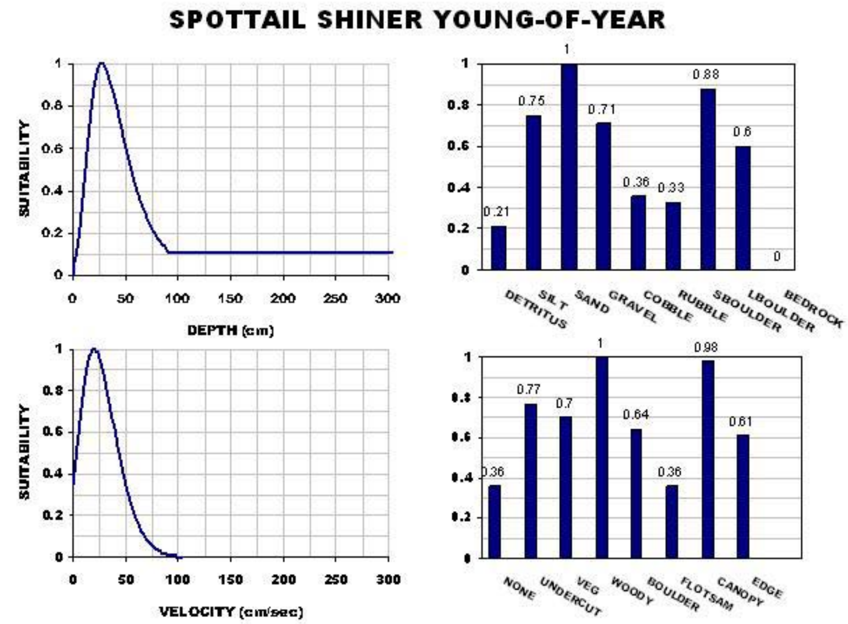

Figure 132. Habitat suitability curves and preference histograms for spottail shiner young-of-year.

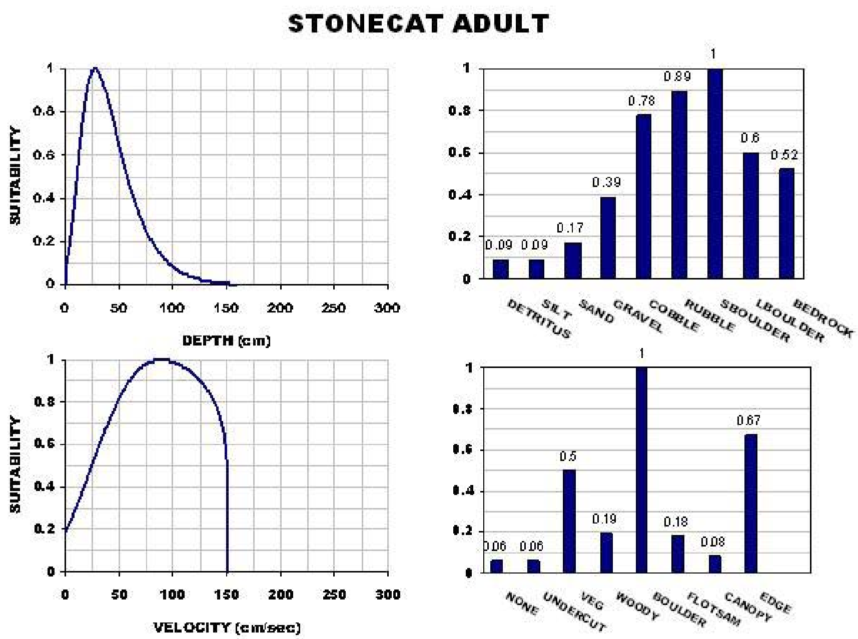

Figure 133. Habitat suitability curves and preference histograms for stonecat adult.

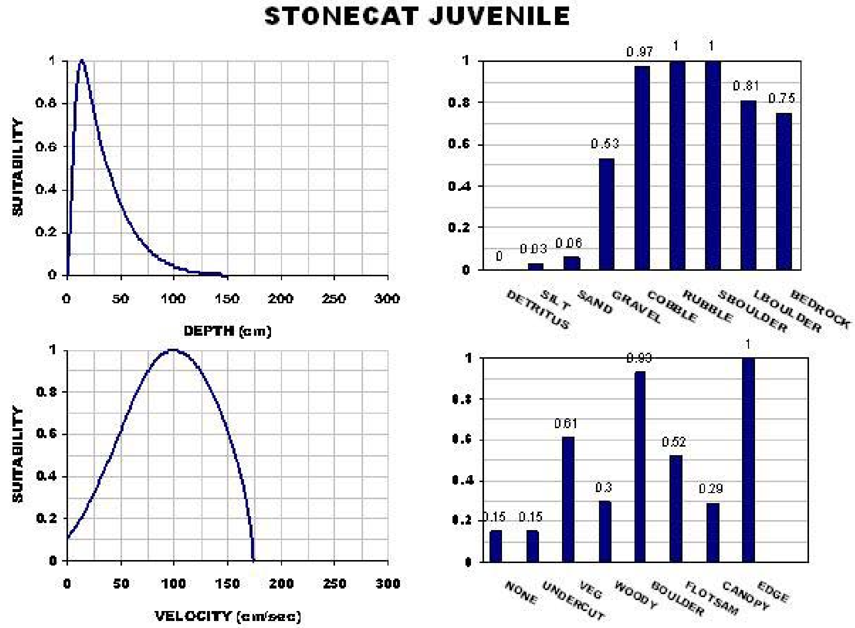

Figure 134. Habitat suitability curves and preference histograms for stonecat juvenile.

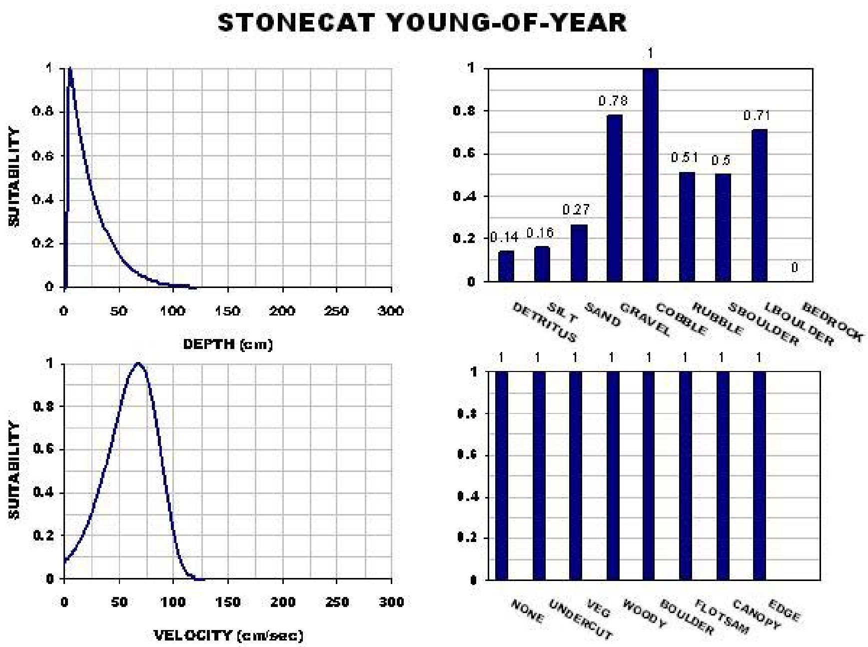

Figure 135. Habitat suitability curves and preference histograms for stonecat young-of-year.

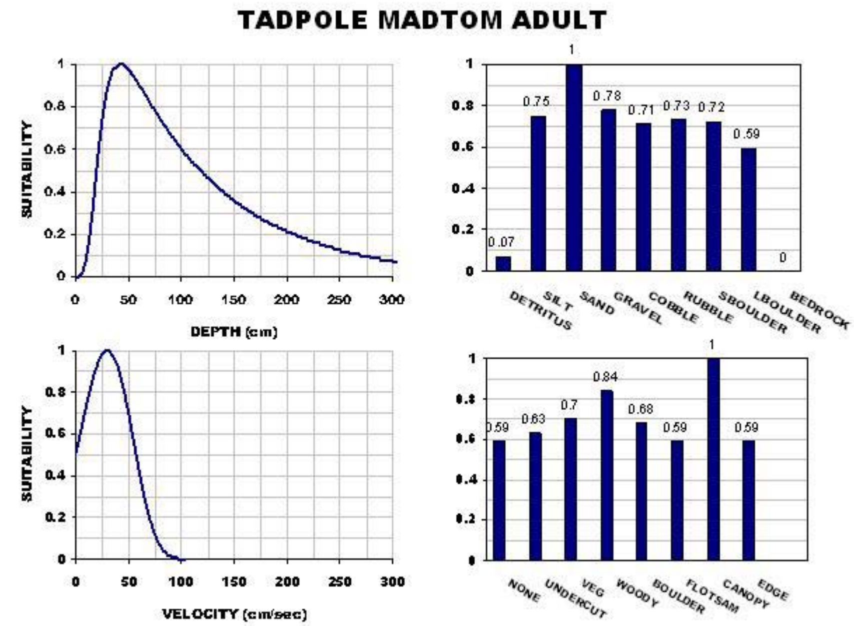

Figure 136. Habitat suitability curves and preference histograms for tadpole madtom adult.

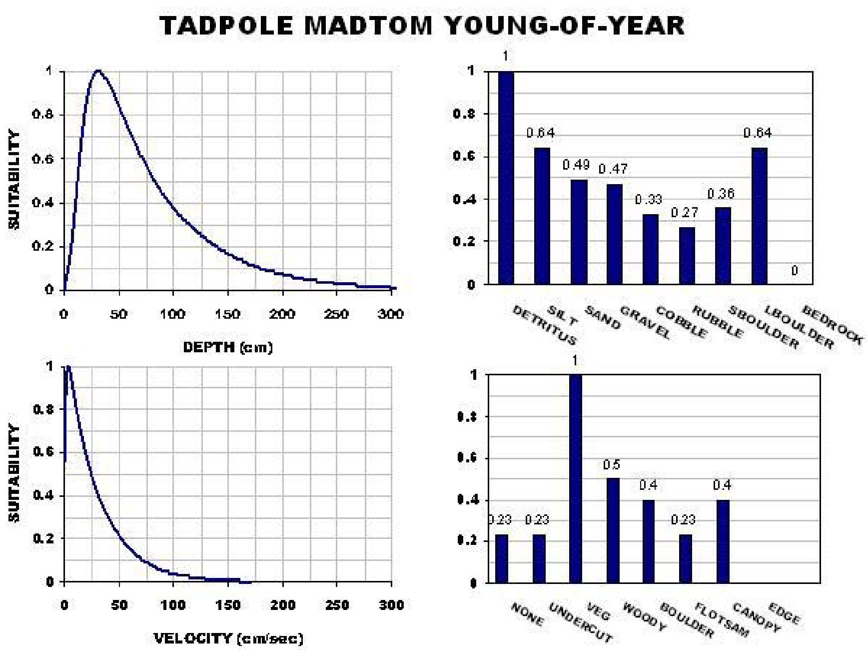

Figure 137. Habitat suitability curves and preference histograms for tadpole madtom young-of-year.

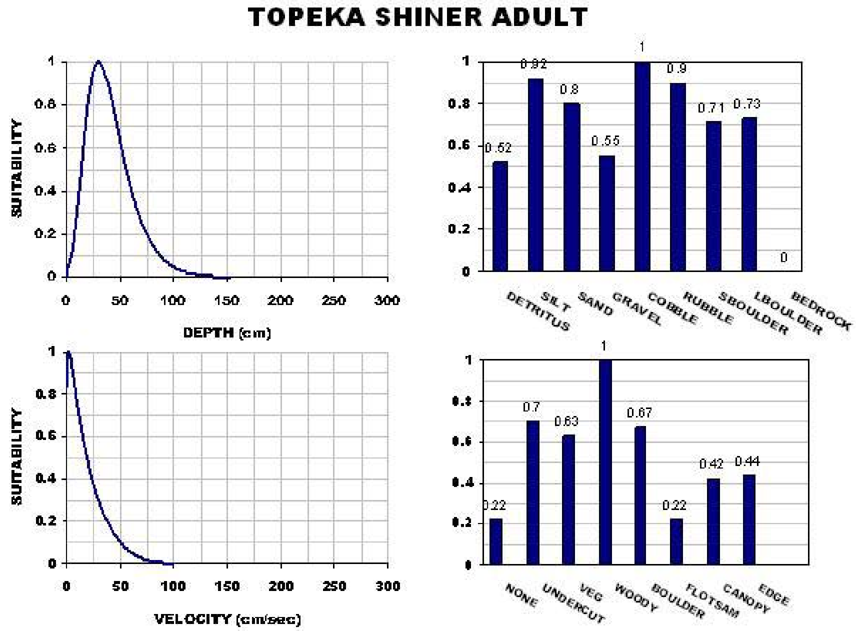

Figure 138. Habitat suitability curves and preference histograms for Topeka shiner adult.

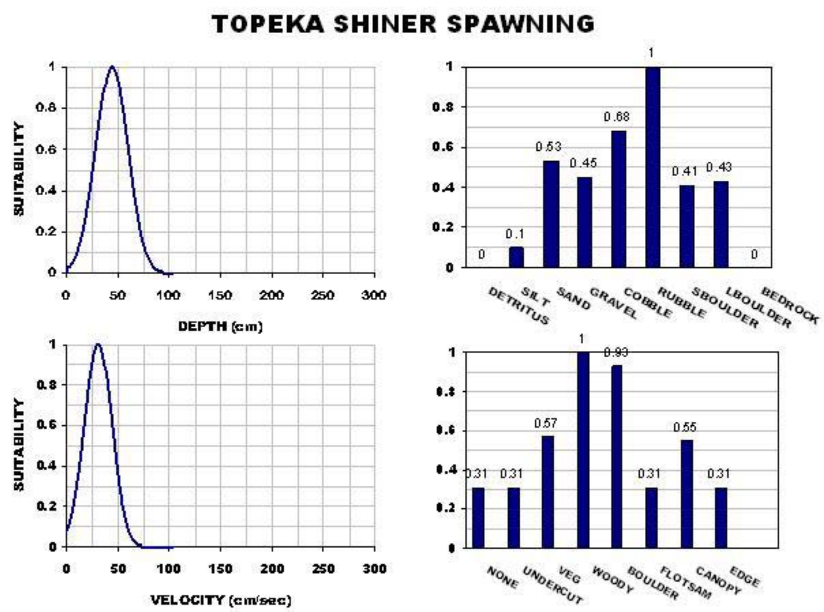

Figure 139. Habitat suitability curves and preference histograms for spawning Topeka shiner.

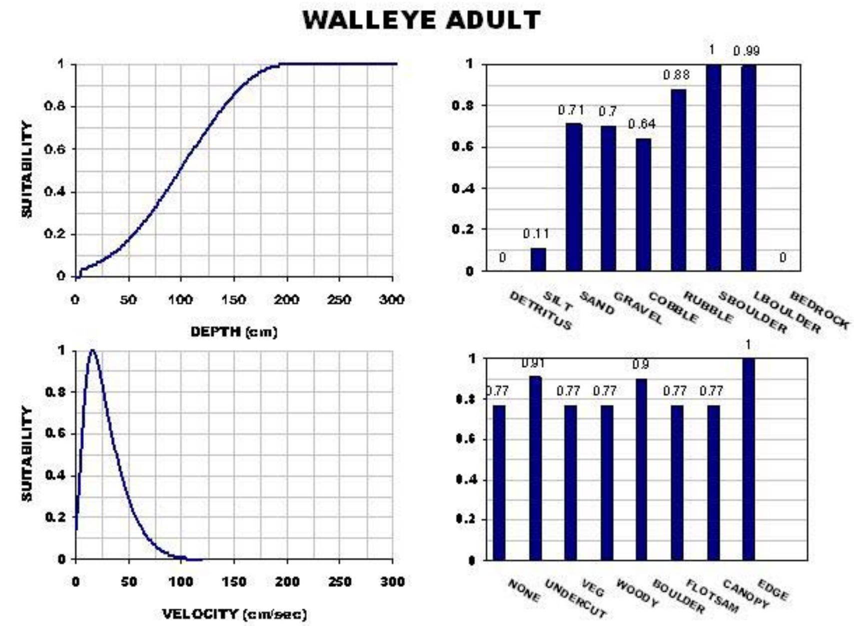

Figure 140. Habitat suitability curves and preference histograms for walleye adult.

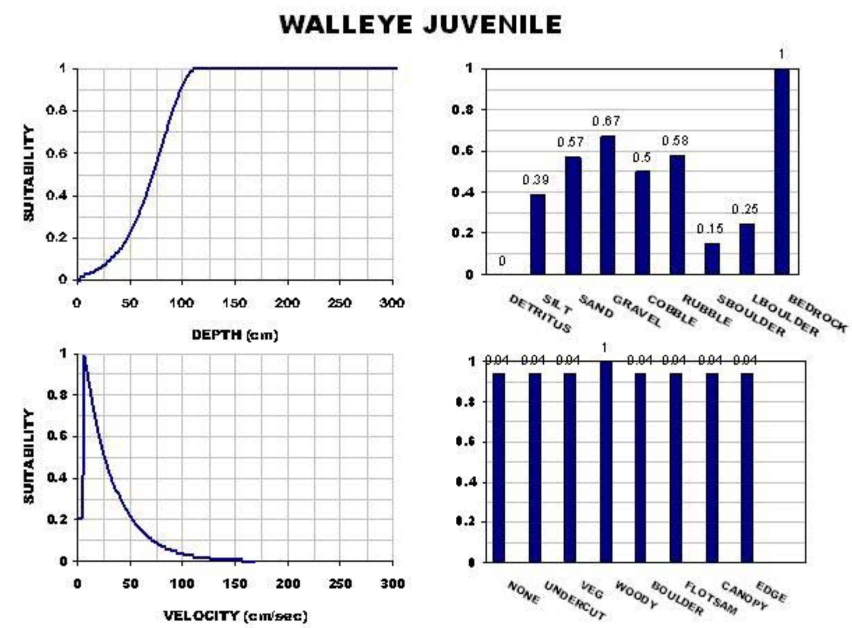

Figure 141. Habitat suitability curves and preference histograms for walleye juvenile.

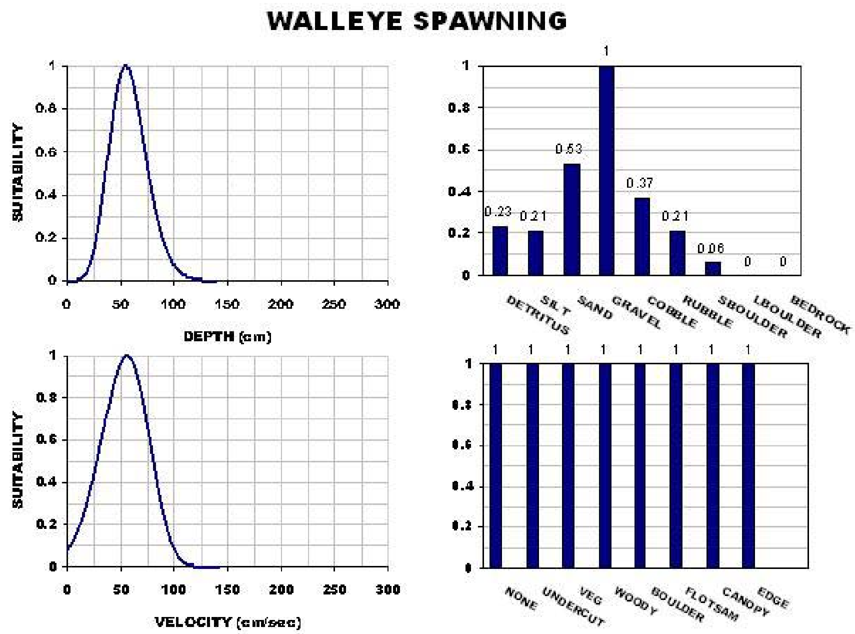

Figure 142. Habitat suitability curves and preference histograms for spawning walleye.

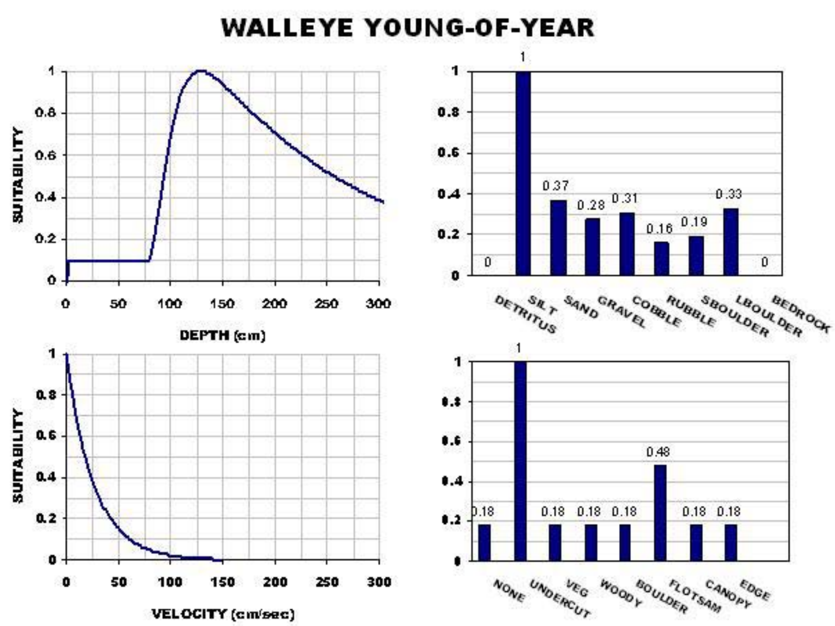

Figure 143. Habitat suitability curves and preference histograms for walleye young-of-year.

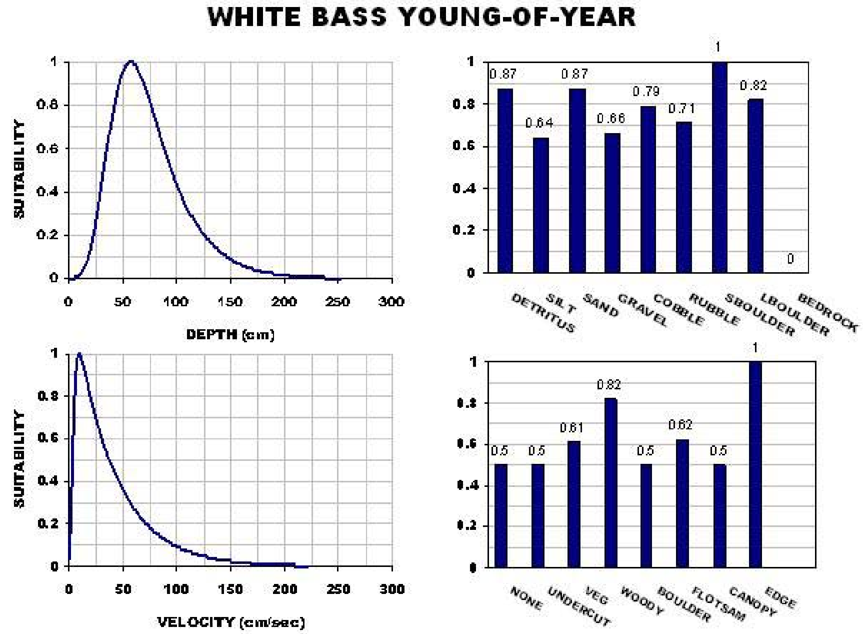

Figure 144. Habitat suitability curves and preference histograms for white bass young-of-year.

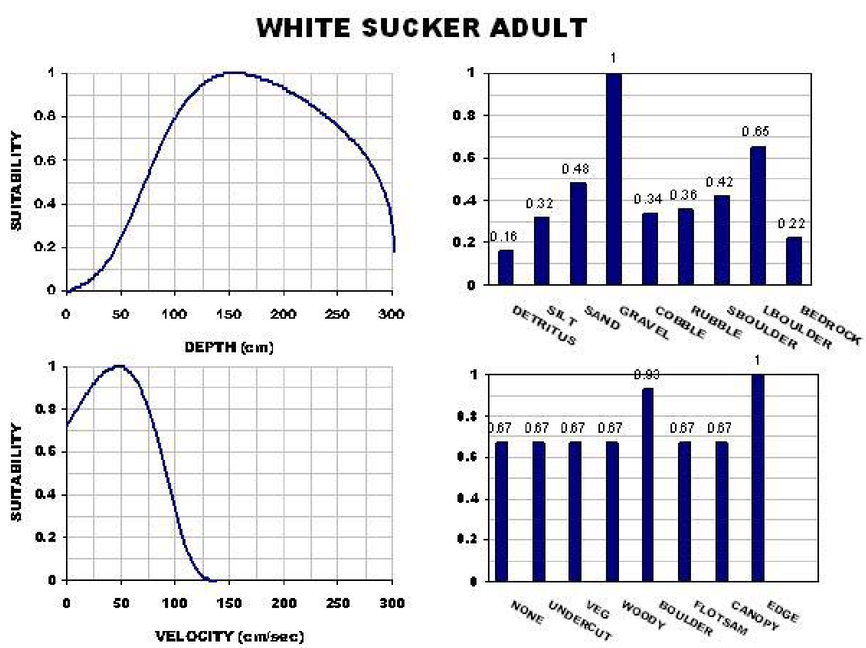

Figure 145. Habitat suitability curves and preference histograms for white sucker adult.

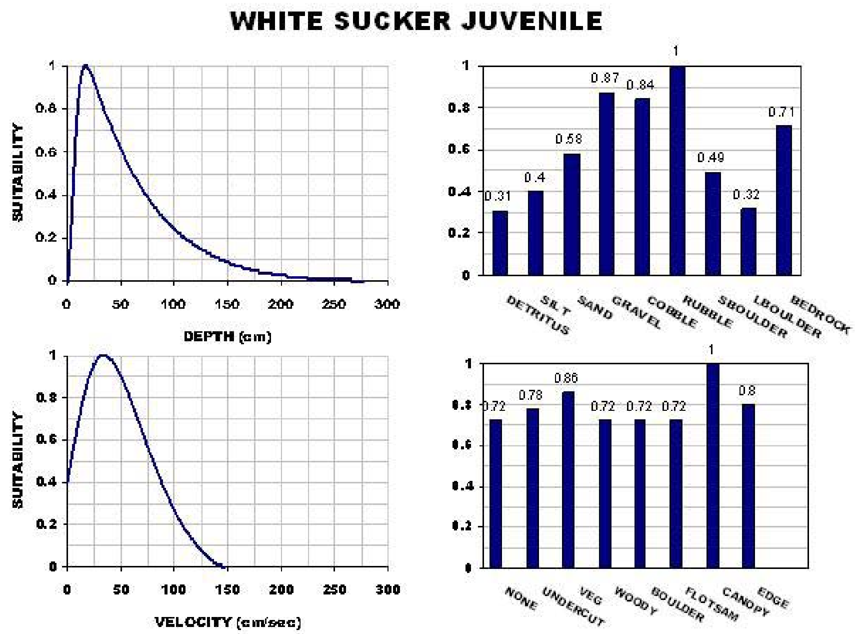

Figure 146. Habitat suitability curves and preference histograms for white sucker juvenile.

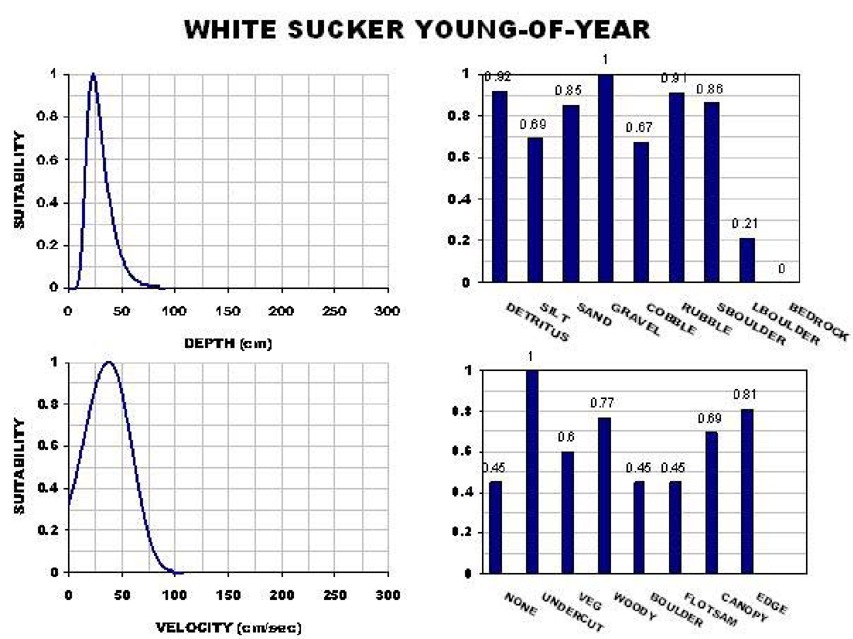

Figure 147. Habitat suitability curves and preference histograms for white sucker young-of-year.

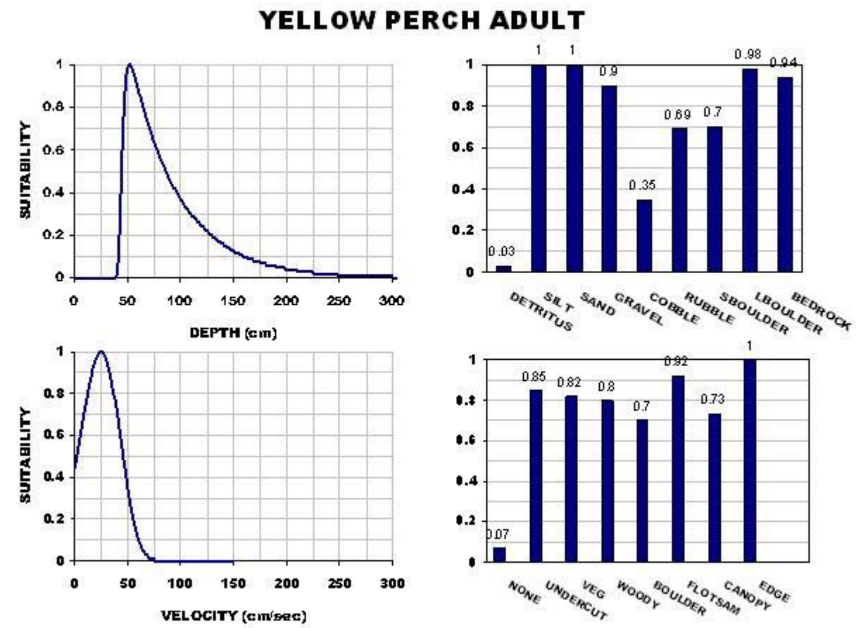

Figure 148. Habitat suitability curves and preference histograms for yellow perch adult.

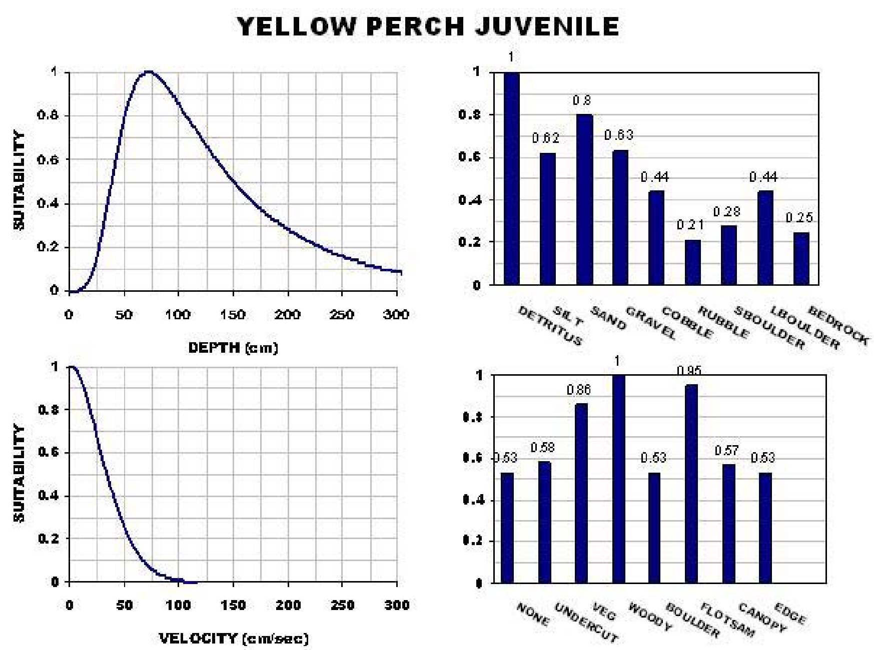

Figure 149. Habitat suitability curves and preference histograms for yellow perch juvenile.

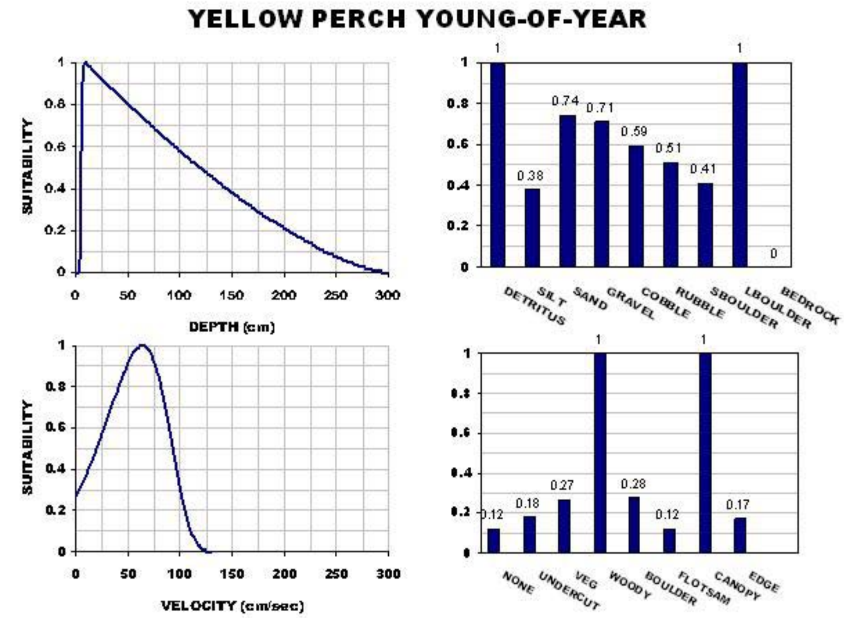

Figure 150. Habitat suitability curves and preference histograms for yellow perch young-of-year.

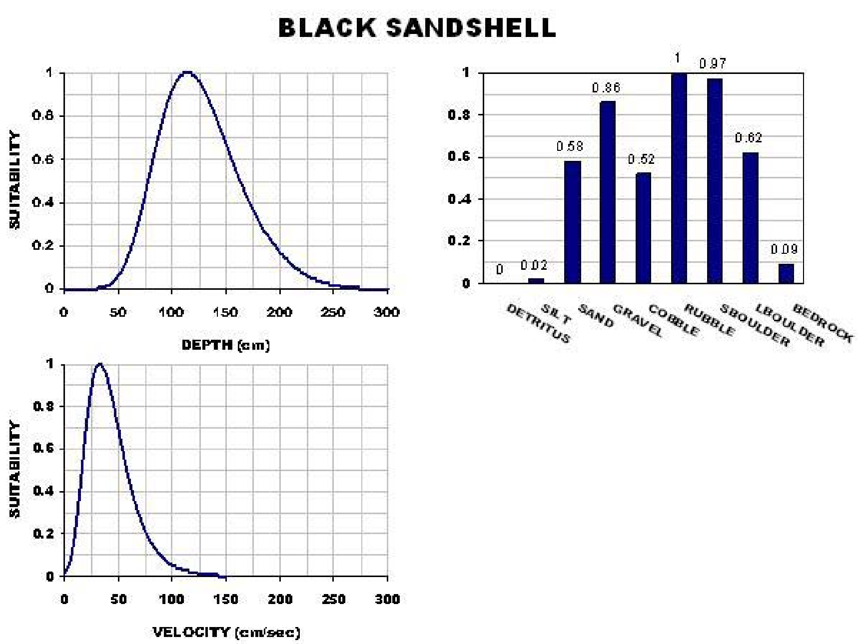

Figure 151. Habitat suitability curves and preference histogram for black sandhell mussels.

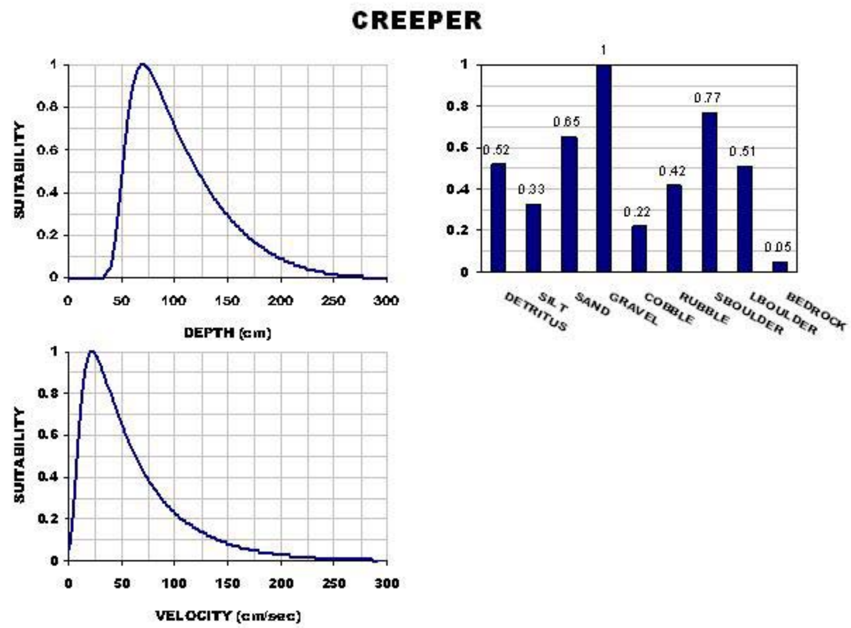

Figure 152. Habitat suitability curves and preference histogram for creeper mussels.

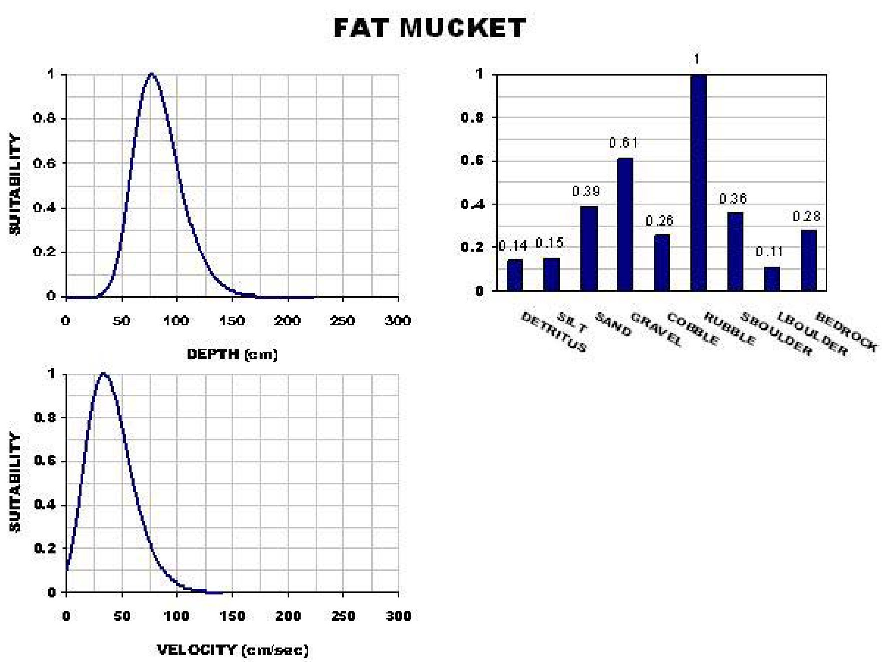

Figure 153. Habitat suitability curves and preference histogram for fat mucket mussels.

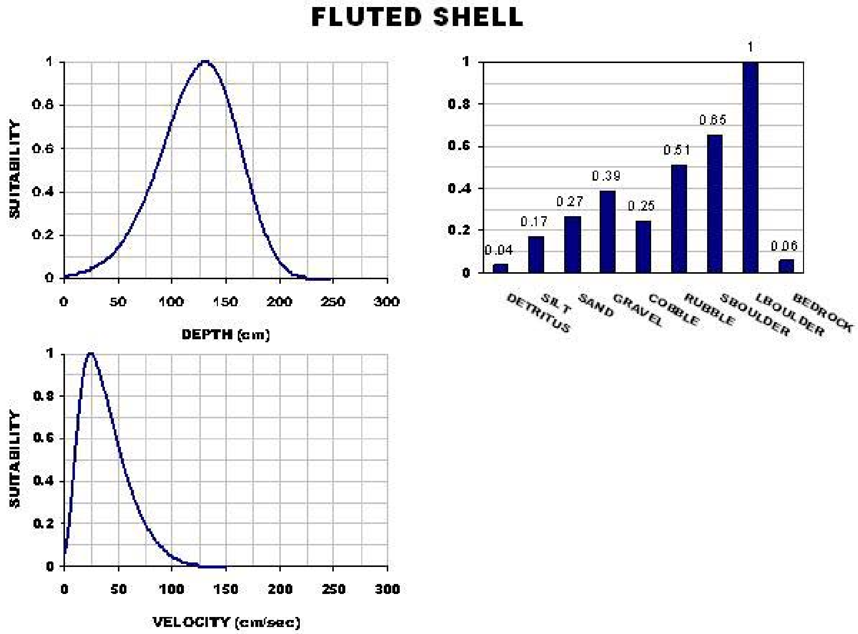

Figure 154. Habitat suitability curves and preference histogram for fluted shell mussels.

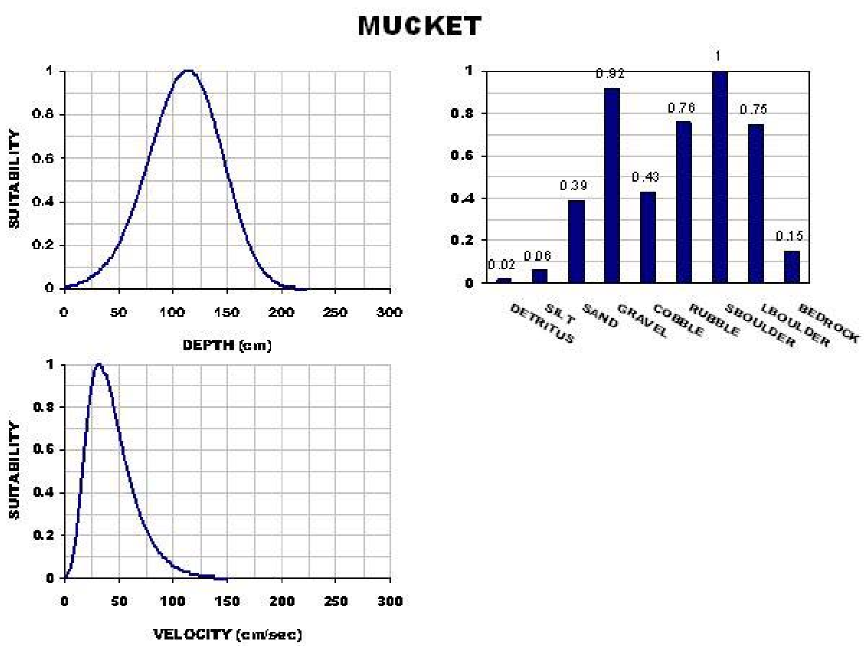

Figure 155. Habitat suitability curves and preference histogram for mucket mussels.

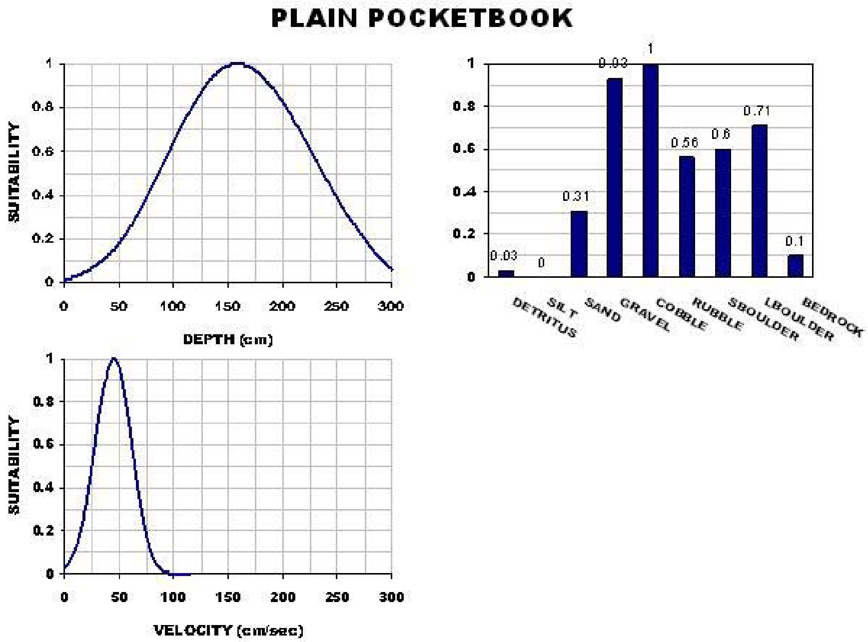

Figure 156. Habitat suitability curves and preference histogram for plain pocketbook mussels.

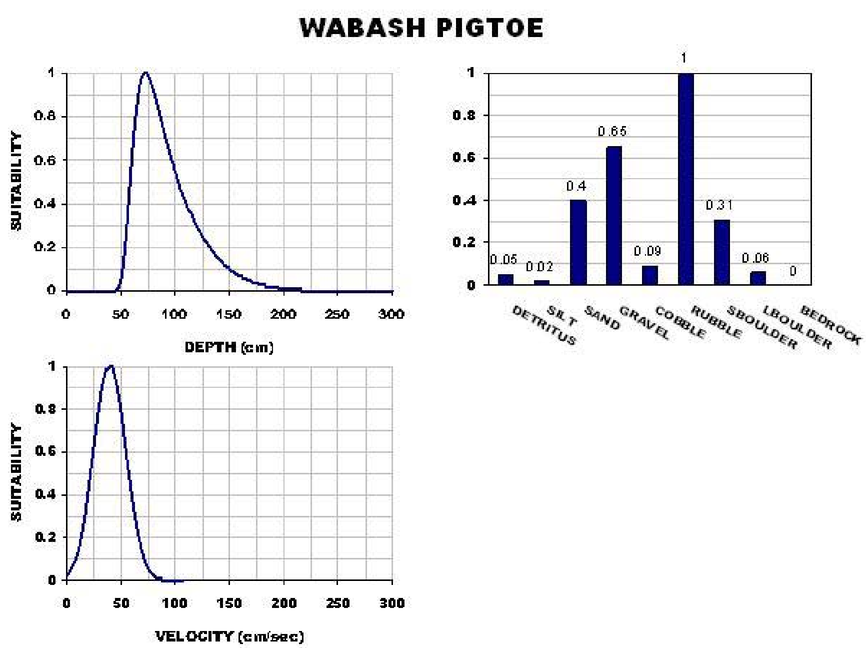

Figure 157. Habitat suitability curves and preference histogram for Wabash pigtoe mussels.

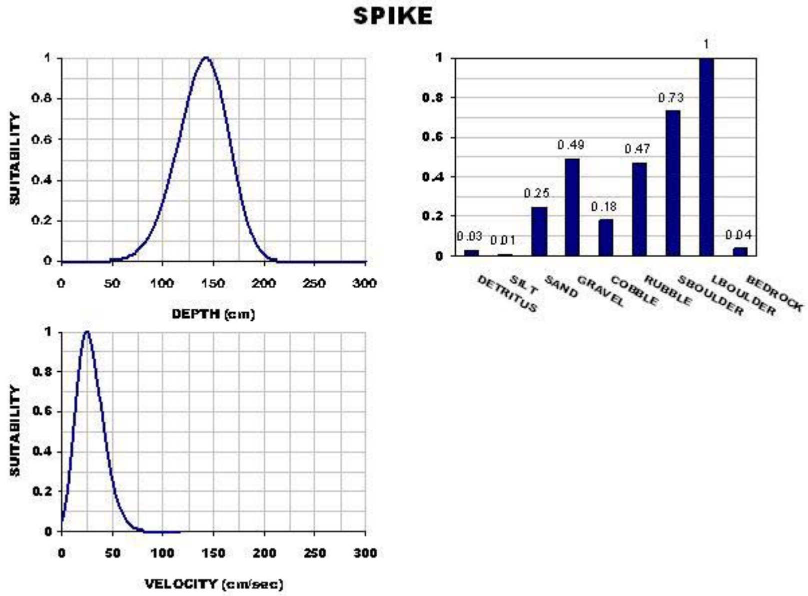

Figure 158. Habitat suitability curves and preference histogram for spike mussels.

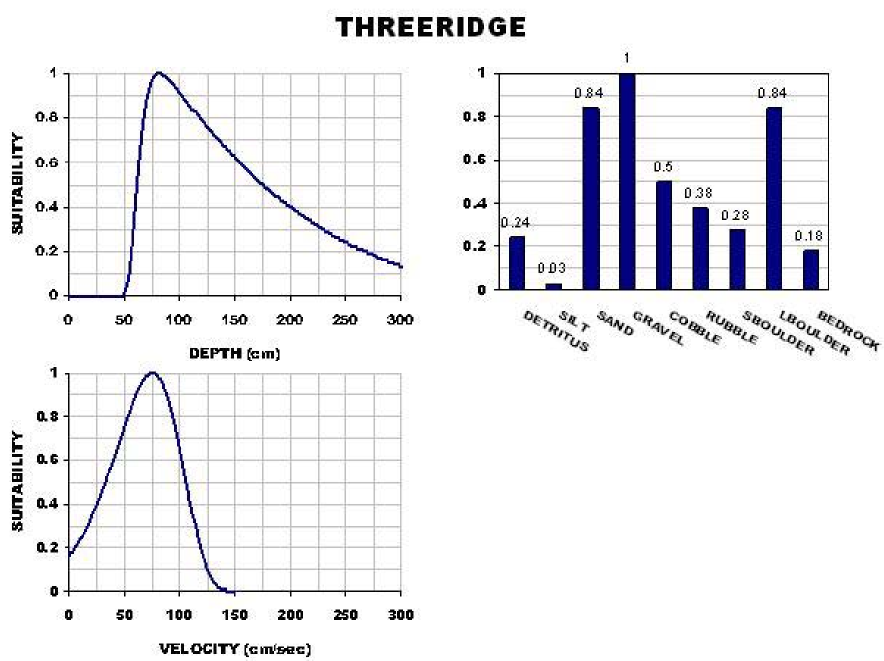

Figure 159. Habitat suitability curves and preference histogram for threeridge mussels.

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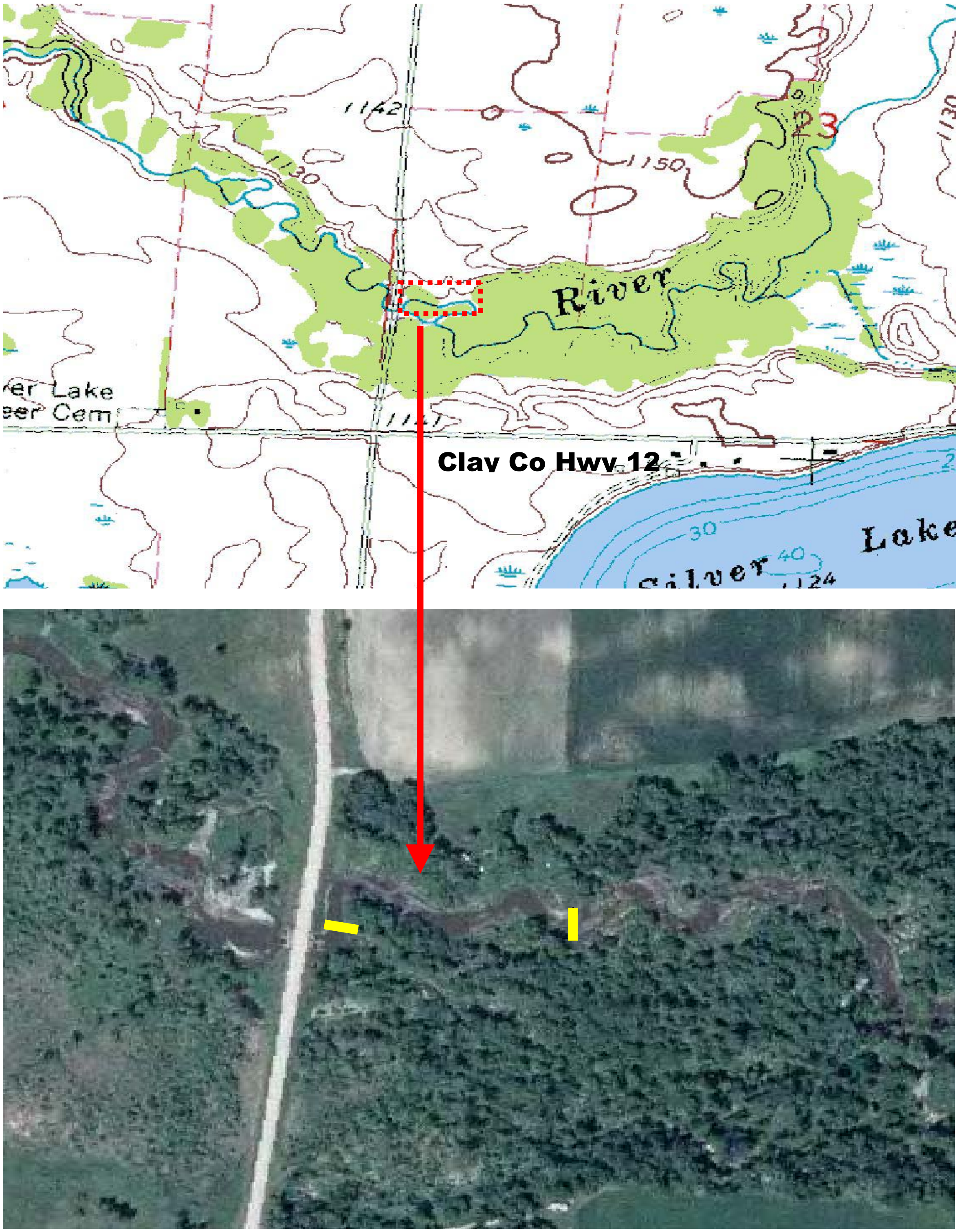
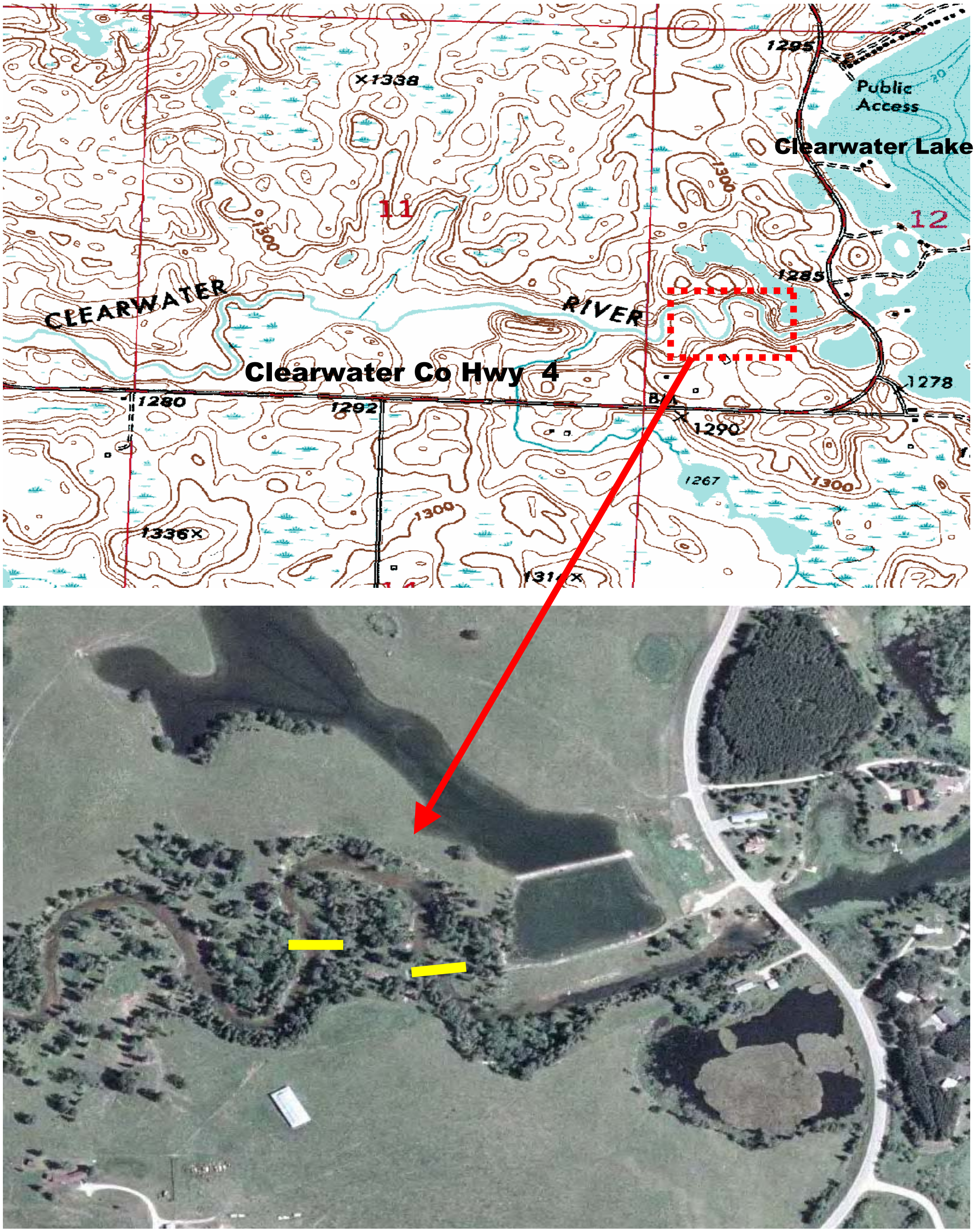
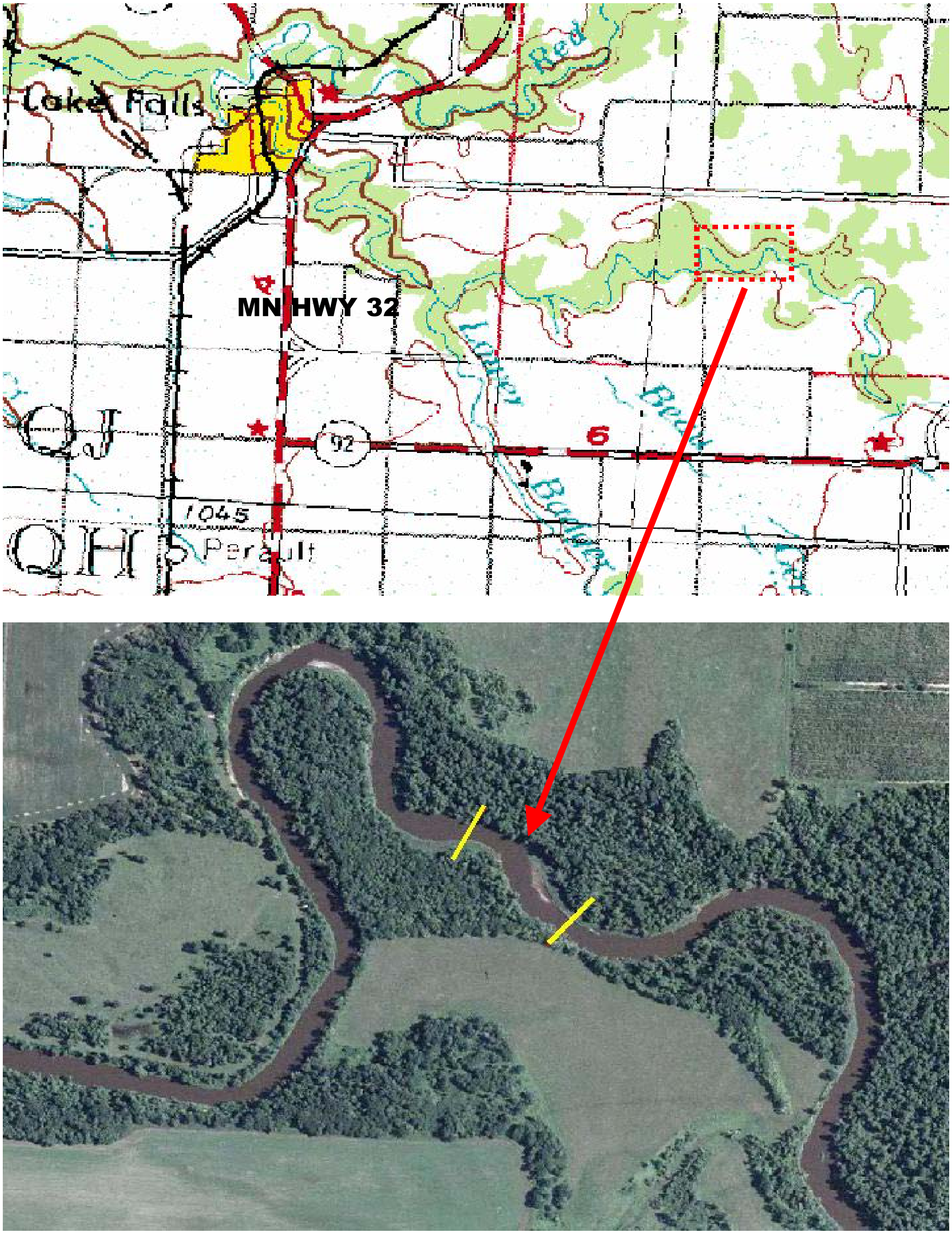
Appendix A1. Topographic map and aerial photograph of the Buffalo River study site. The yellow lines indicate the upper and lower boundaries of the site.



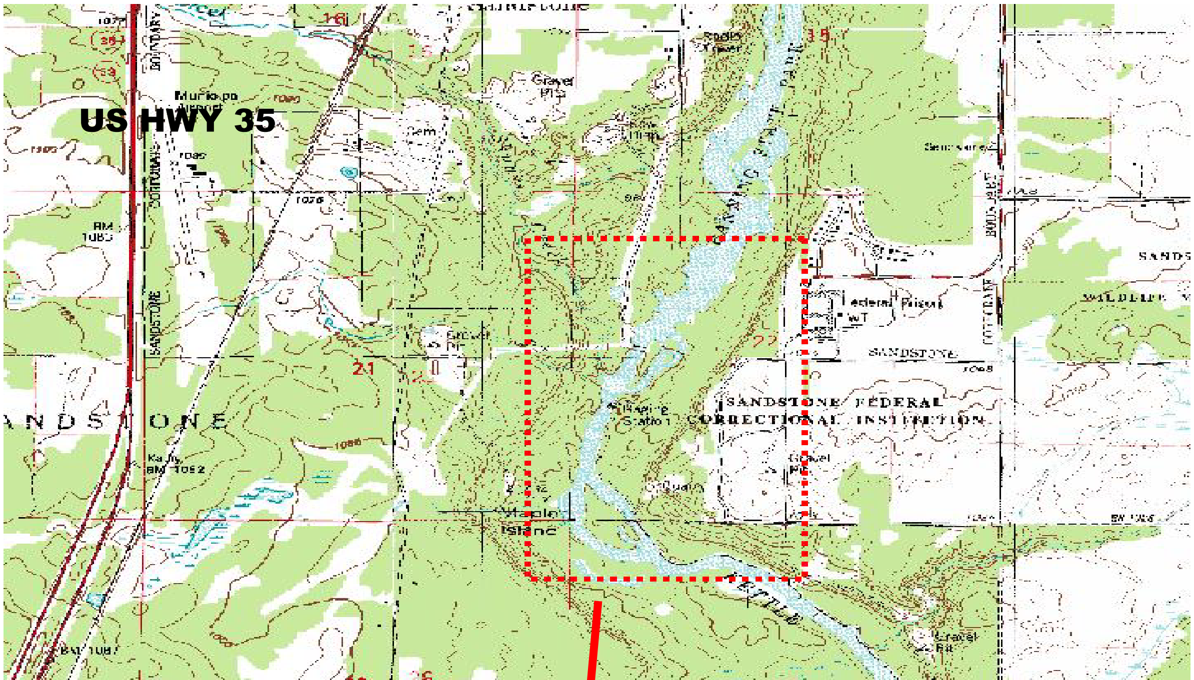
Appendix A2. Topographic map and aerial photograph of the upper study site on the Clearwater River. The yellow lines indicate the upper and lower boundaries of the site.

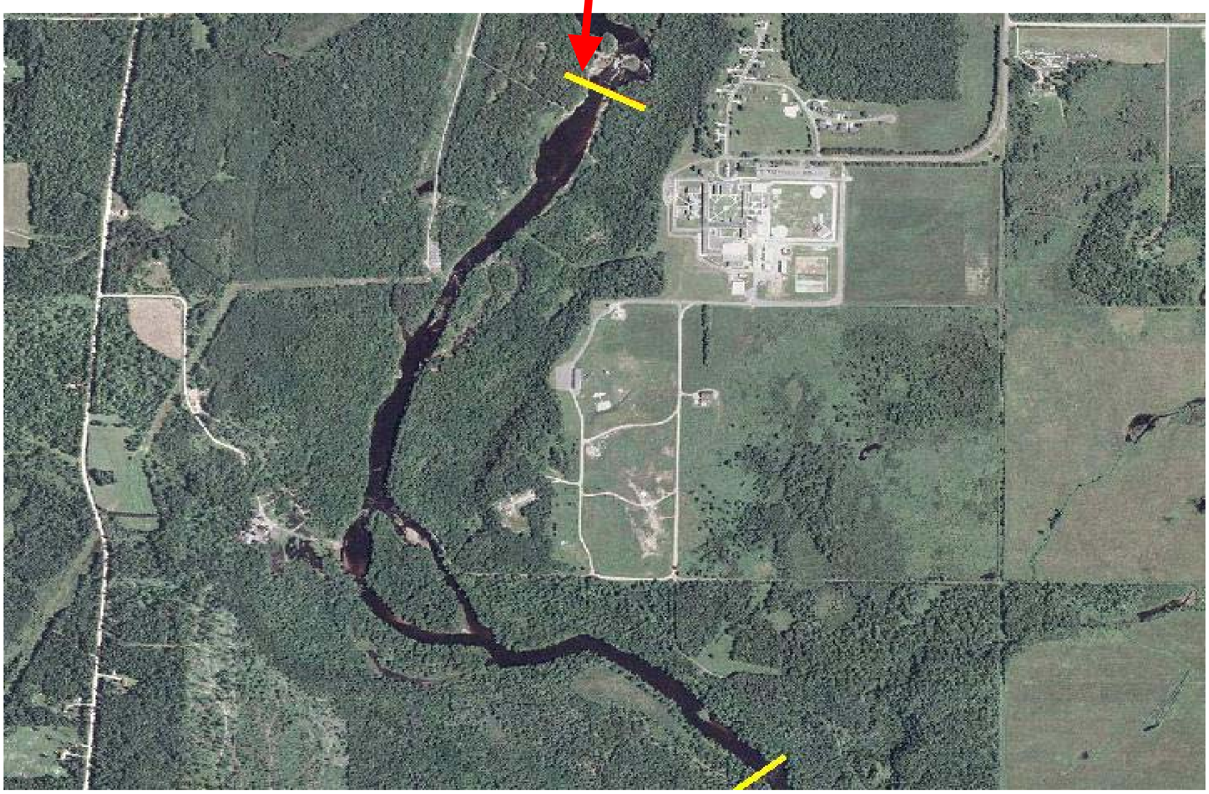


Appendix A3. Topographic map and aerial photograph of the lower study site on the Clearwater River. The yellow lines indicate the upper and lower boundaries of the site.

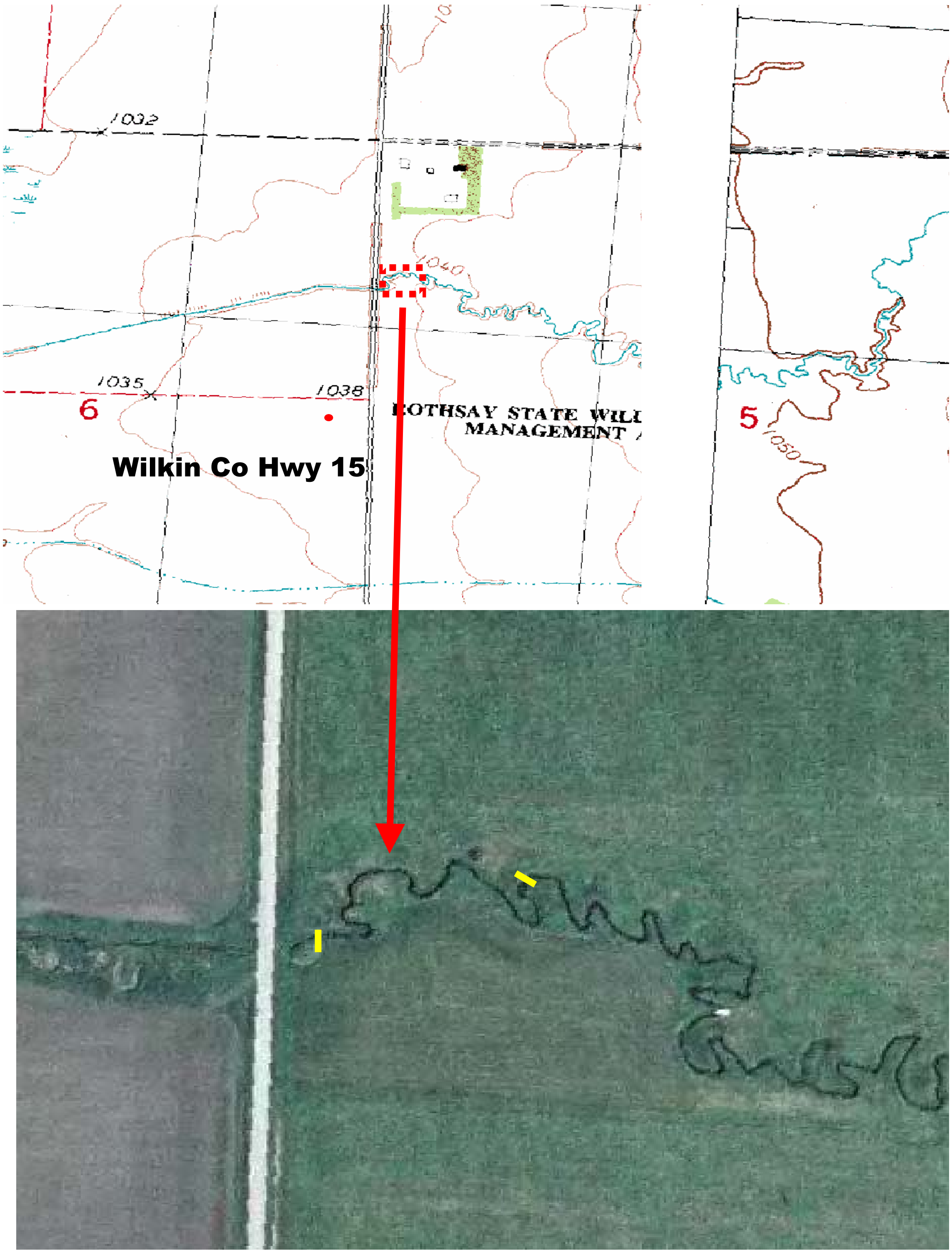


Appendix A4. Topographic map and aerial photograph of the Kettle River study site. The yellow lines indicate the upper and lower boundaries of the site.

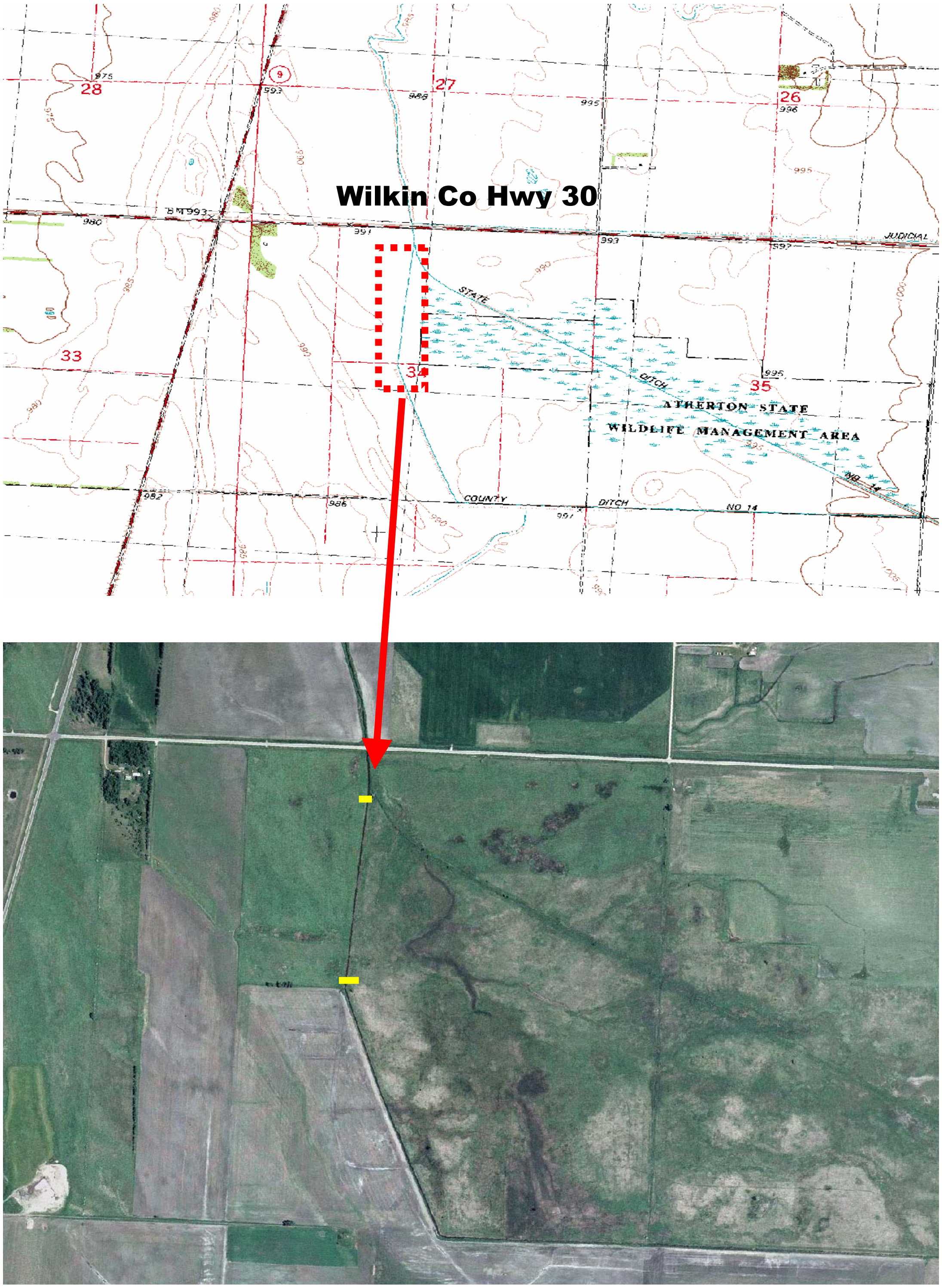




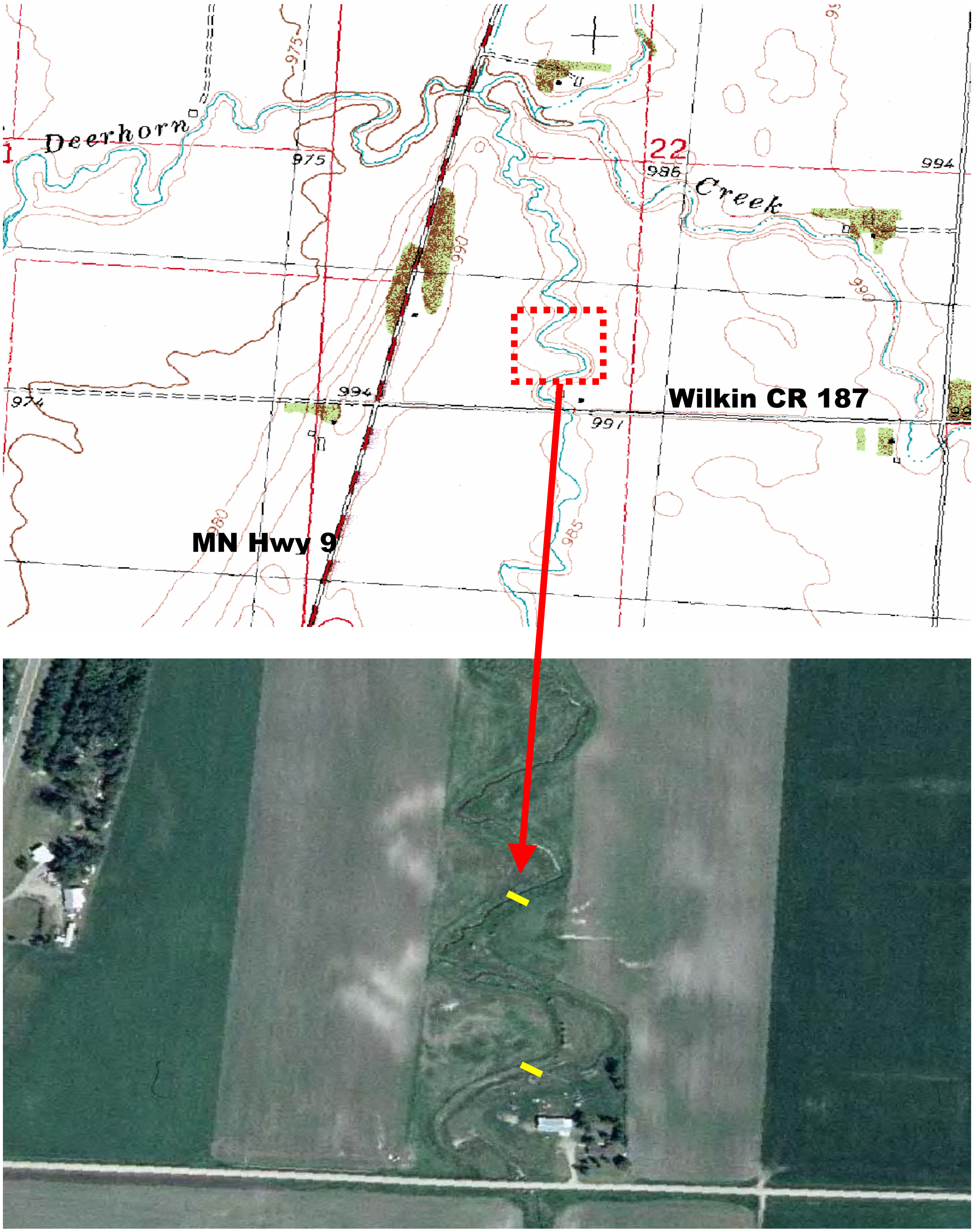
Appendix A5. Topographic map and aerial photograph of the upper study site on Lawndale Creek. The yellow lines indicate the upper and lower boundaries of the site.



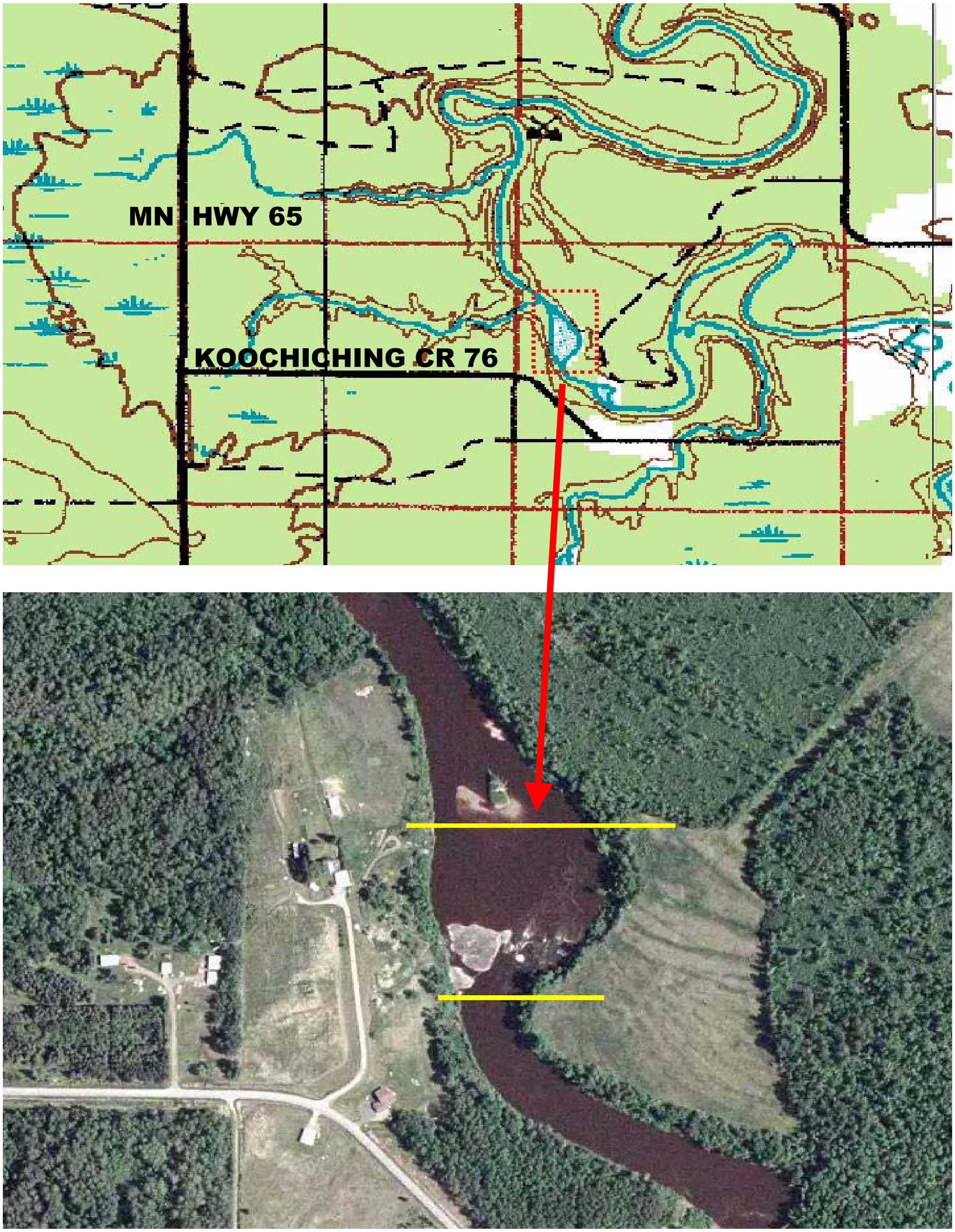
Appendix A6. Topographic map and aerial photograph of the channelized study site on Lawndale Creek. The yellow lines indicate the upper and lower boundaries of the site.



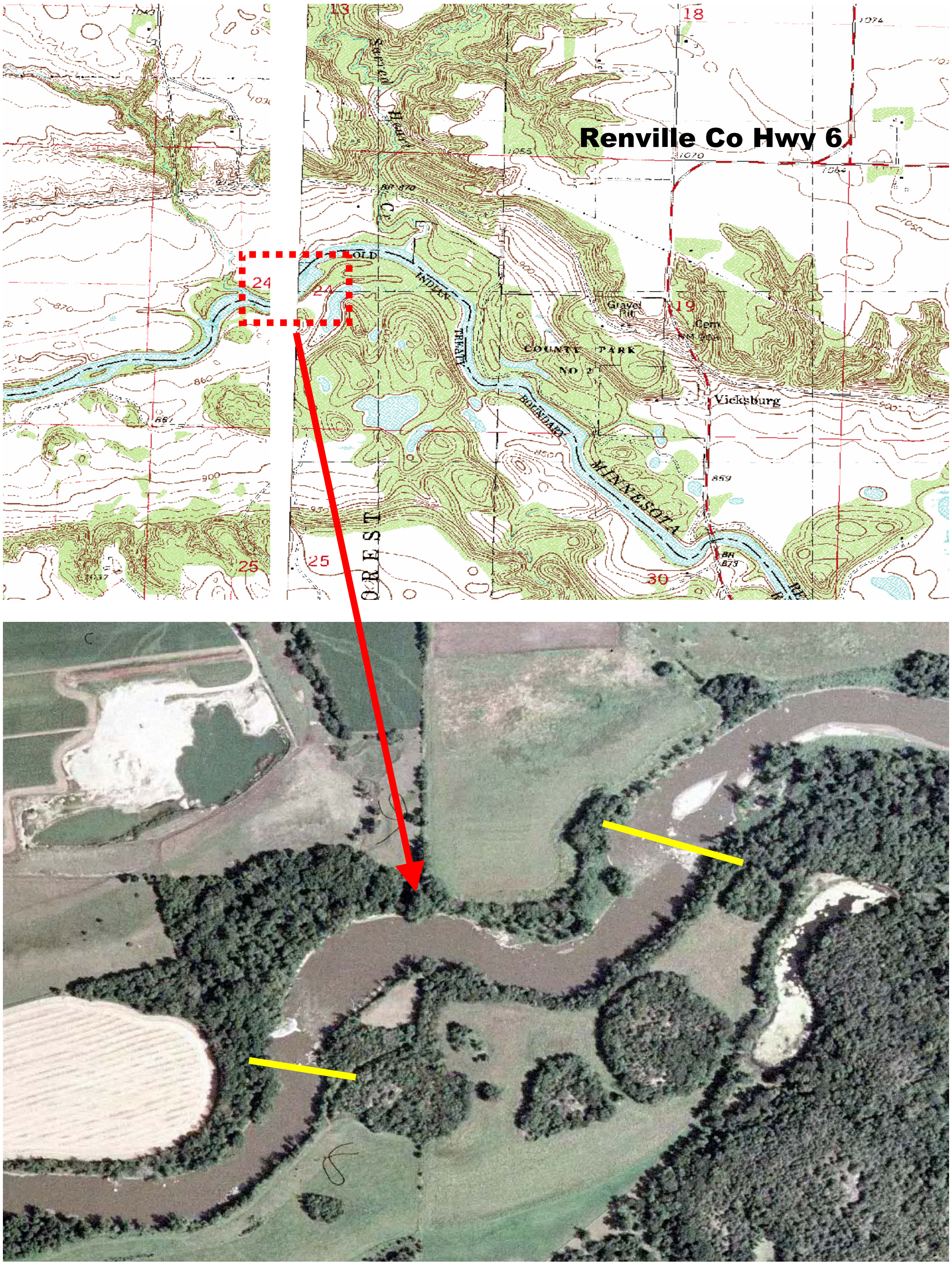
Appendix A7. Topographic map and aerial photograph of the lower study site on Lawndale Creek. The yellow lines indicate the upper and lower boundaries of the site.



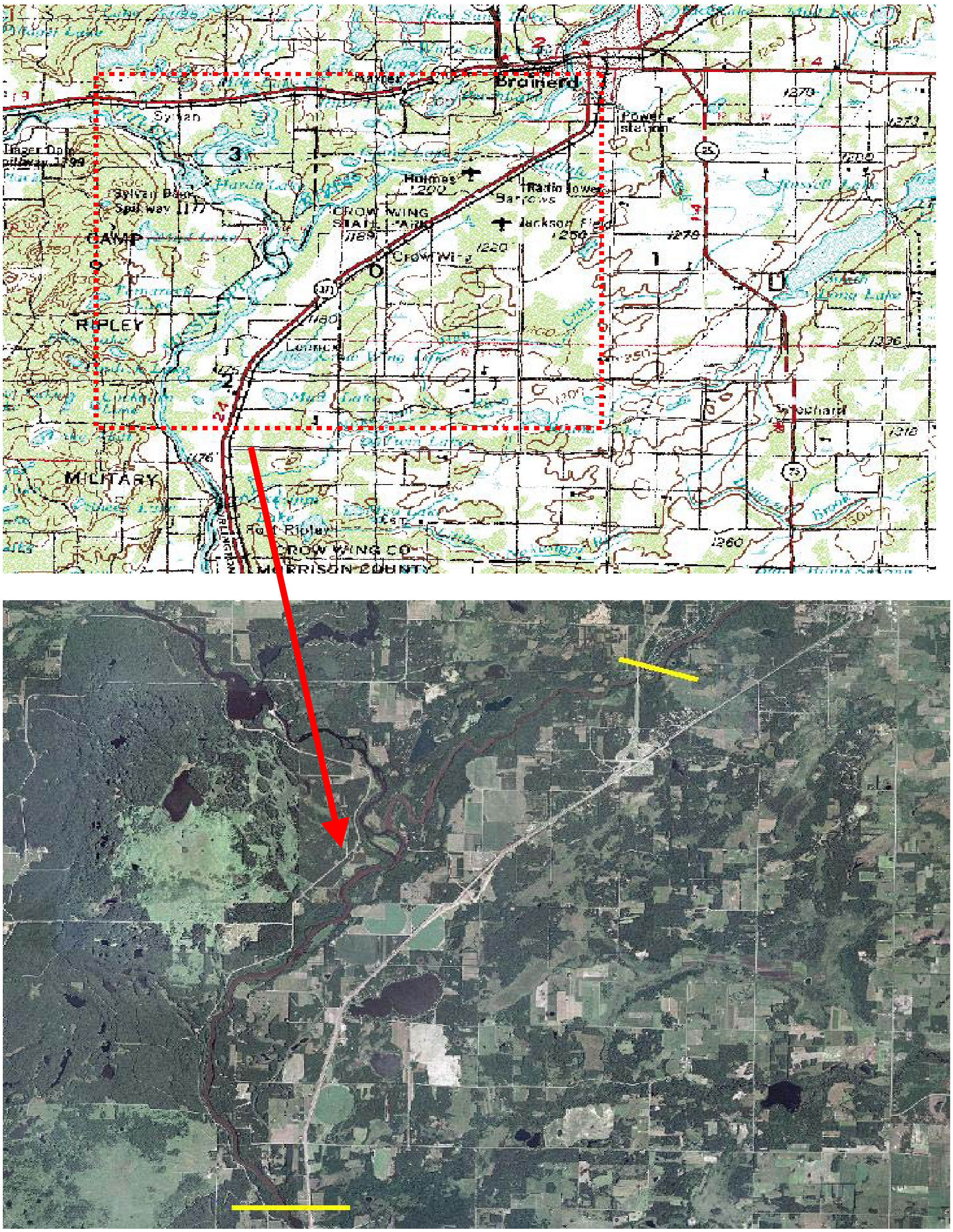
Appendix A8. Topographic map and aerial photograph of the Little Fork River study site. The yellow lines indicate the upper and lower boundaries of the site.



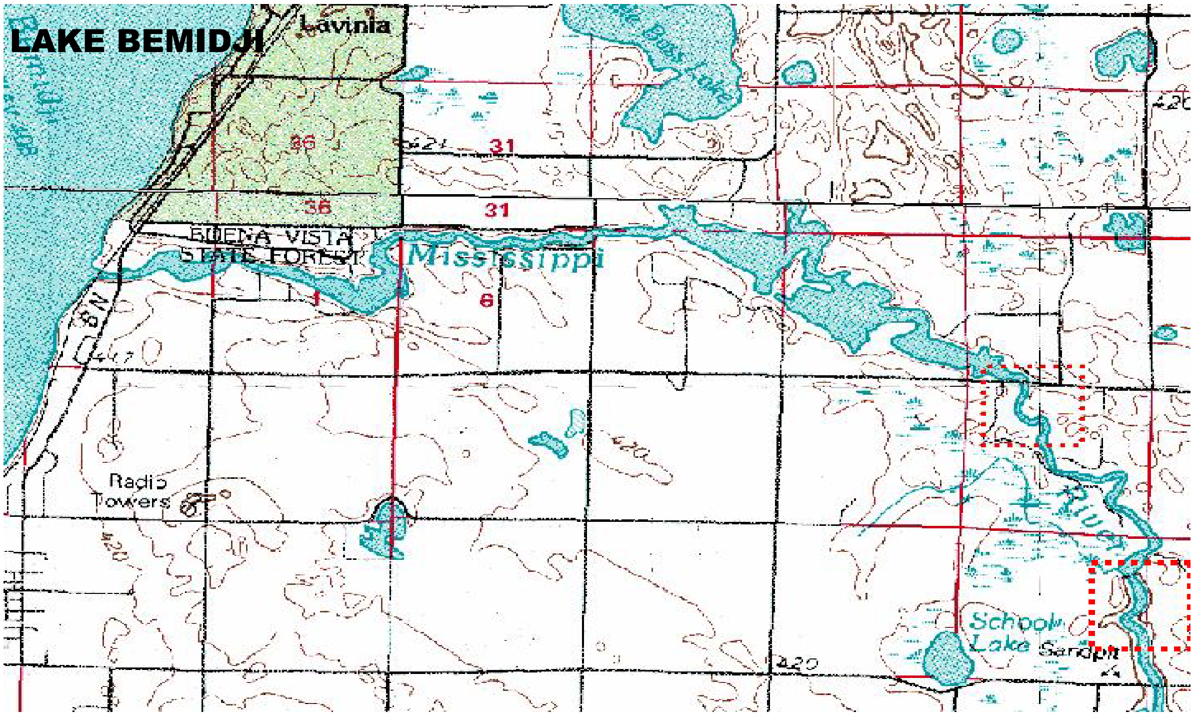
Appendix A9. Topographic map and aerial photograph of the Minnesota River study site. The yellow lines indicate the upper and lower boundaries of the site.

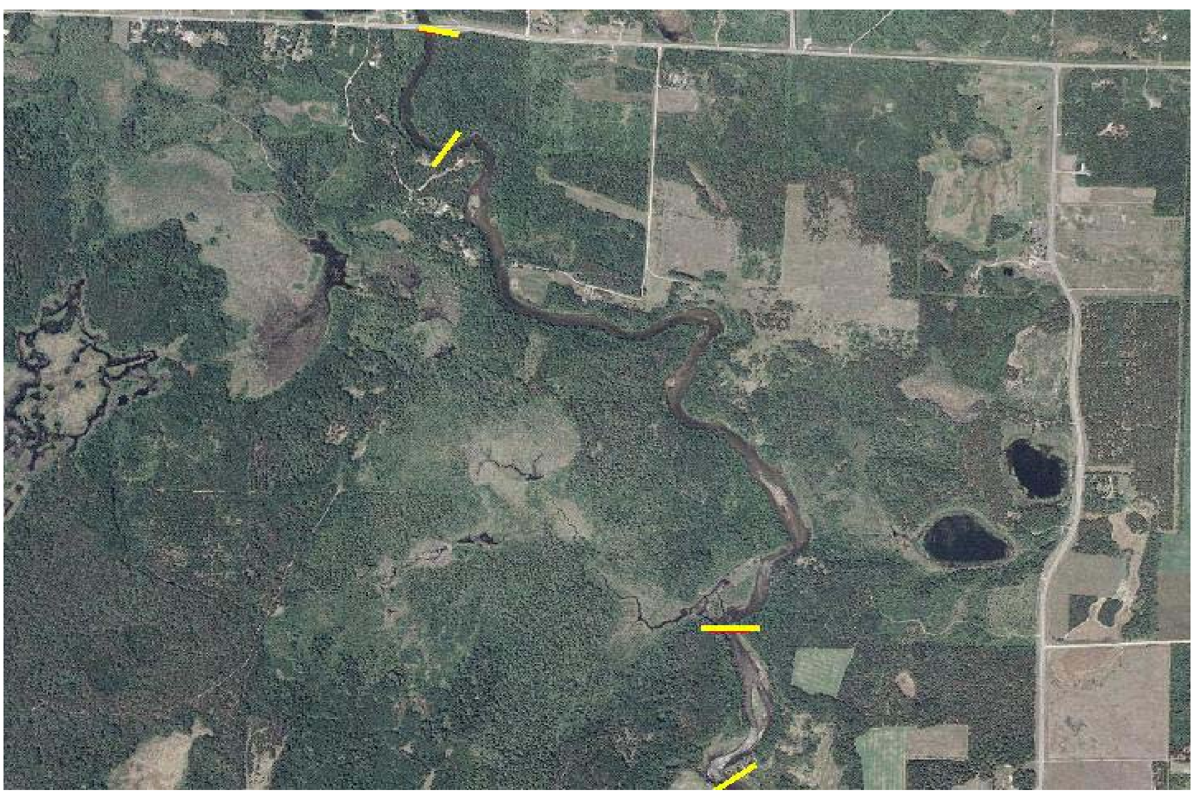


Appendix A10. Topographic map and aerial photograph of the muskellunge study site on the Mississippi River. The yellow lines indicate the upper and lower boundaries of the site.

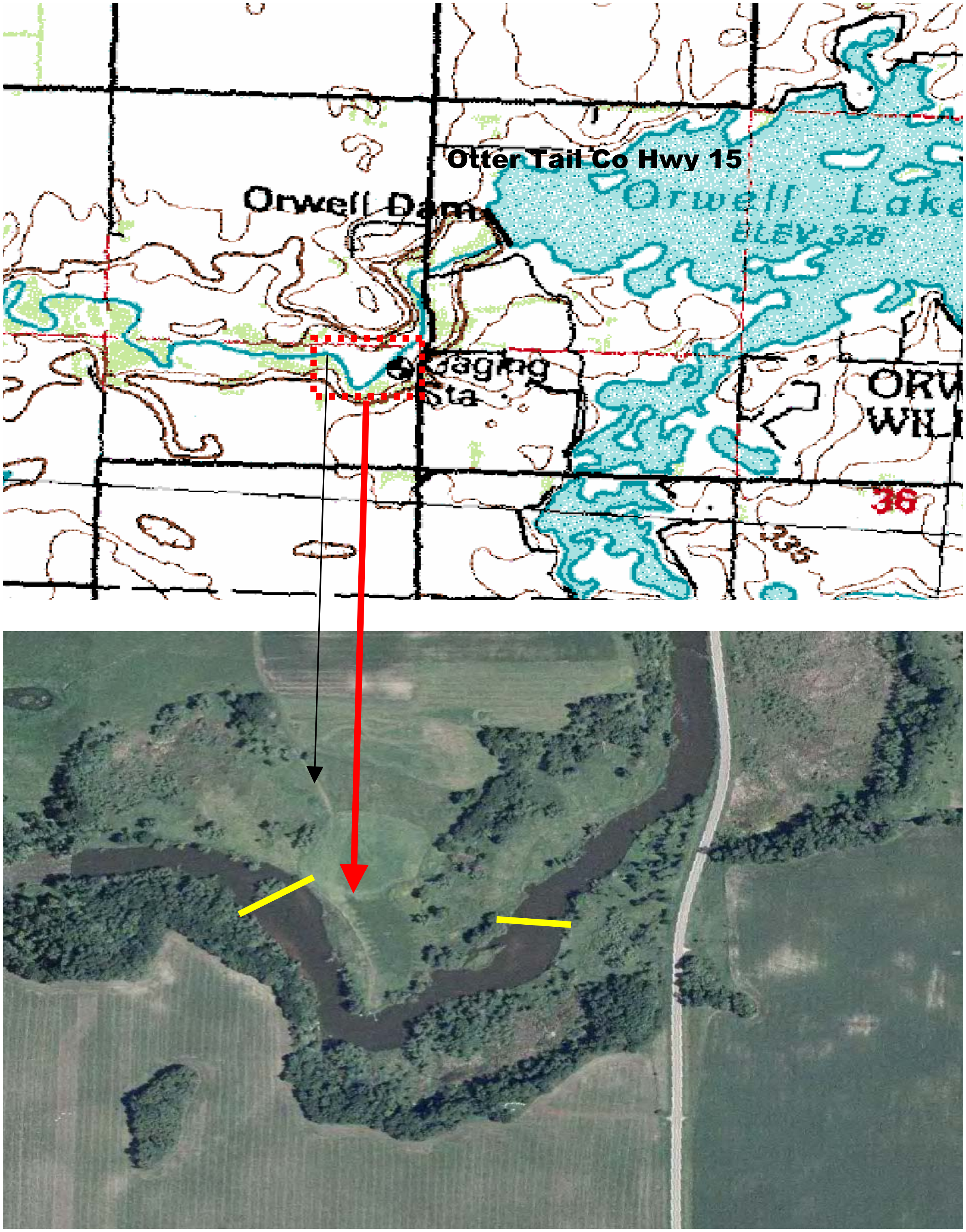


Appendix A10. Topographic map and aerial photograph of the walleye study sites on the Mississippi River. The yellow lines indicate the upper and lower boundaries of the sites.

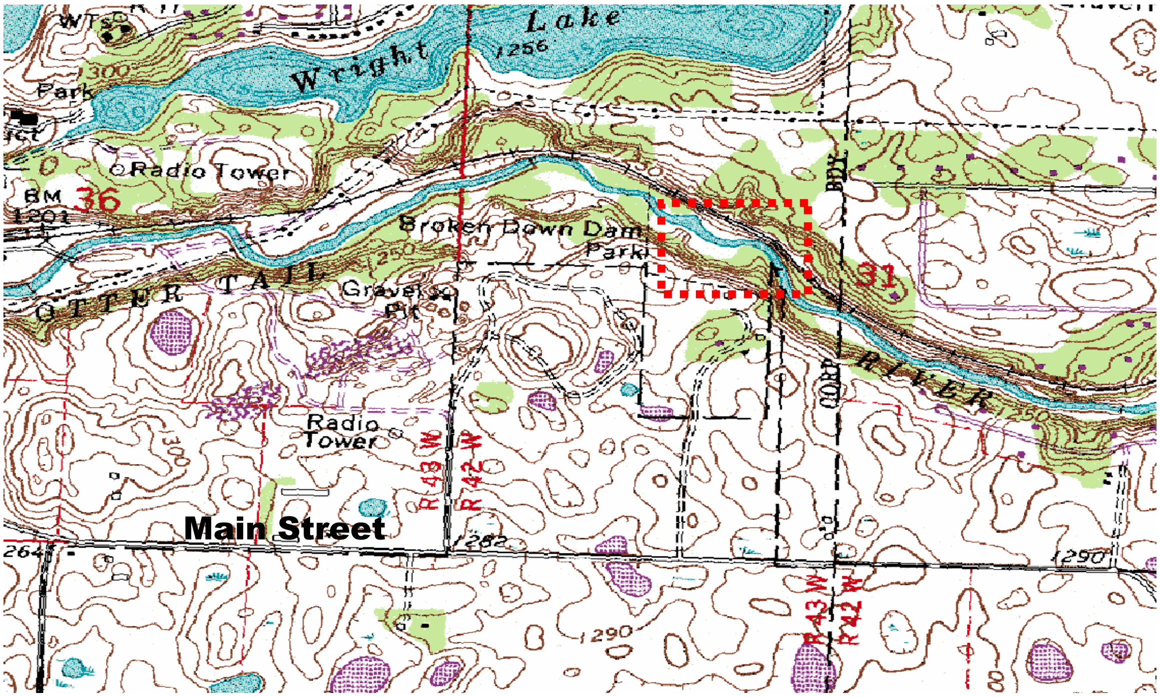




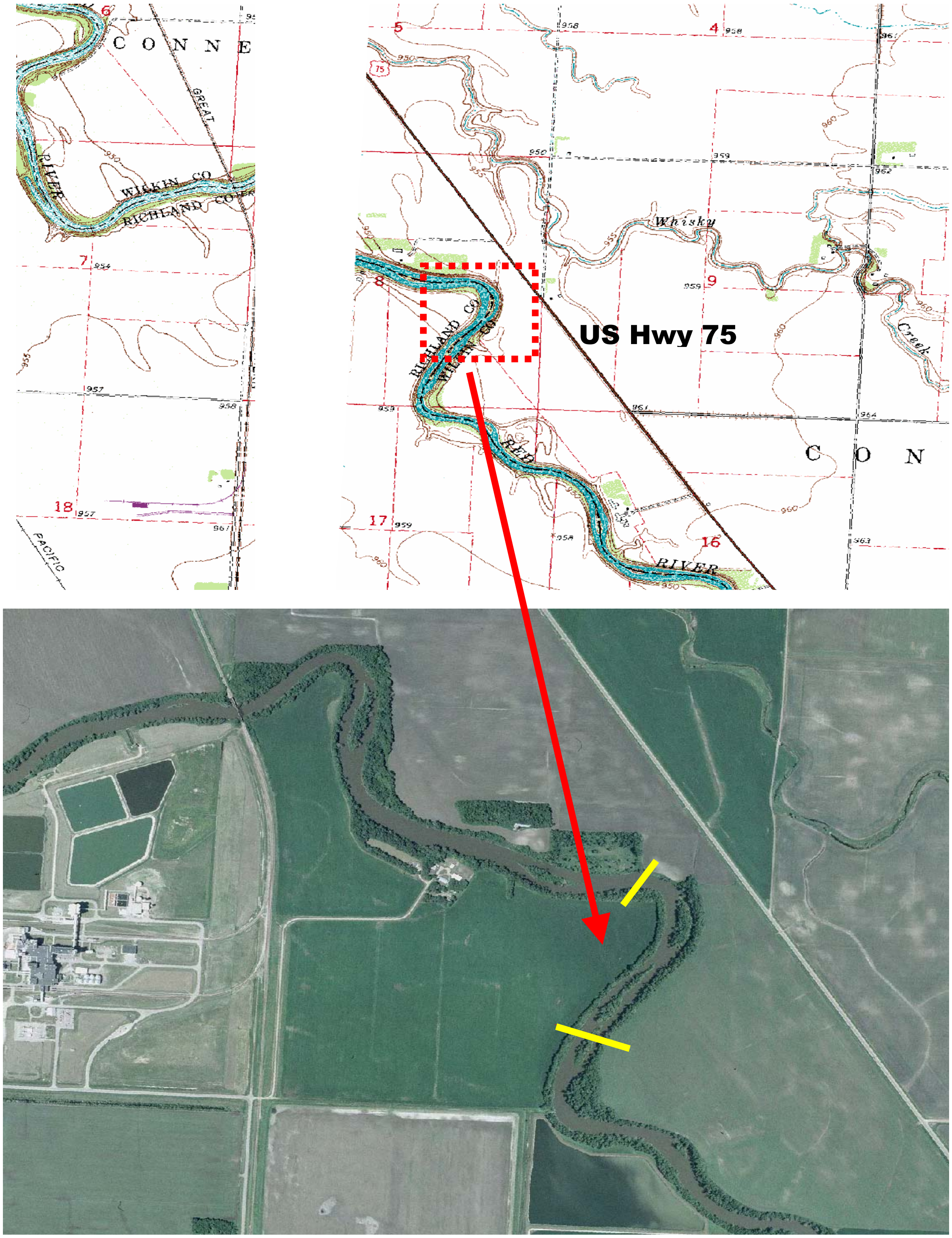
Appendix A12. Topographic map and aerial photograph of the Orwell study site on the Otter Tail River. The yellow lines indicate the upper and lower boundaries of the site.



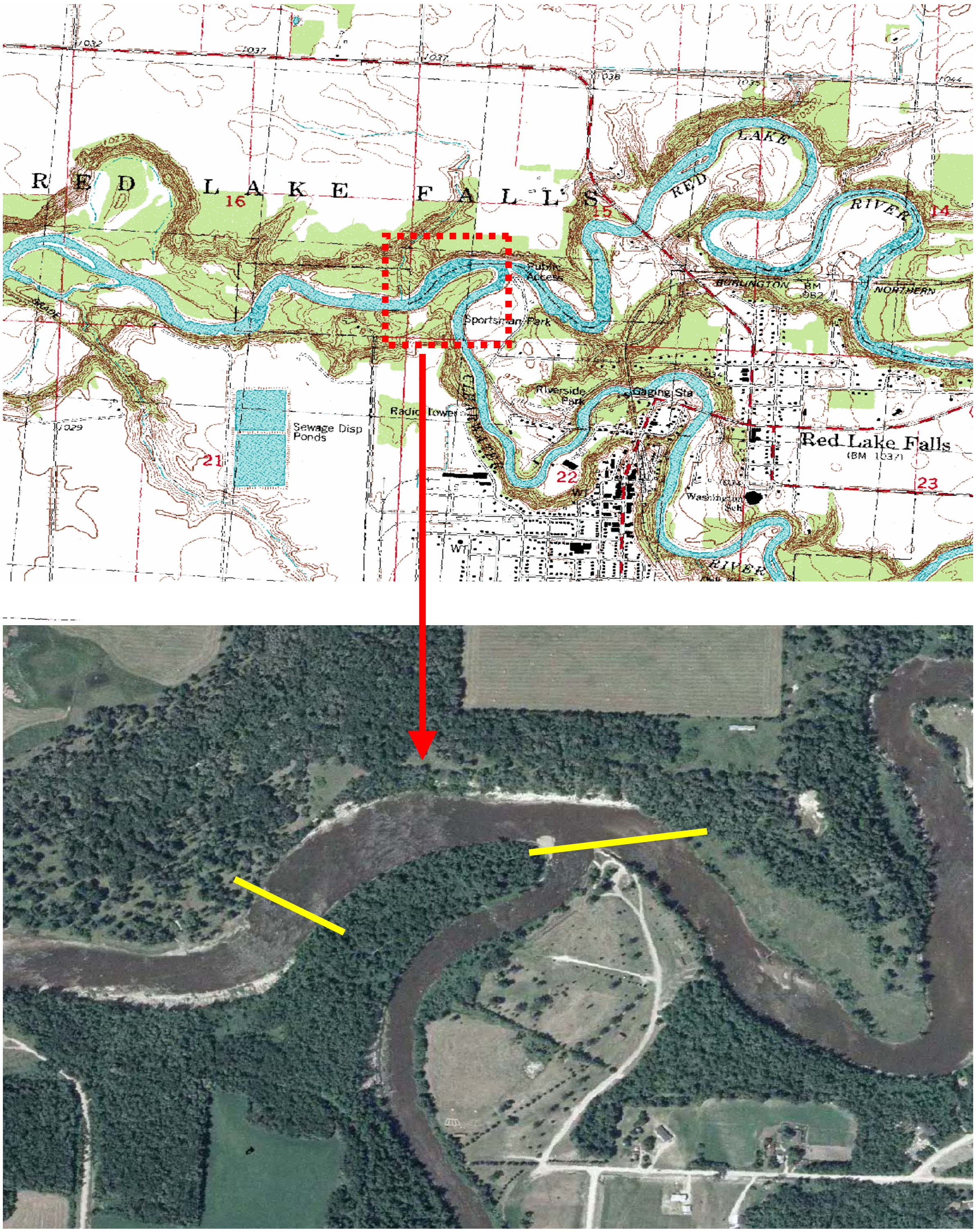
Appendix A13. Topographic map and aerial photograph of the Broken Down Dam study site on the Otter Tail River. The yellow lines indicate the upper and lower boundaries of the site.



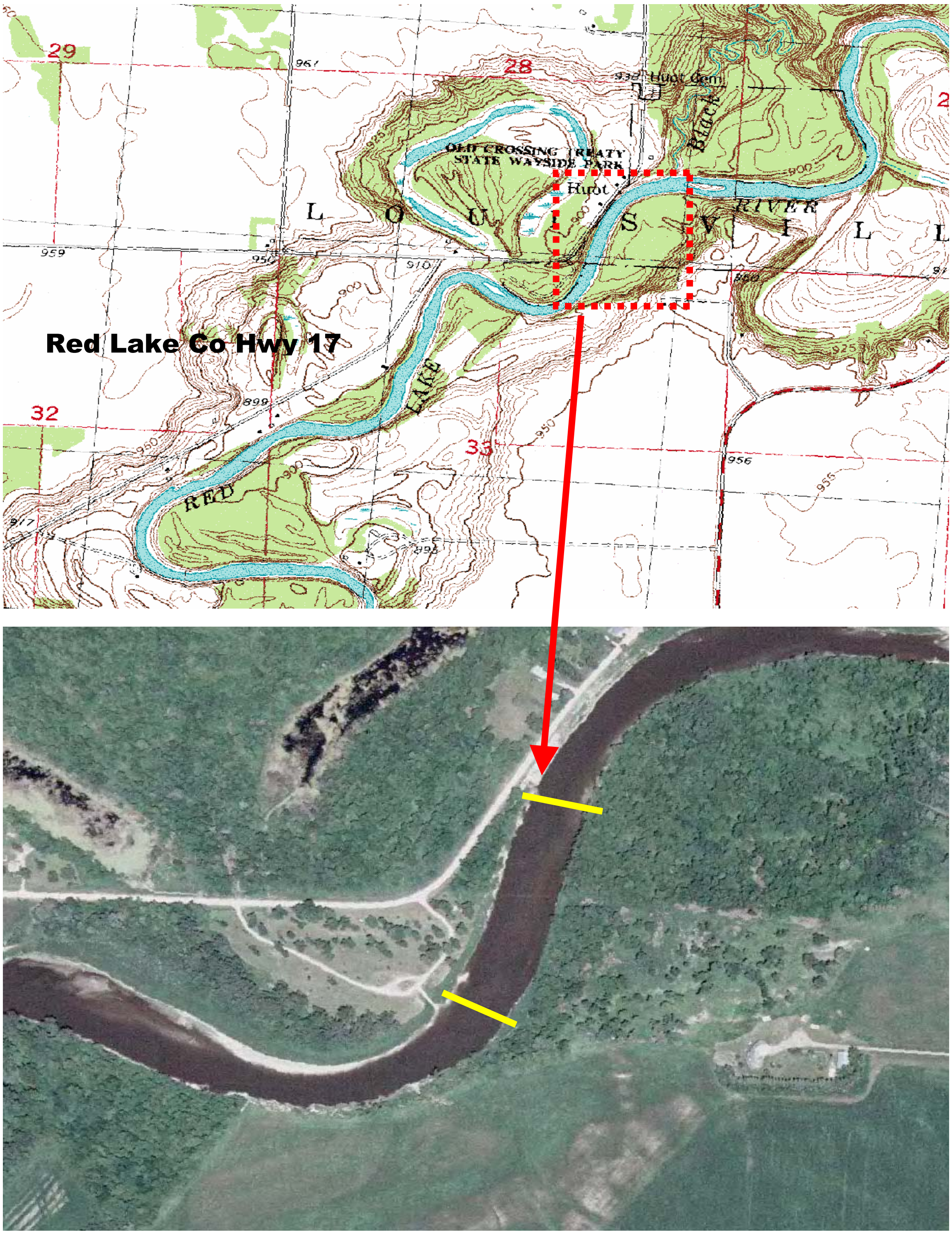
Appendix A14. Topographic map and aerial photograph of the Red River study site. The yellow lines indicate the upper and lower boundaries of the site.



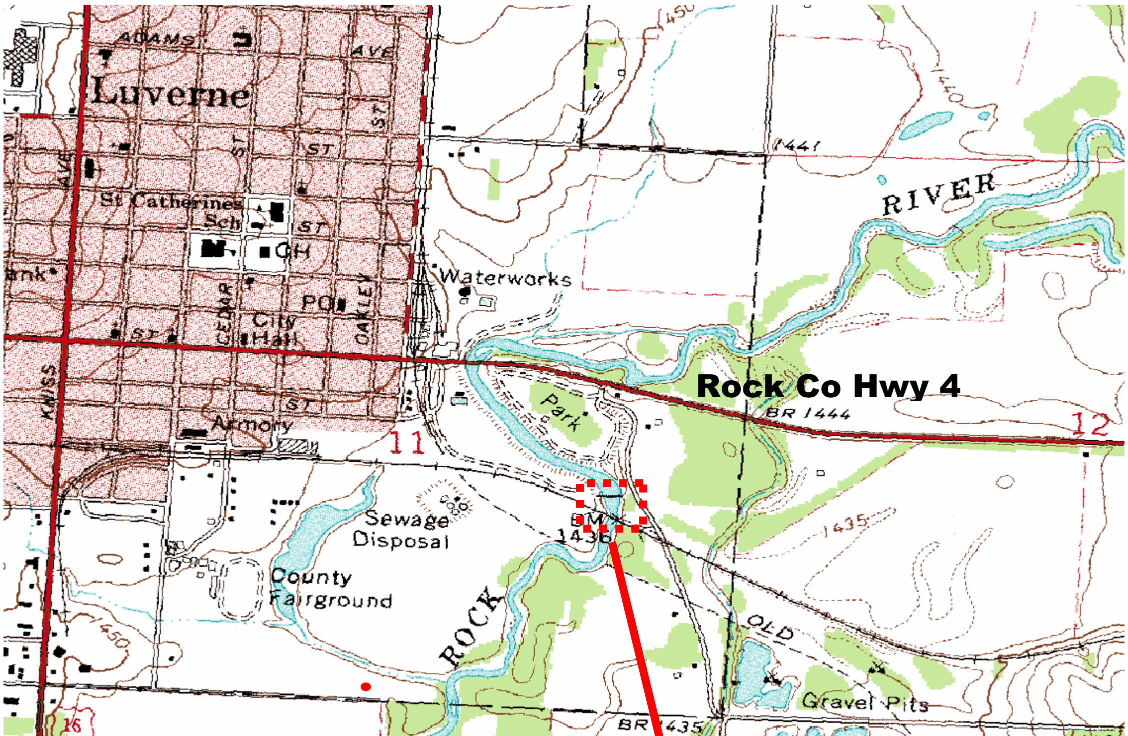
Appendix A15. Topographic map and aerial photograph of the upper study site on the Red Lake River. The yellow lines indicate the upper and lower boundaries of the site.



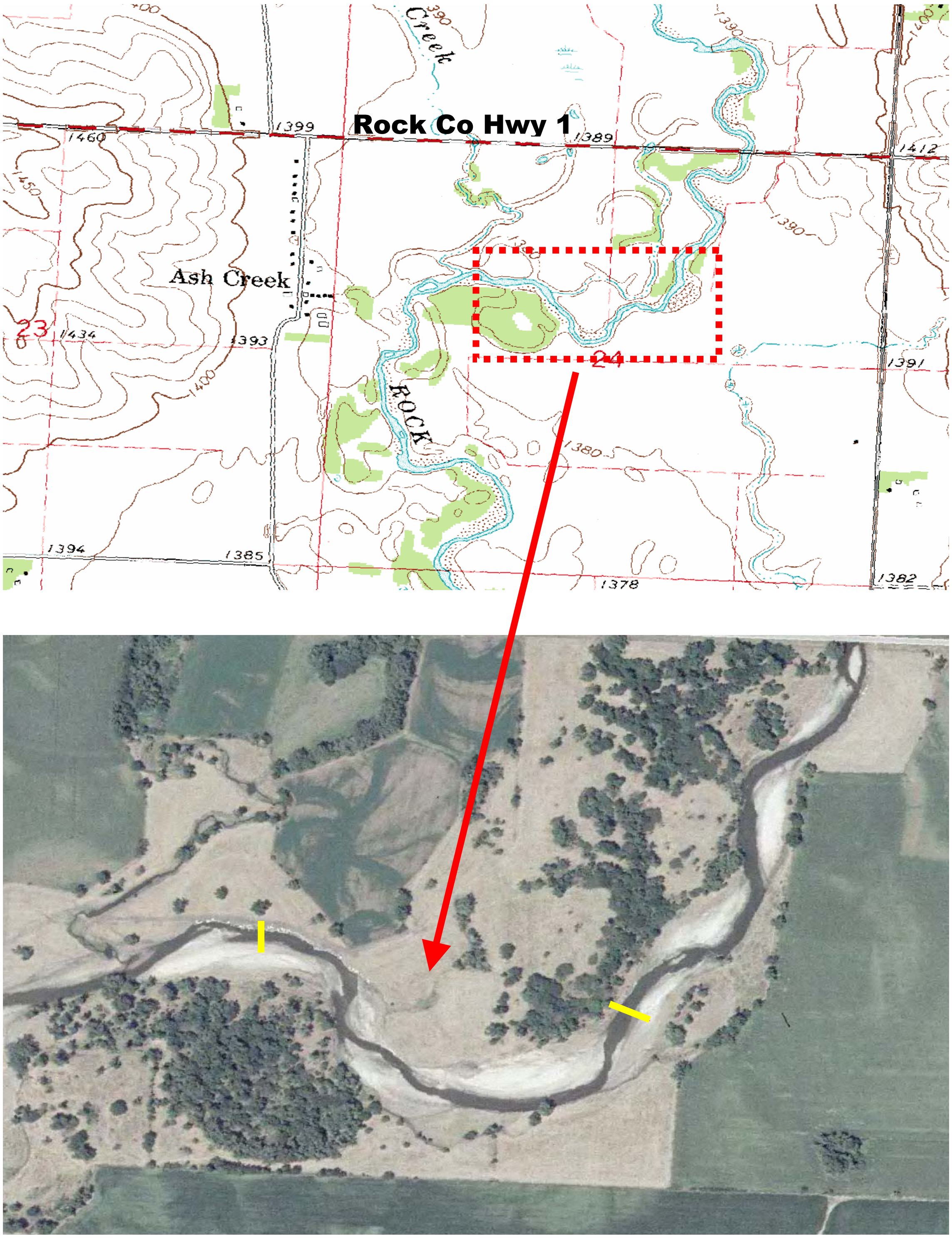
Appendix A16. Topographic map and aerial photograph of the lower study site on the Red Lake River. The yellow lines indicate the upper and lower boundaries of the site.



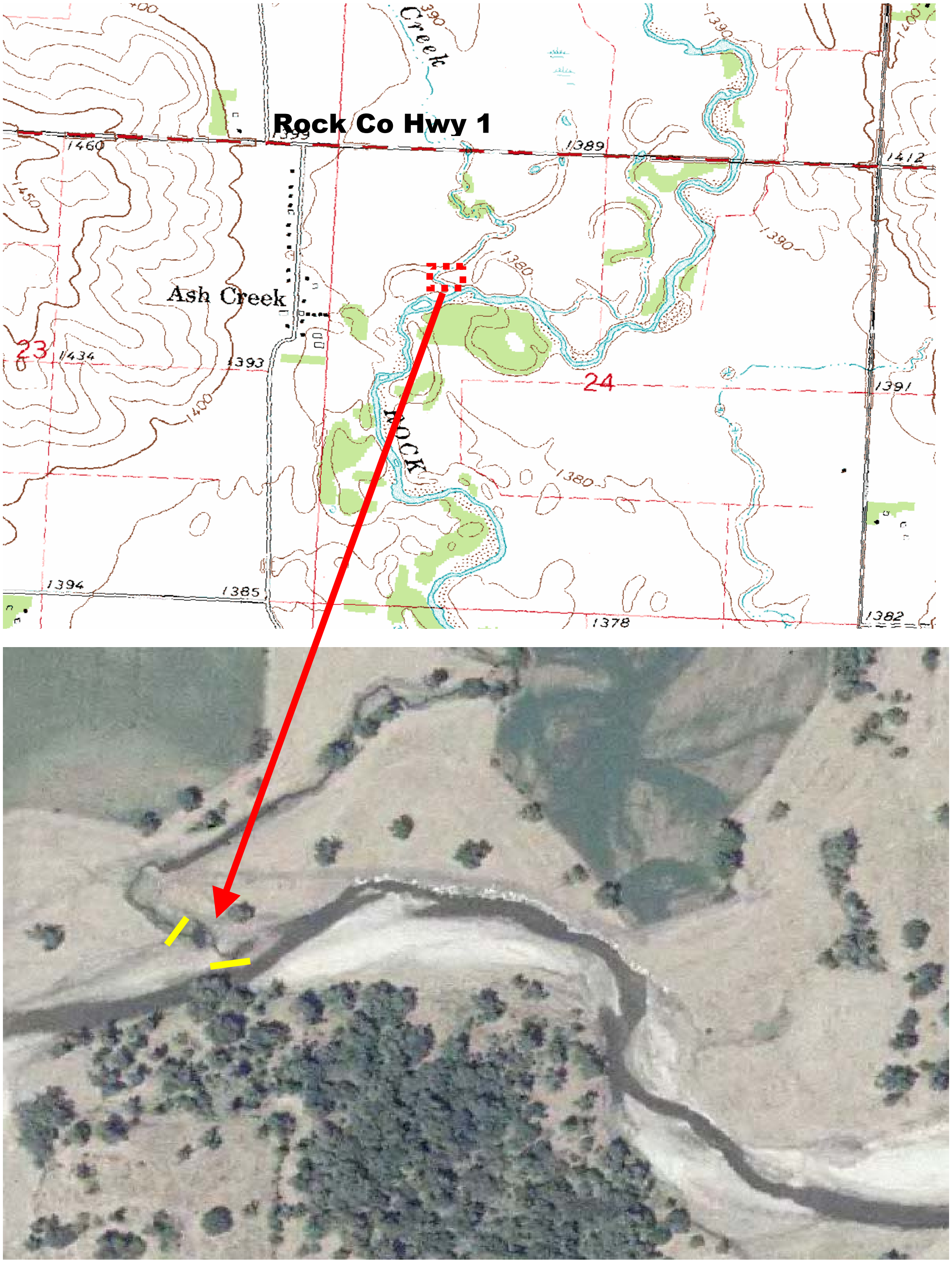
Appendix A17. Topographic map and aerial photograph of the upper study site on the Rock River. The yellow lines indicate the upper and lower boundaries of the site.



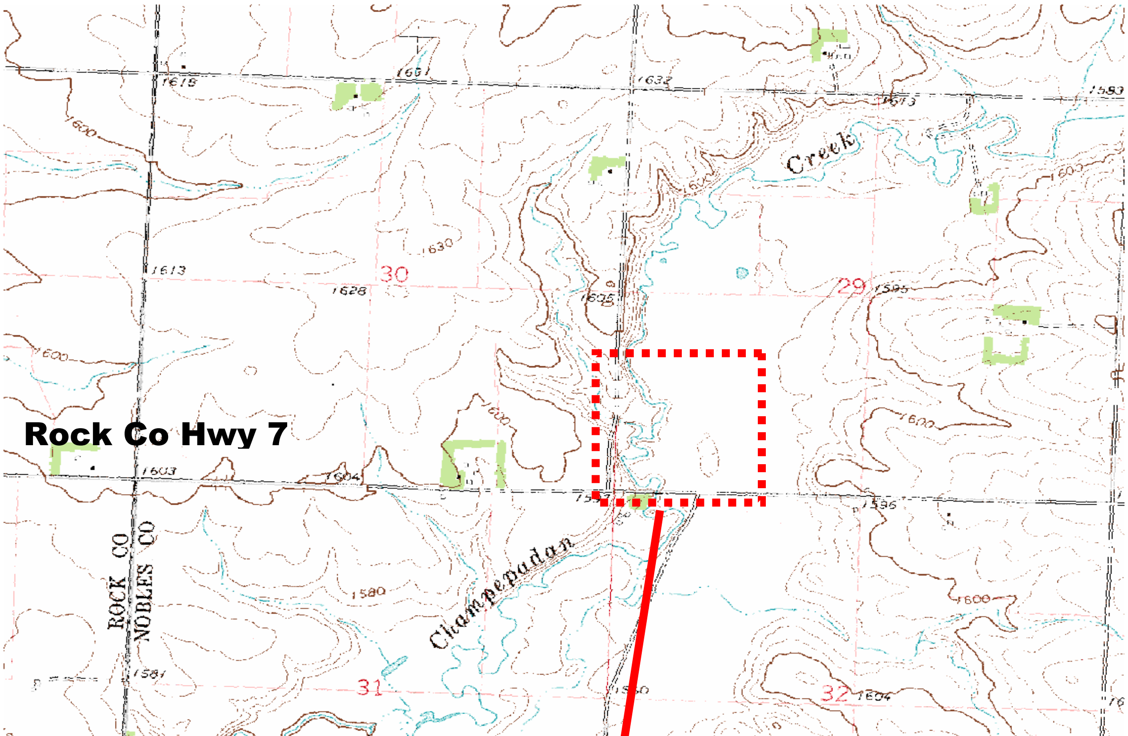
Appendix A18. Topographic map and aerial photograph of the lower study site on the Rock River. The yellow lines indicate the upper and lower boundaries of the site.

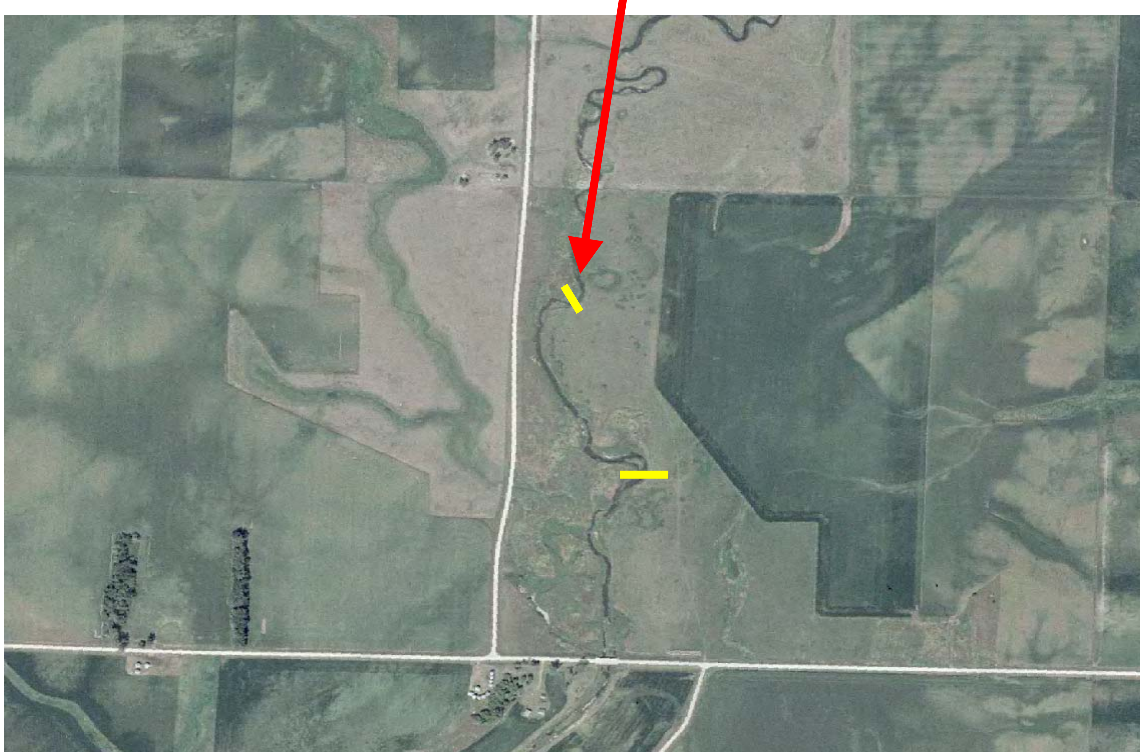


Appendix A19. Topographic map and aerial photograph of the Ash Creek study site. The yellow lines indicate the upper and lower boundaries of the site.

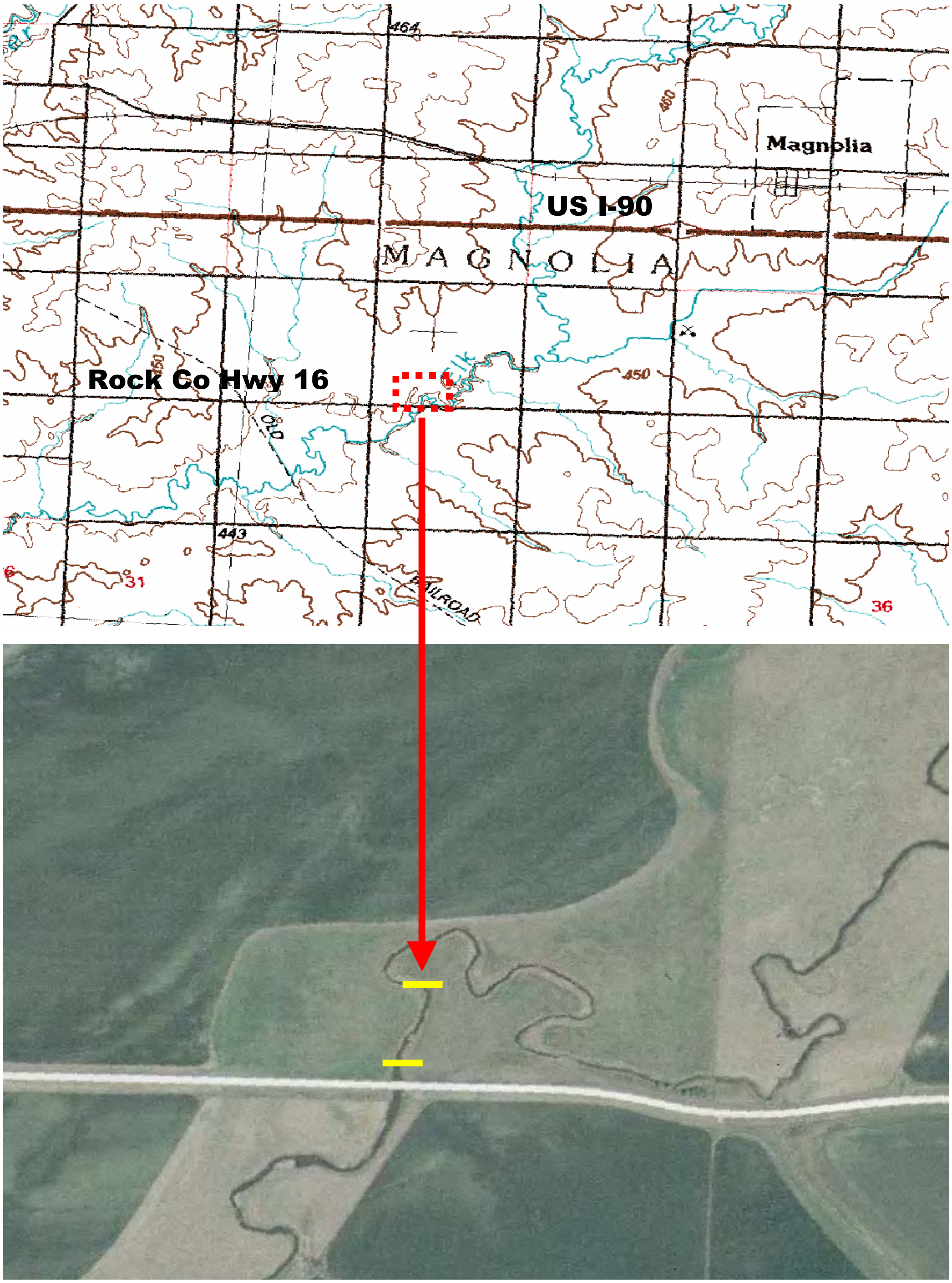


Appendix A20. Topographic map and aerial photograph of the Champepadan Creek study site. The yellow lines indicate the upper and lower boundaries of the site.

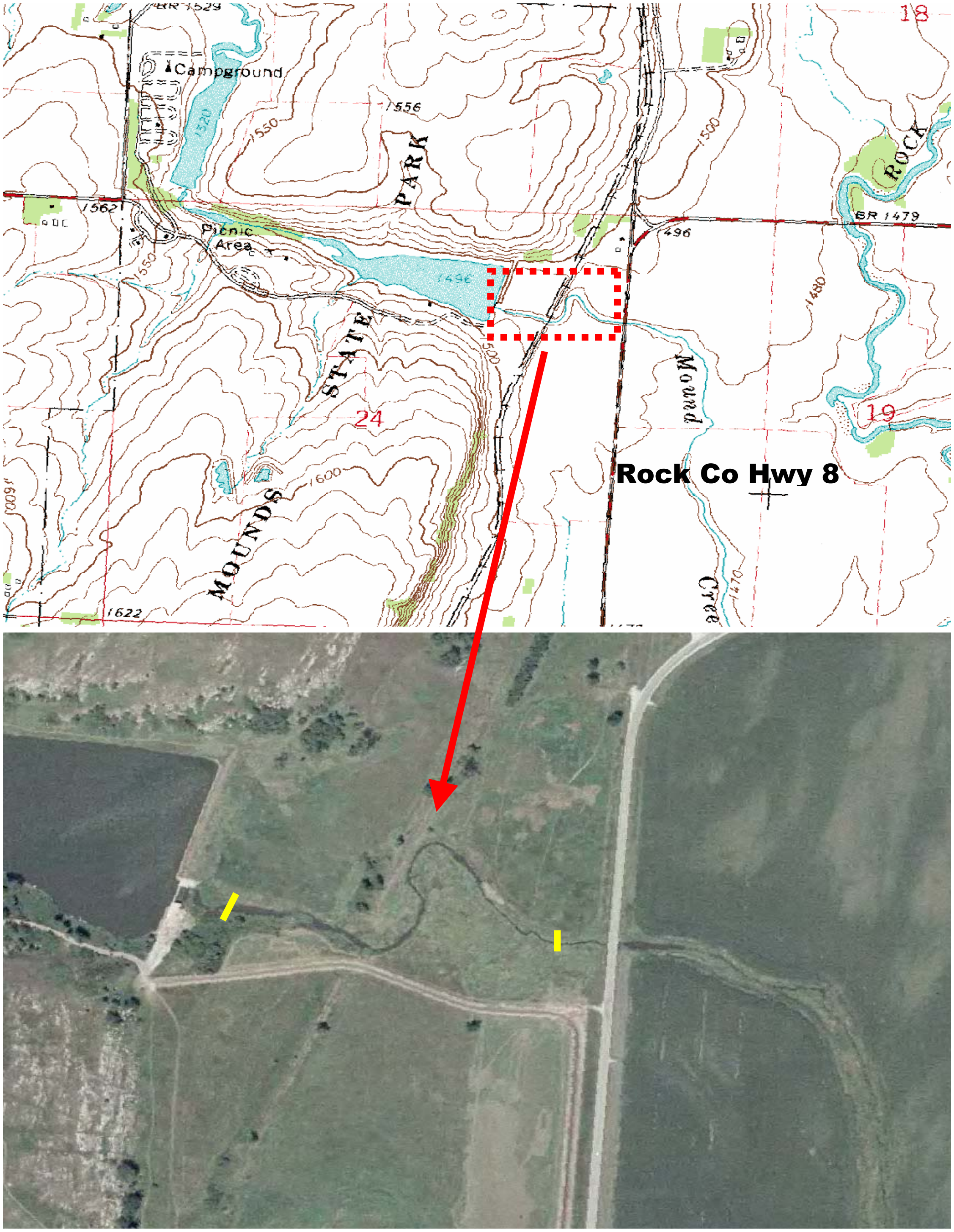




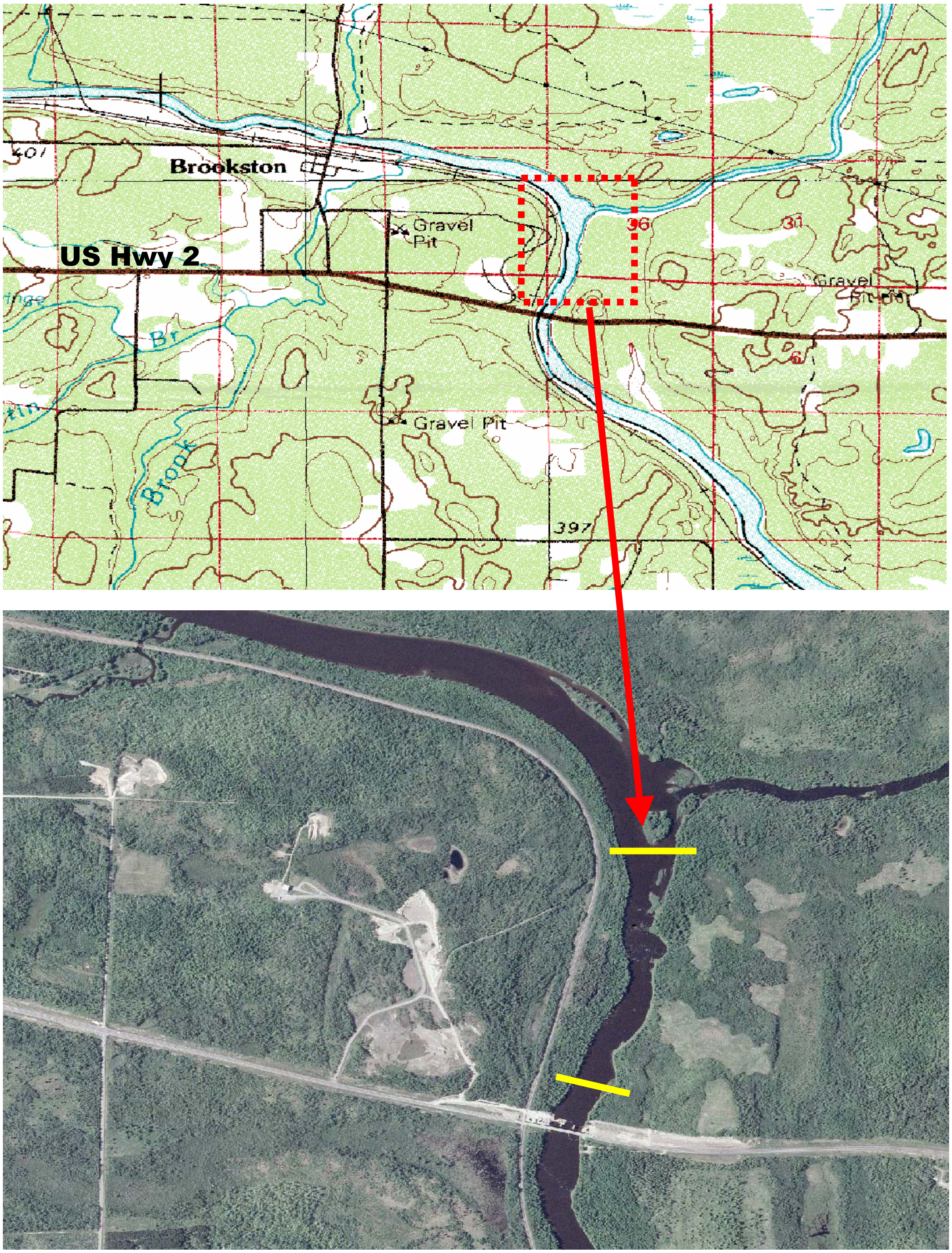
Appendix A21. Topographic map and aerial photograph of the Elk Creek study site. The yellow lines indicate the upper and lower boundaries of the site.



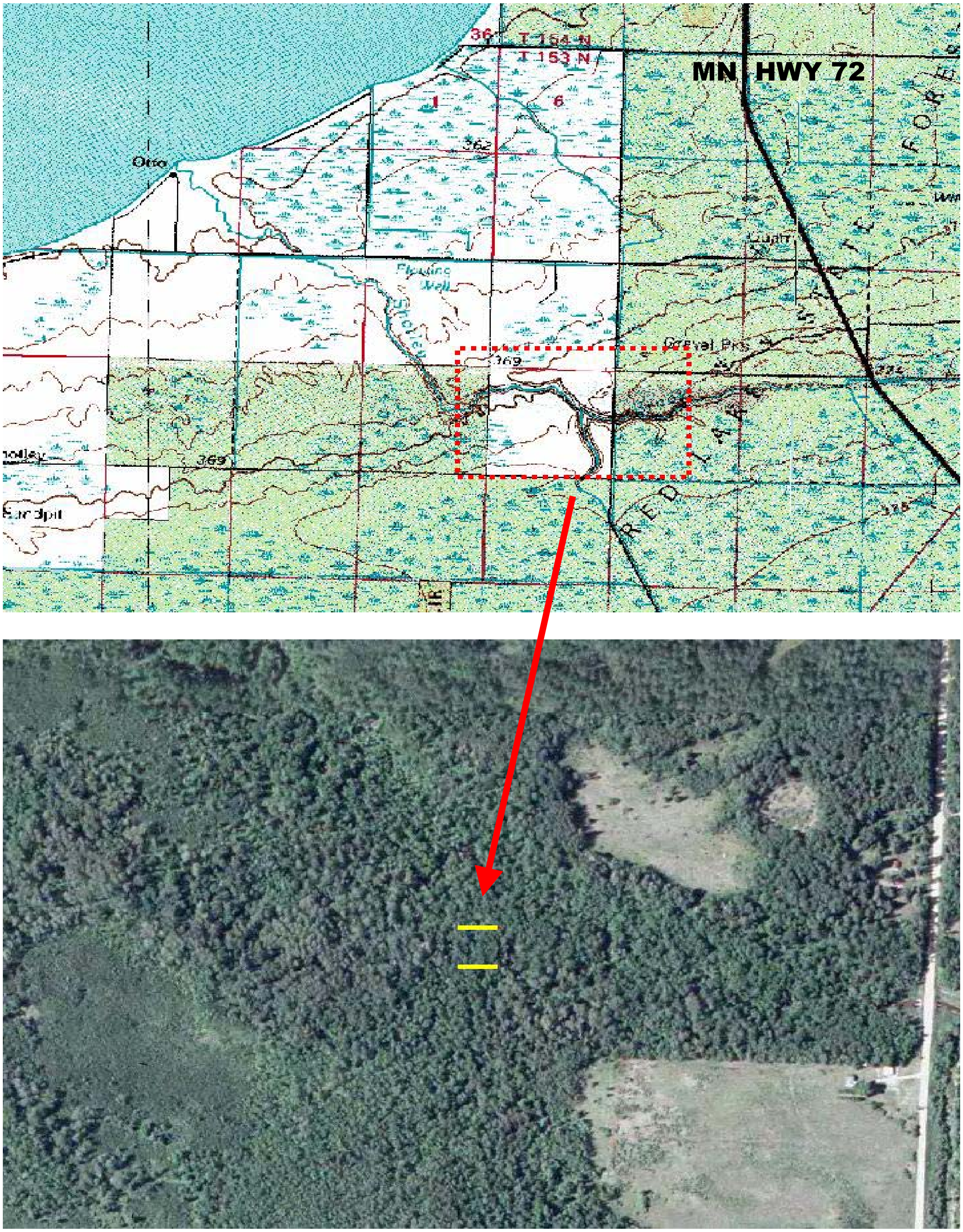
Appendix A22.Topographic map and aerial photograph of the Mound Creek study site. The yellow lines indicate the upper and lower boundaries of the site.



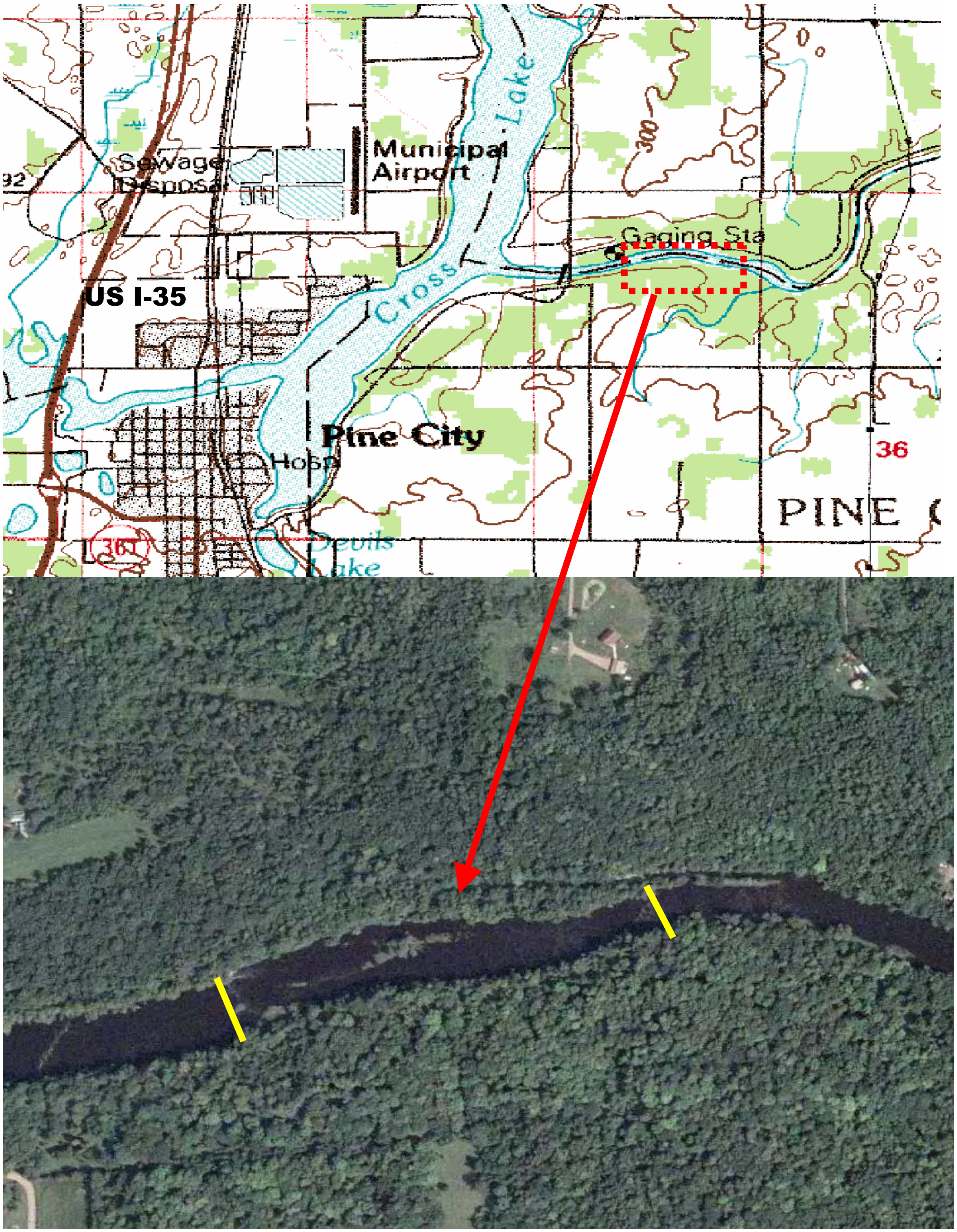
Appendix A23. Topographic map and aerial photograph of the St. Louis River study site. The yellow lines indicate the upper and lower boundaries of the site.



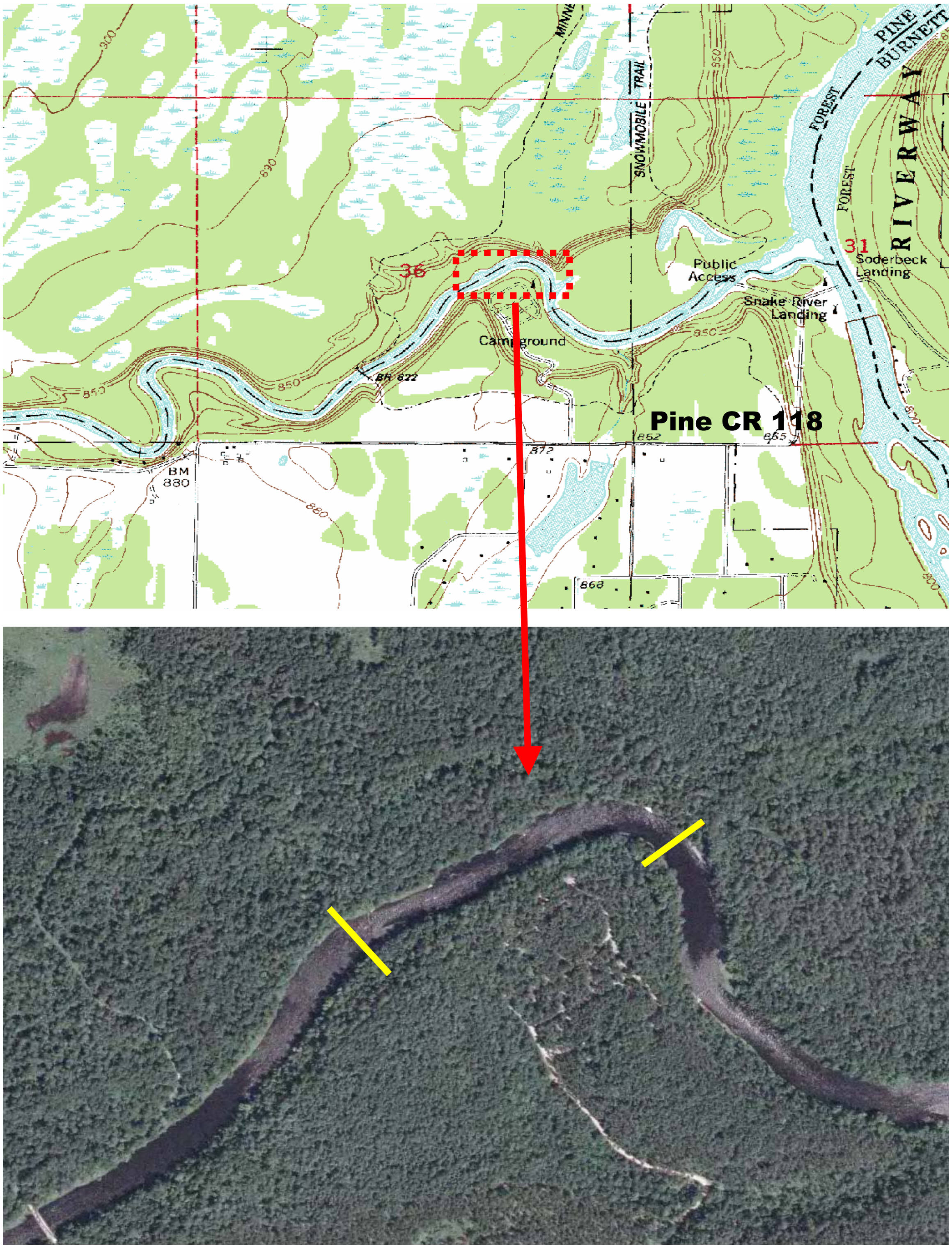
Appendix A24. Topographic map and aerial photograph of the Shotley Brook study site. The yellow lines indicate the upper and lower boundaries of the site.



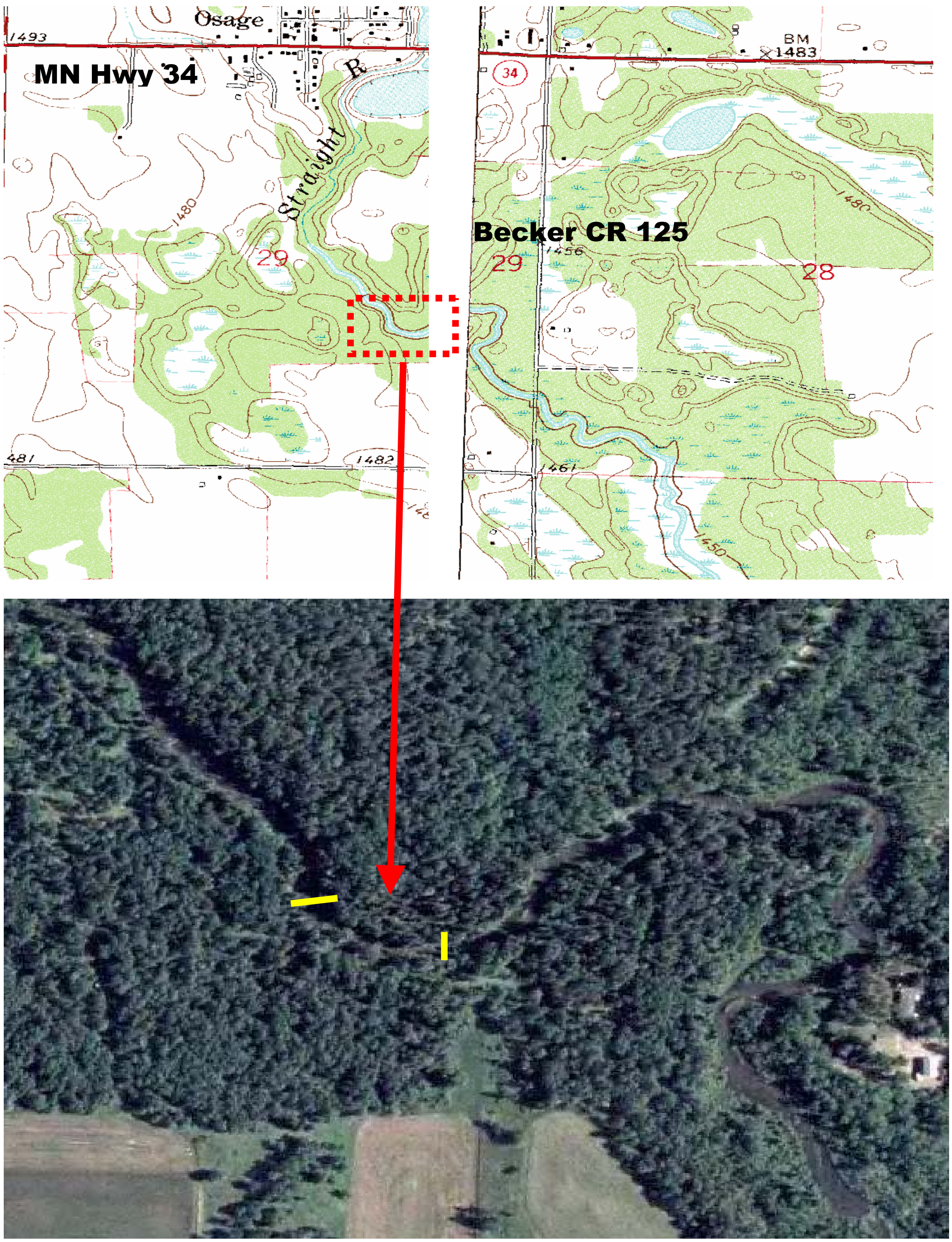
Appendix A25. Topographic map and aerial photograph of the upper study site on the Snake River. The yellow lines indicate the upper and lower boundaries of the site.



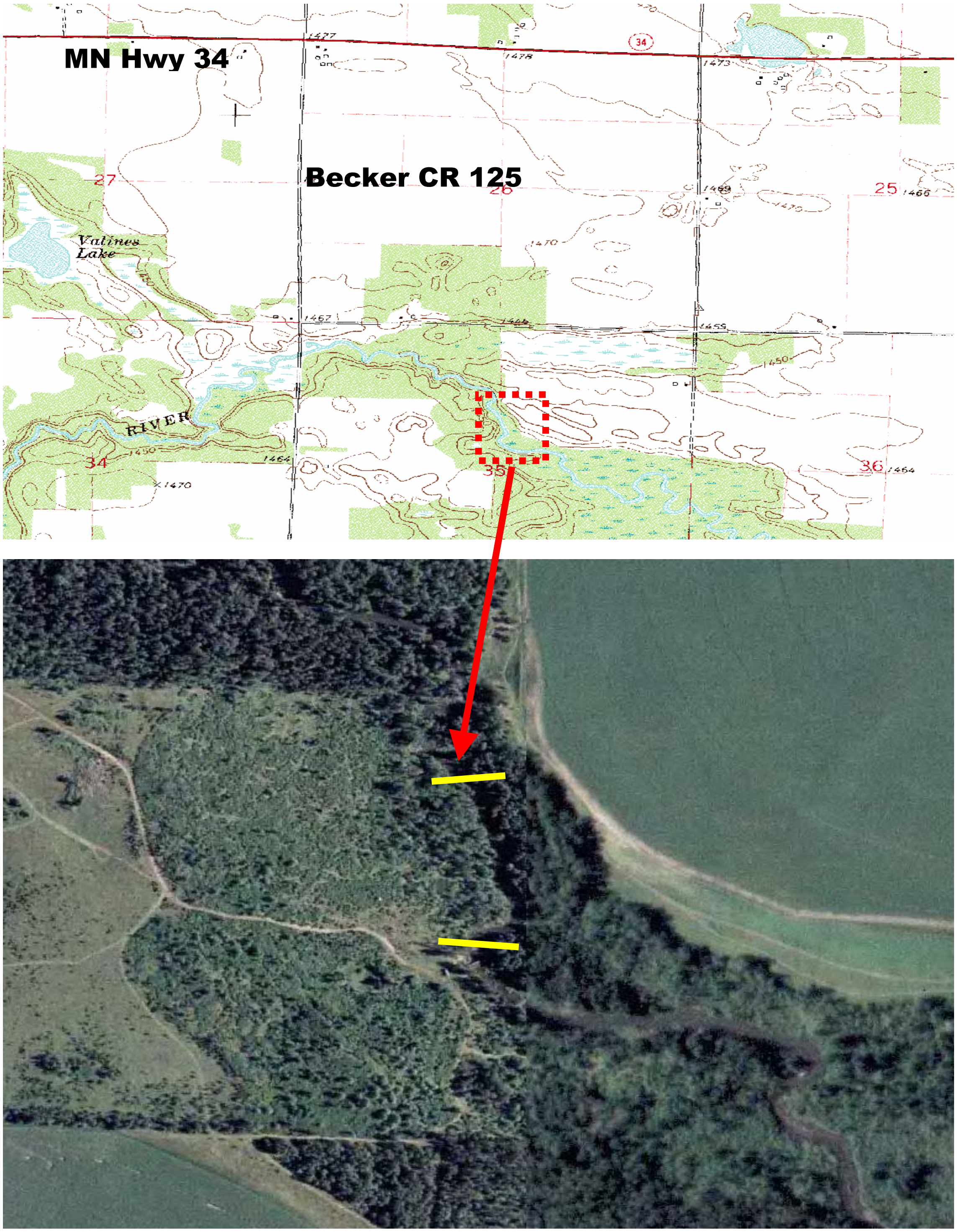
Appendix A26. Topographic map and aerial photograph of the lower study site on the Snake River. The yellow lines indicate the upper and lower boundaries of the site.



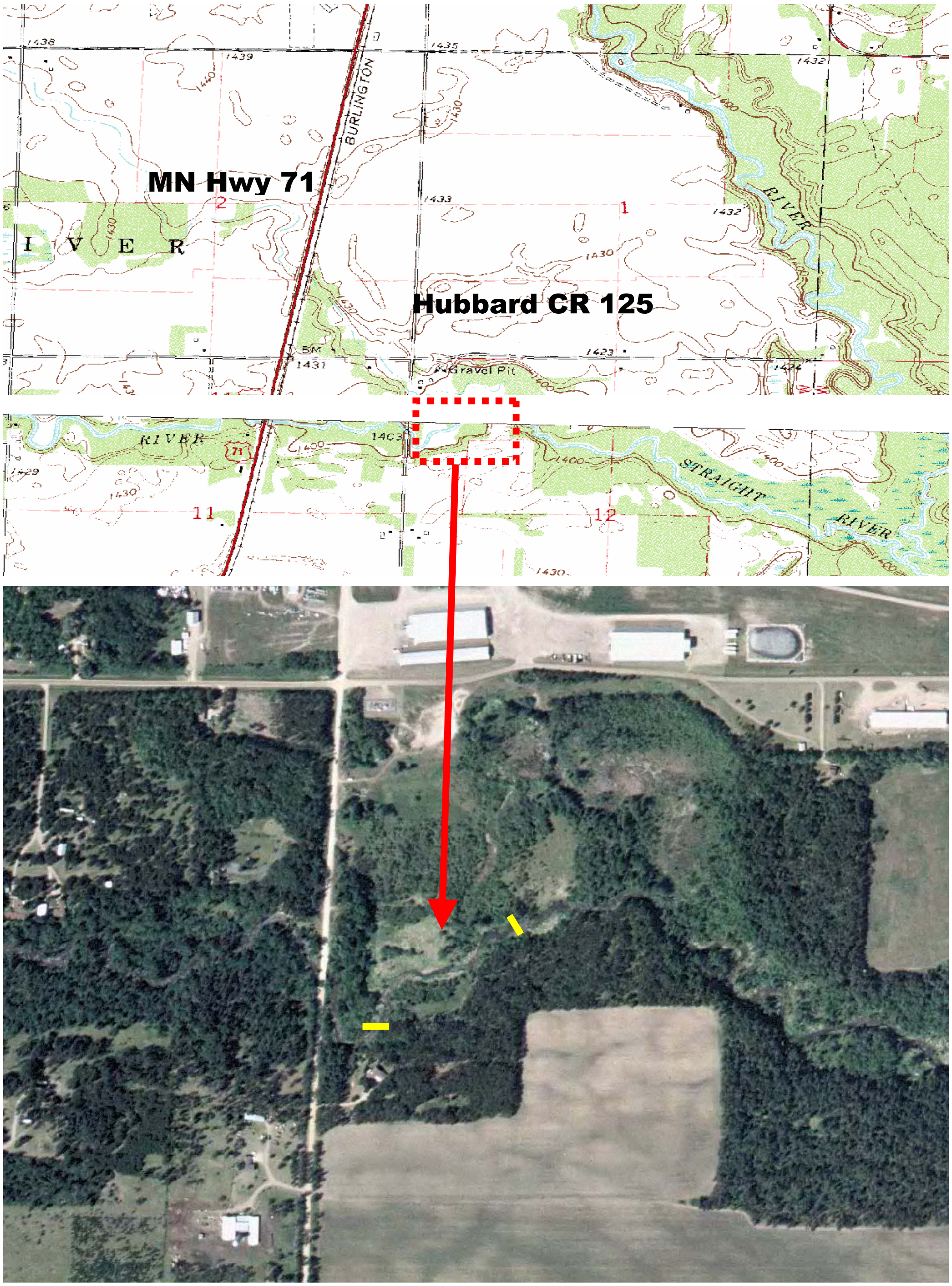
Appendix A27. Topographic map and aerial photograph of the upper study site on the Straight River. The yellow lines indicate the upper and lower boundaries of the site.



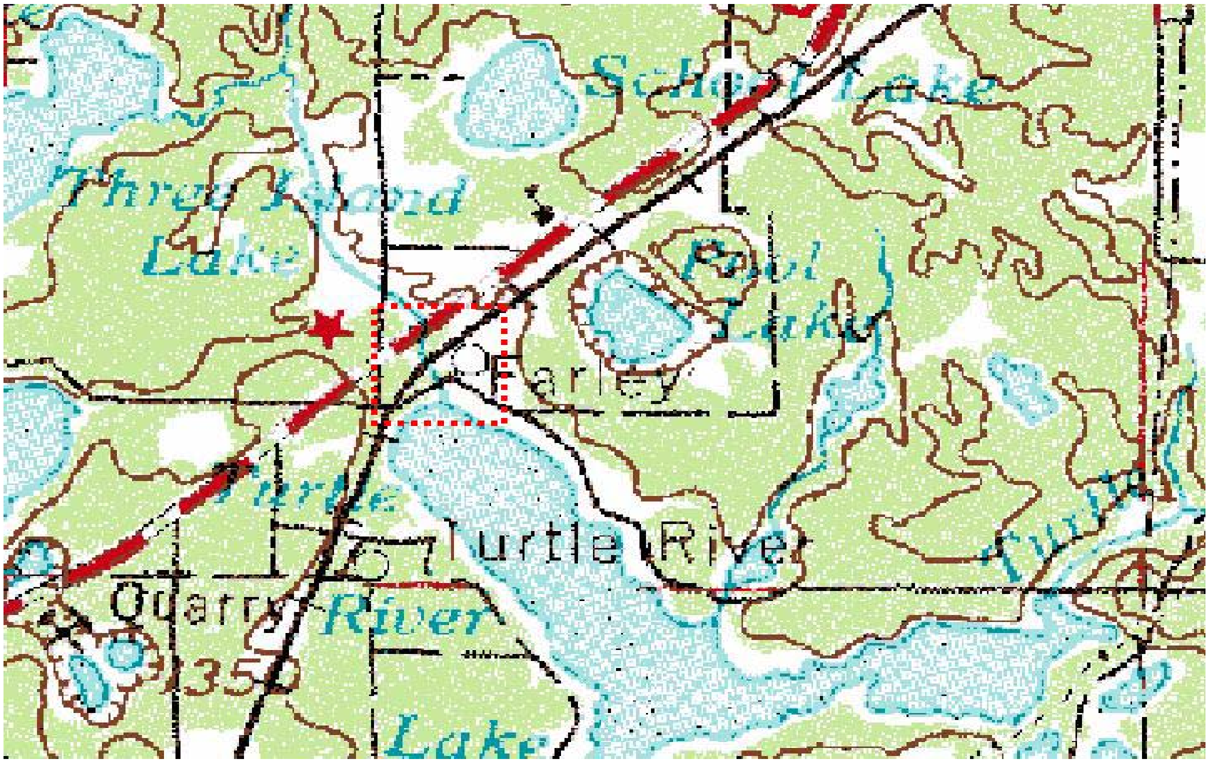
Appendix A28. Topographic map and aerial photograph of the middle study site on the Straight River. The yellow lines indicate the upper and lower boundaries of the site.



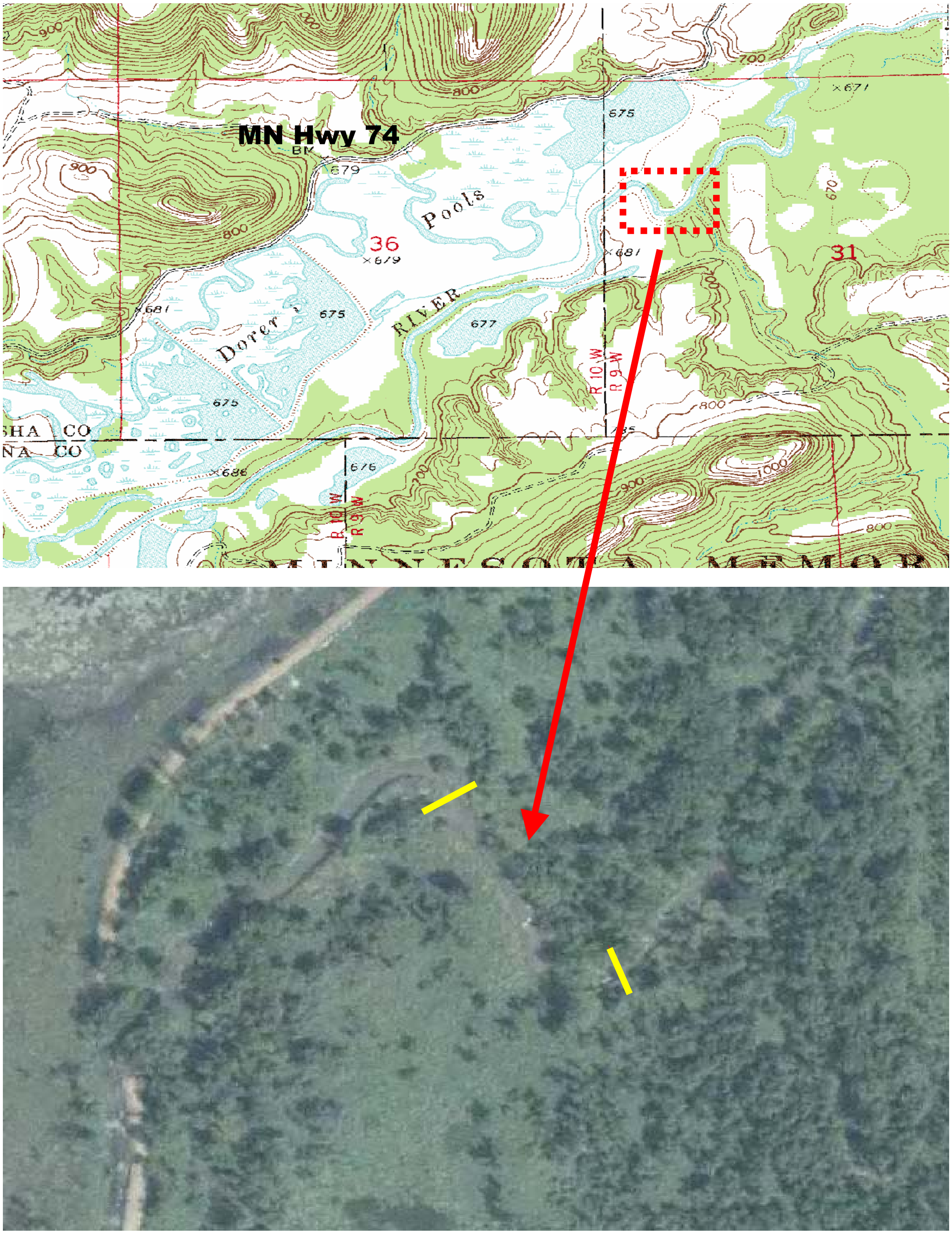
Appendix A29. Topographic map and aerial photograph of the lower study site on the Straight River. The yellow lines indicate the upper and lower boundaries of the site.



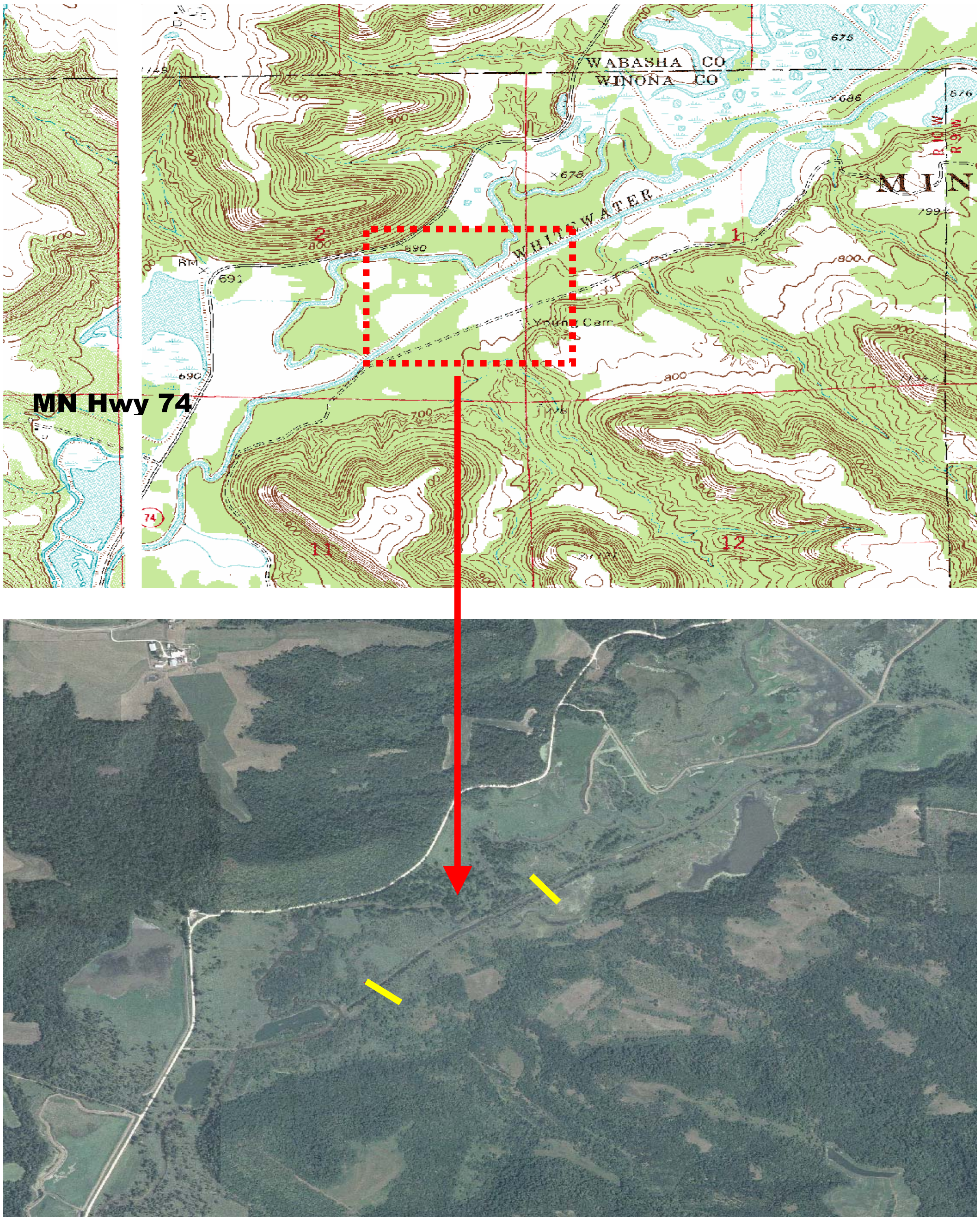
Appendix A30. Topographic map and aerial photograph of the Turtle River study site. The yellow lines indicate the upper and lower boundaries of the site.



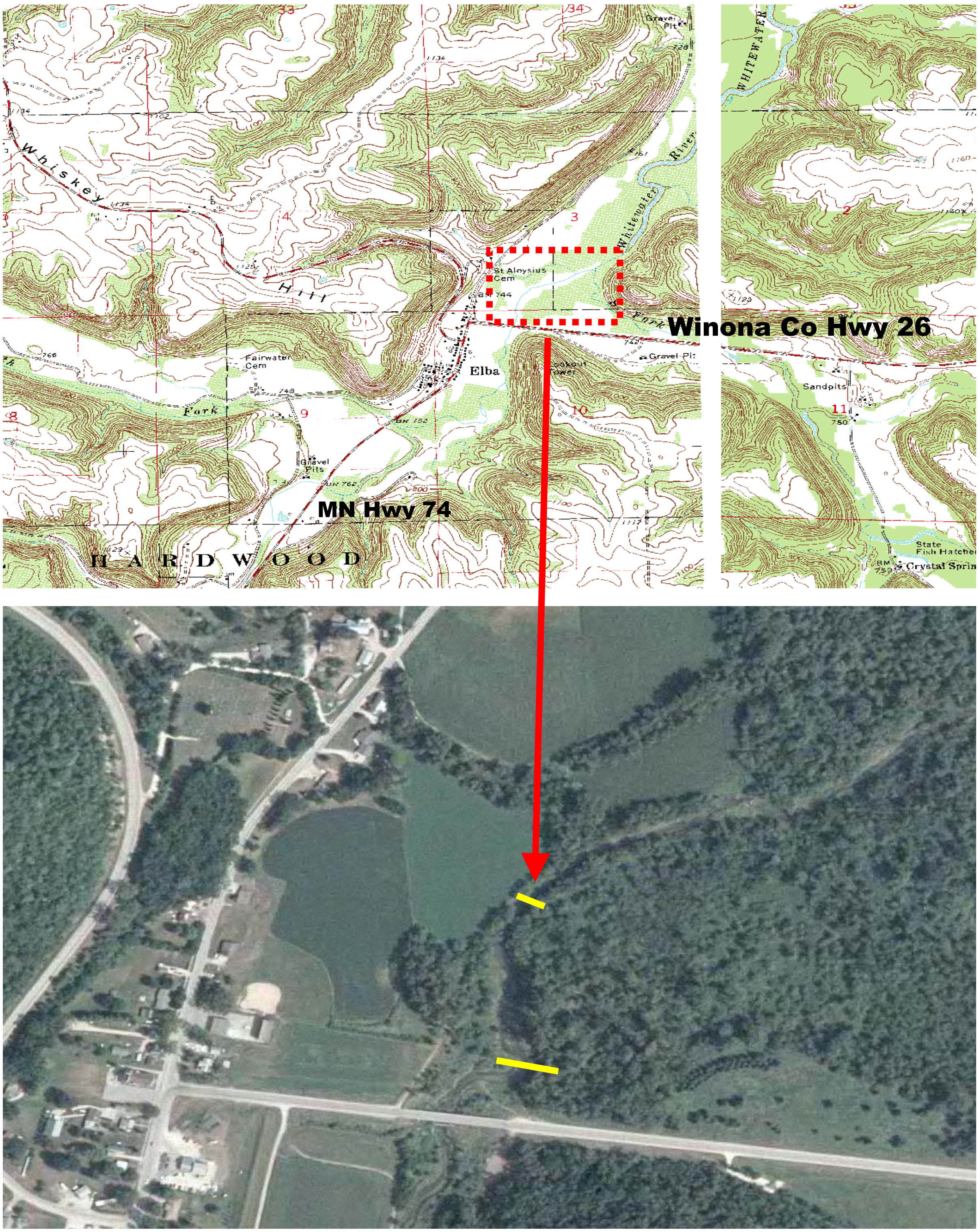
Appendix A31. Topographic map and aerial photograph of study site 1 on the Whitewater River. The yellow lines indicate the upper and lower boundaries of the site.



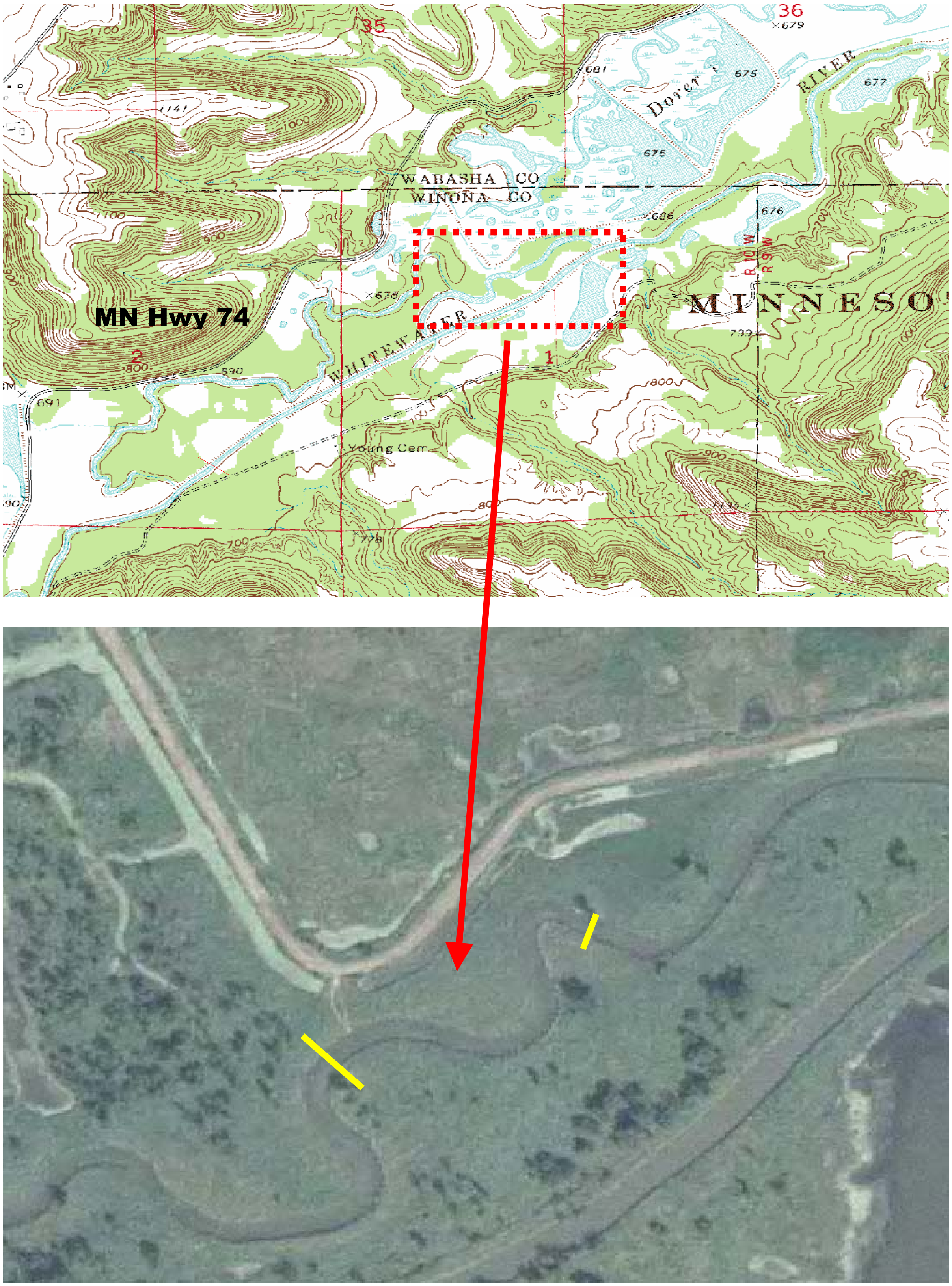
Appendix A32. Topographic map and aerial photograph of study site 2 on the Whitewater River. The yellow lines indicate the upper and lower boundaries of the site.



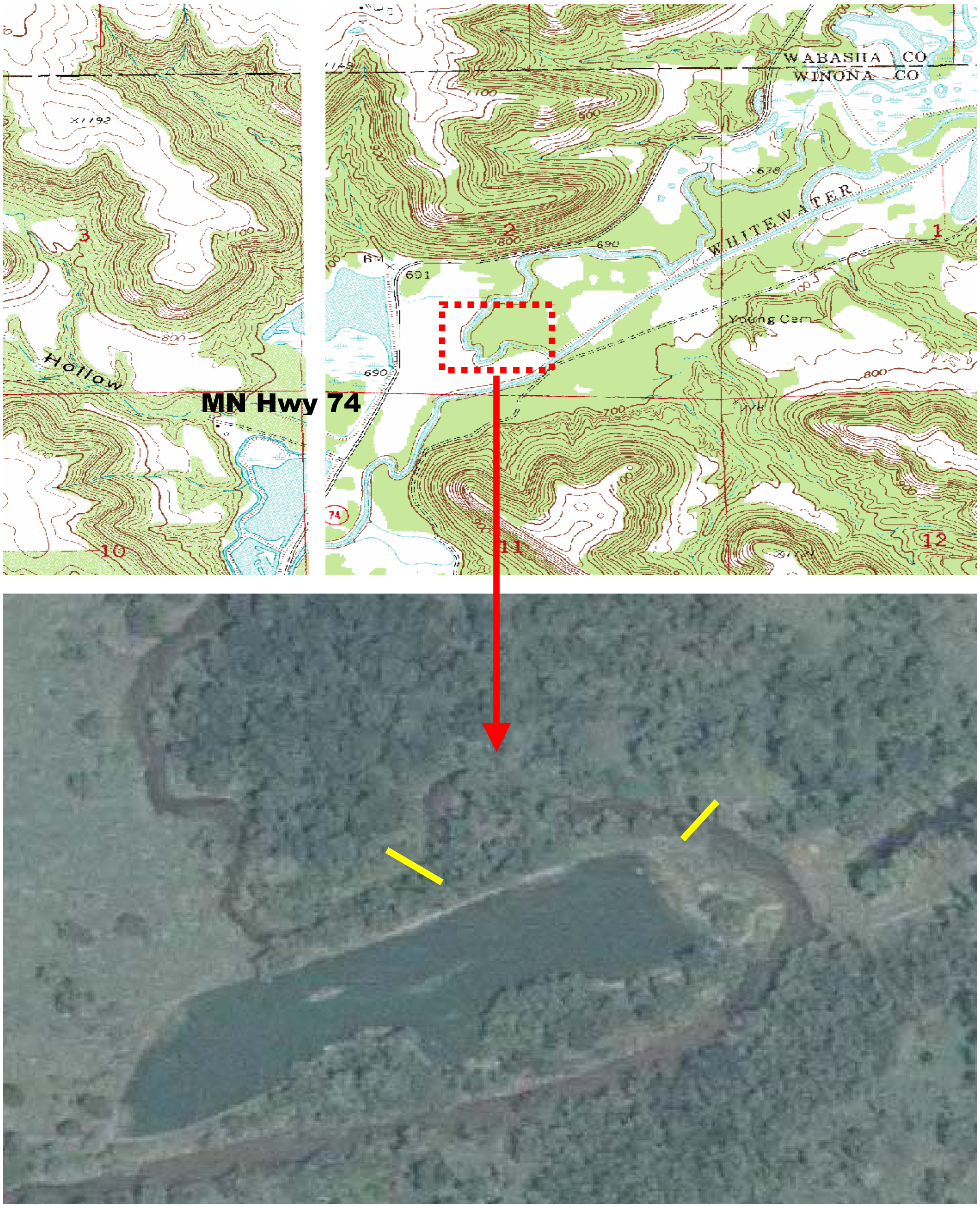
Appendix A33. Topographic map and aerial photograph of study site 3 on the Whitewater River. The yellow lines indicate the upper and lower boundaries of the site.



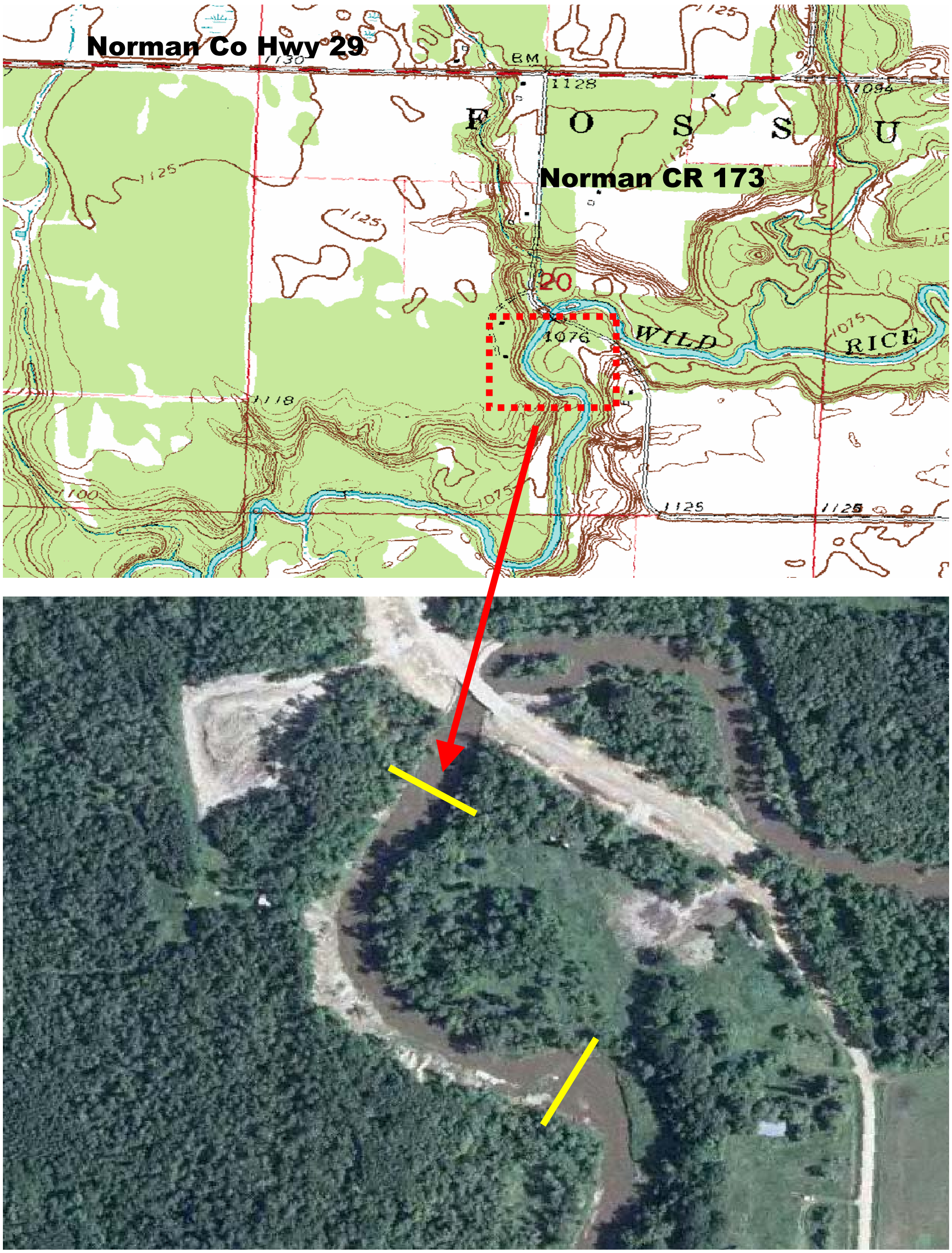
Appendix A34. Topographic map and aerial photograph of study site 4 of the Whitewater River. The yellow lines indicate the upper and lower boundaries of the site.



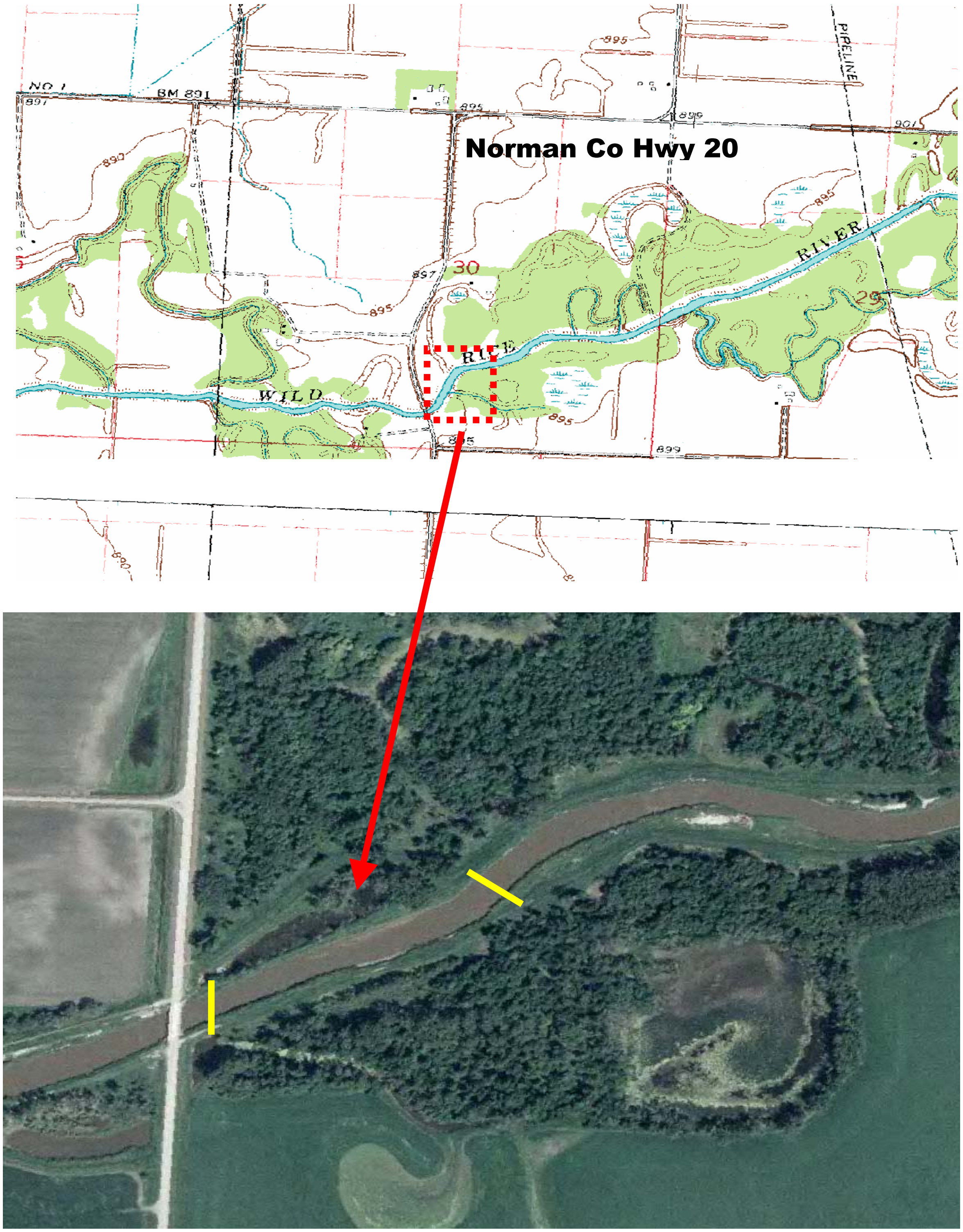
Appendix A35. Topographic map and aerial photograph of study site 5 on the Whitewater River. The yellow lines indicate the upper and lower boundaries of the site.



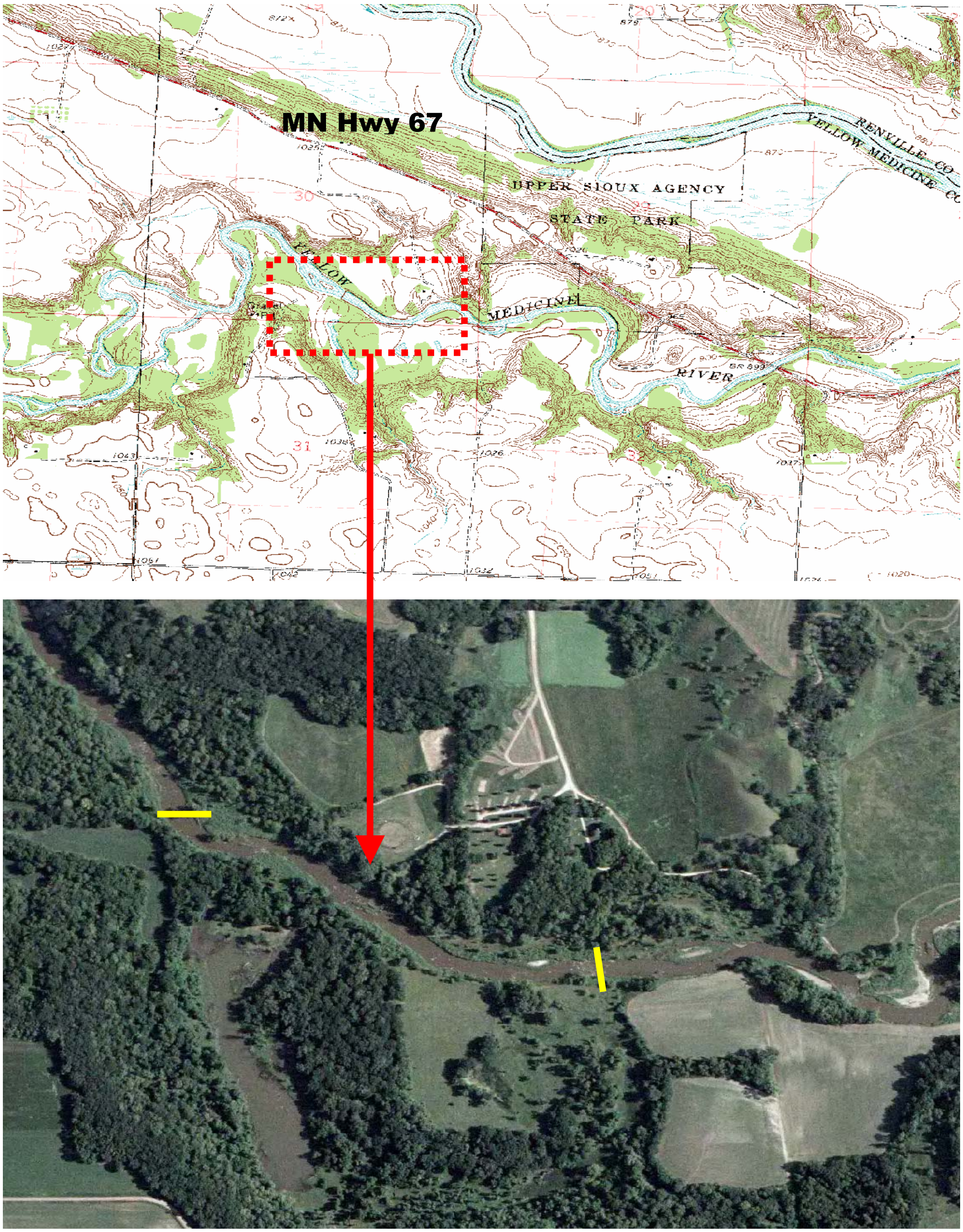
Appendix A36. Topographic map and aerial photograph of the upper study site on the Wild Rice River. The yellow lines indicate the upper and lower boundaries of the site.



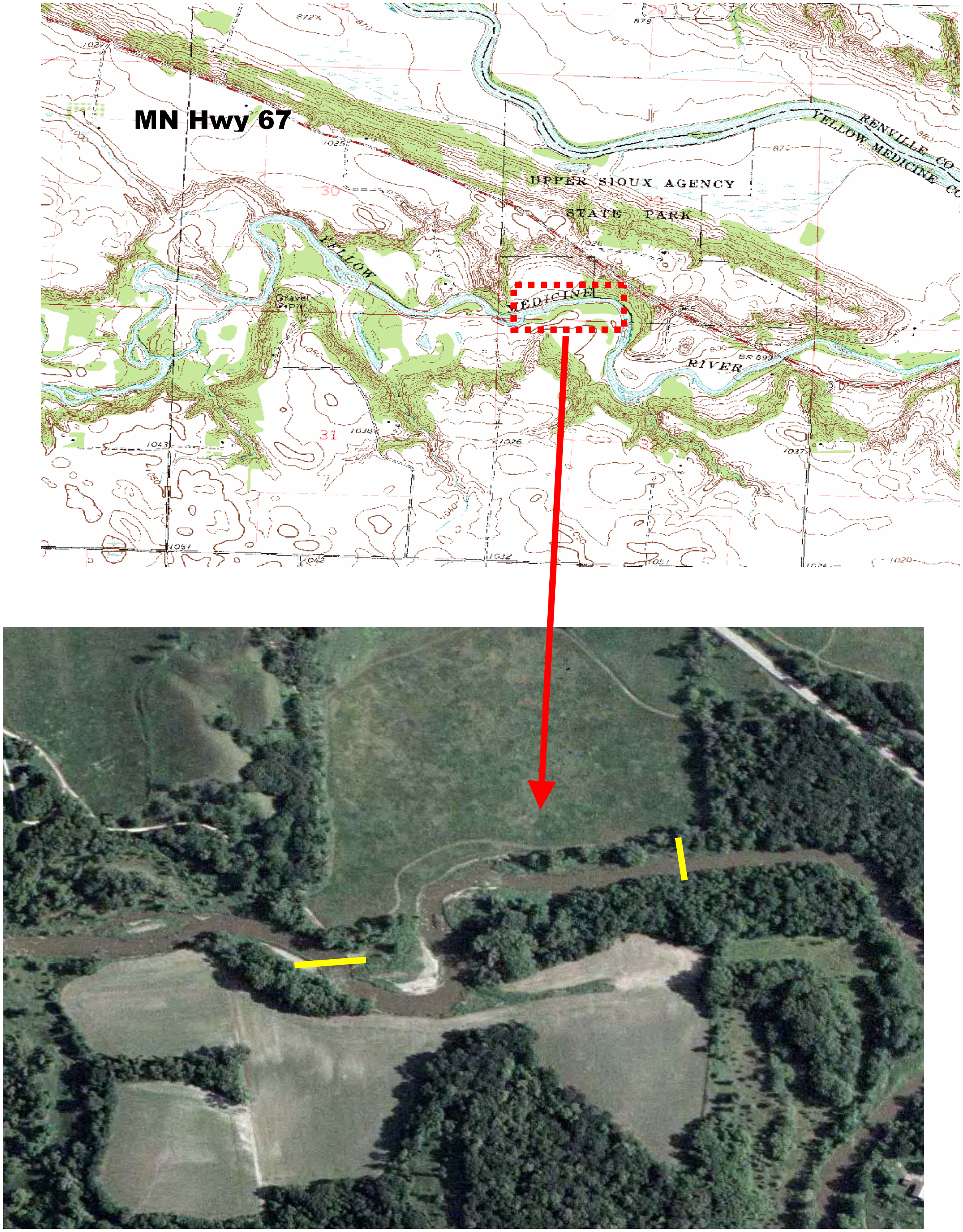
Appendix A37. Topographic map and aerial photograph of the lower study site on the Wild Rice River. The yellow lines indicate the upper and lower boundaries of the site.



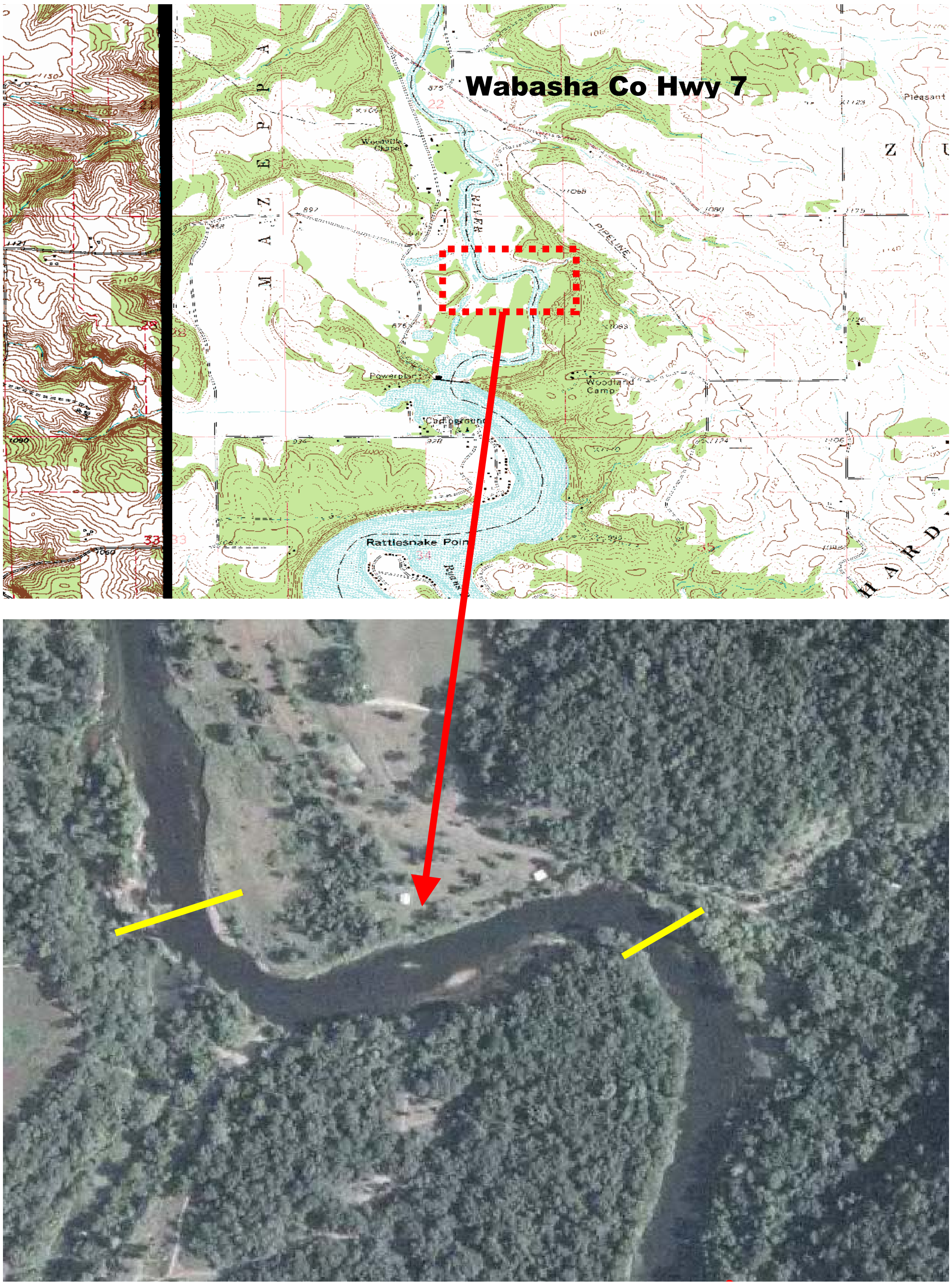
Appendix A38. Topographic map and aerial photograph of the upper study site on the Yellow Medicine River. The yellow lines indicate the upper and lower boundaries of the site.



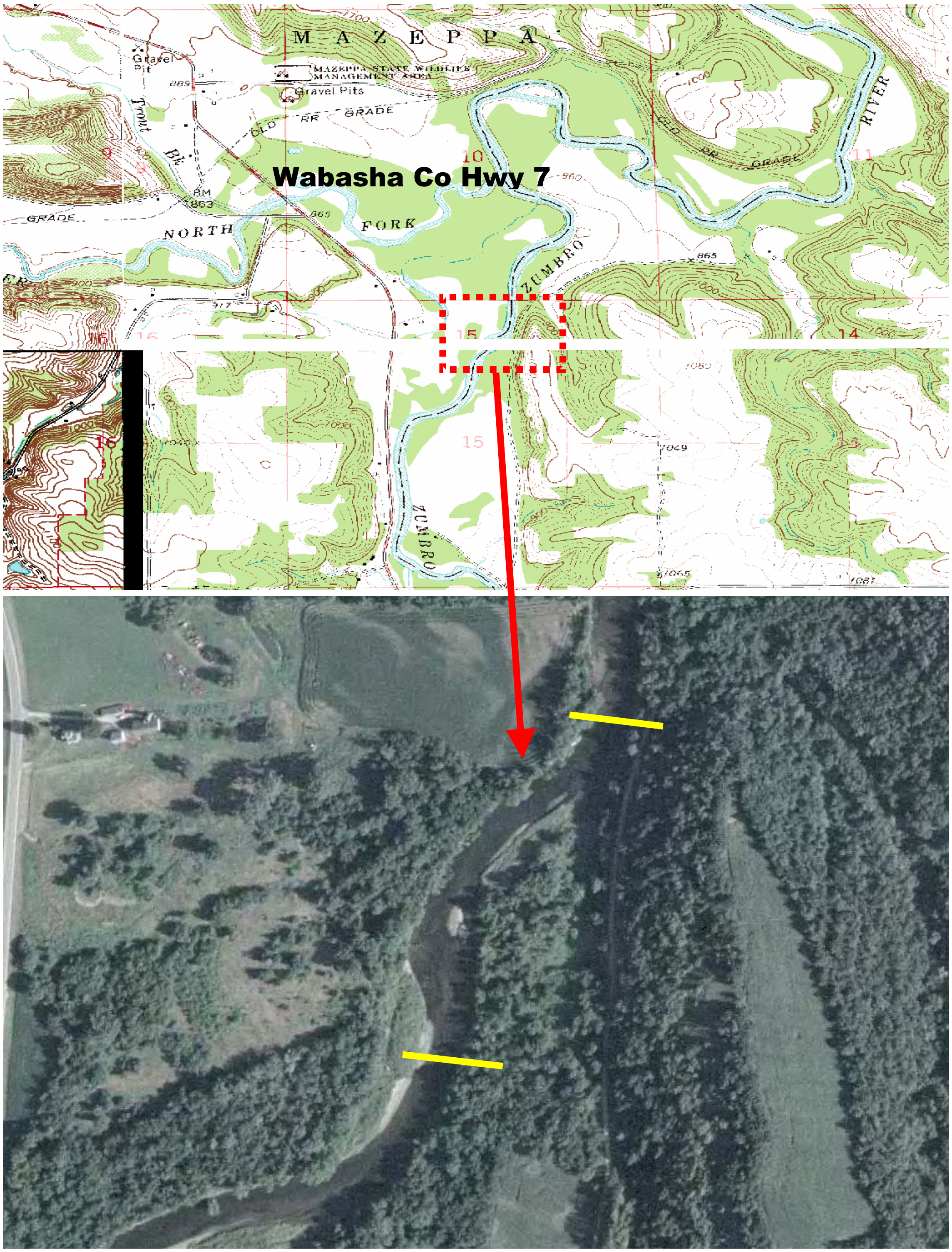
Appendix A39. Topographic map and aerial photograph of the lower study site on the Yellow Medicine River. The yellow lines indicate the upper and lower boundaries of the site.



Appendix A40. Topographic map and aerial photograph of the upper study site on the Zumbro River. The yellow lines indicate the upper and lower boundaries of the site.



Appendix A41. Topographic map and aerial photograph of the lower study site on the Zumbro River. The yellow lines indicate the upper and lower boundaries of the site.



Appendix B1. Table of the HSC Poisson/Arctangent equations for depth (D) and velocity (V). The depths and velocities in the formulas are in centimeters with the exception of lake sturgeon adults, the depths and velocities are in feet. For many of the depth curves, we have manually set the value for 0 depth to 0, although the formula gave a higher value. The depth curves for some species were asymptoted at 1 the values at the upper end were averaged and straight lined rather than going to 0, as we feel that biologically high depths won't be avoided if the preferred velocity is present. Curves were asymptoted for the following: black bullhead juvenile, black crappie juvenile, bluegill adult and juvenile, brown trout adult, channel catfish adult, northern hogsucker adult, tadpole madtom adult, walleye adult and juvenile, and yellow perch adult and juvenile. Curves were averaged and straight lined for the following: bigmouth shiner young-of-year, creek chub juvenile, golden redhorse juvenile, largemouth bass juvenile, quillback carpsucker young-of-year, sand shiner adult, slenderhead darter young-of-year, and spotfine shiner young-of-year. For walleye young-of-year depth, the curve ignored values at the depths, even though there was some use. The actual values used were averaged for the lower values.

Species-life stage	Formula
Banded darter adult D	=(((355-DEPTH)/(355-23.6))^10.8)*2.718^((10.8/41.1)*(1-((355-DEPTH)/(355-23.6))^41.1))
Banded darter adult V	=(((194-VELOCITY)/(194-88.3))^62.3)*2.718^((62.3/0.183)*(1-((194-VELOCITY)/(194-88.3))^0.183))
Banded darter spawning D	=(((300-DEPTH)/(300-30.271))^20.029)*2.718^((20.029/16.929)*(1-((300-DEPTH)/(300-30.271))^16.929))
Banded darter spawning V	=(((150-VELOCITY)/(150-108.172))^10.186)*2.718^((10.186/0.334)*(1-((150-VELOCITY)/(150-108.172))^0.334))
Banded darter young-of -year D	=(((355-DEPTH)/(355-19.2))^15.1)*2.718^((15.1/48.5)*(1-((355-DEPTH)/(355-19.2))^48.5))
Banded darter young-of -year V	=(((150-VELOCITY)/(150-64.906))^28.748)*2.718^((28.748/0.371)*(1-((150-VELOCITY)/(150-64.906))^0.371))
Bigmouth shiner adult D	=(((2092580000-DEPTH)/(2092580000-13.122))^63821100)*2.718^((63821100/555475000)*(1-((2092580000-DEPTH)/(2092580000-13.122))^555475000))
Bigmouth shiner adult V	=(((202262000-VELOCITY)/(202262000-28.839))^29945400)*2.718^((29945400/4715582.763)*(1-((202262000-VELOCITY)/(202262000-28.839))^4715582.763))
Bigmouth shiner young-of -year D	=(((300-DEPTH)/(300-11.599))^10.162)*2.718^((10.162/92.604)*(1-((300-DEPTH)/(300-11.599))^92.604))
Bigmouth shiner young-of -year V	=(((150-VELOCITY)/(150-10.293))^6.082)*2.718^((6.082/62.765)*(1-((150-VELOCITY)/(150-10.293))^62.765))
Black bullhead juvenile D	=(((568102000-DEPTH)/(568102000-29.945))^31373900)*2.718^((31373900/42356800)*(1-((568102000-DEPTH)/(568102000-29.945))^42356800))

Species-life stage	Formula
Black bullhead juvenile V	=(((150.104-VELOCITY)/(150.104-20.18))^54.205)*2.718^((54.205/0.667)*(1-((150.104-VELOCITY)/(150.104-20.18))^0.667))
Black bullhead young-of -year D	=(((300-DEPTH)/(300-44.495))^167.835)*2.718^((167.835/2.082)*(1-((300-DEPTH)/(300-44.495))^2.082))
Black bullhead young-of -year V	=(((150-VELOCITY)/(150-0))^10.247)*2.718^((10.247/570.162)*(1-((150-VELOCITY)/(150-0))^570.162))
Black crappie adult D	=(((689296000-DEPTH)/(689296000-355.708))^134007.943)*2.718^((134007.943/12560500)*(1-((689296000-DEPTH)/(689296000-355.708))^12560500))
Black crappie adult V	=(((6614511.67-VELOCITY)/(6614511.67-4.509))^1764965.356)*2.718^((1764965.356/2425355.978)*(1-((6614511.67-VELOCITY)/(6614511.67-4.509))^2425355.978))
Black crappie juvenile D	=(((418.608-DEPTH)/(418.608-136.829))^0.07)*2.718^((0.07/28.865)*(1-((418.608-DEPTH)/(418.608-136.829))^28.865))
Black crappie juvenile V	=(((150-VELOCITY)/(150-0))^11.471)*2.718^((11.471/4.248)*(1-((150-VELOCITY)/(150-0))^4.248))
Black crappie young-of -year D	=(((315553000-DEPTH)/(315553000-387.151))^587759.801)*2.718^((587759.801/1700243.592)*(1-((315553000-DEPTH)/(315553000-387.151))^1700243.592))
Black crappie young-of -year V	=(((21213.835-VELOCITY)/(21213.835-0))^1164.098)*2.718^((1164.098/82083.164)*(1-((21213.835-VELOCITY)/(21213.835-0))^82083.164))
Blacknose shiner adult D	=(((300.547-DEPTH)/(300.547-183.464))^28.036)*2.718^((28.036/0.263)*(1-((300.547-DEPTH)/(300.547-183.464))^0.263))
Blacknose shiner adult V	=(((4934530000-VELOCITY)/(4934530000-9.064))^213361000)*2.718^((213361000/2016800000)*(1-((4934530000-VELOCITY)/(4934530000-9.064))^2016800000))
Blacknose shiner young-of-year D	=(((1765360000-DEPTH)/(1765360000-9.395))^41999000)*2.718^((41999000/996900000)*(1-((1765360000-DEPTH)/(1765360000-9.395))^996900000))
Blacknose shiner young-of-year V	=(((150-VELOCITY)/(150-9.537))^2.839)*2.718^((2.839/40.155)*(1-((150-VELOCITY)/(150-9.537))^40.155))
Blackside darter adult D	=(((1556500000-DEPTH)/(1556500000-31.445))^40031700)*2.718^((40031700/139659000)*(1-((1556500000-DEPTH)/(1556500000-31.445))^139659000))
Blackside darter adult V	=(((541305000-VELOCITY)/(541305000-28.67))^39998400)*2.718^((39998400/12526800)*(1-((541305000-VELOCITY)/(541305000-28.67))^12526800))
Blackside darter young-of-year D	=(((1294040000-DEPTH)/(1294040000-26.07))^36829500)*2.718^((36829500/177064000)*(1-((1294040000-DEPTH)/(1294040000-26.07))^177064000))
Blackside darter young-of-year V	=(((150-VELOCITY)/(150-39.358))^15.072)*2.718^((15.072/0.543)*(1-((150-VELOCITY)/(150-39.358))^0.543))

Species-life stage	Formula
Bluegill adult D	=(((300.549-DEPTH)/(300.549-175.352))^32.392)*2.718^((32.392/0.338)*(1-((300.549-DEPTH)/(300.549-175.352))^0.338))
Bluegill adult V	=(((687184000-VELOCITY)/(687184000-3.198))^73313600)*2.718^((73313600/489890000)*(1-((687184000-VELOCITY)/(687184000-3.198))^489890000))
Bluegill juvenile D	=(((16760400-DEPTH)/(16760400-26.091))^3892028.405)*2.718^((3892028.405/496062.457)*(1-((16760400-DEPTH)/(16760400-26.091))^496062.457))
Bluegill juvenile V	=(((150-VELOCITY)/(150-0))^11.471)*2.718^((11.471/4.248)*(1-((150-VELOCITY)/(150-0))^4.248))
Bluegill young-of-year D	=(((2148120000-DEPTH)/(2148120000-33.743))^121205000)*2.718^((121205000/366890000)*(1-((2148120000-DEPTH)/(2148120000-33.743))^366890000))
Bluegill young-of-year V	=(((150-VELOCITY)/(150-0))^10.048)*2.718^((10.048/312.706)*(1-((150-VELOCITY)/(150-0))^312.706))
Bluntnose minnow adult D	=(((500-DEPTH)/(500-25.4))^9.92)*2.718^((9.92/60.8)*(1-((500-DEPTH)/(500-25.4))^60.8))
Bluntnose minnow adult V	=(((489-VELOCITY)/(489-25.4))^319)*2.718^((319/0.477)*(1-((489-VELOCITY)/(489-25.4))^0.477))
Bluntnose minnow young-of-year D	=(((331.614-DEPTH)/(331.614-10.9))^25.064)*2.718^((25.064/87.592)*(1-((331.614-DEPTH)/(331.614-10.9))^87.592))
Bluntnose minnow young-of-year V	=(((331262000-VELOCITY)/(331262000-12.753))^34749100)*2.718^((34749100/73984900)*(1-((331262000-VELOCITY)/(331262000-12.753))^73984900))
Brassy minnow adult D	=(((300-DEPTH)/(300-44.514))^147.236)*2.718^((147.236/1.858)*(1-((300-DEPTH)/(300-44.514))^1.858))
Brassy minnow adult V	=(((401715000-VELOCITY)/(401715000-22.54))^34465400)*2.718^((34465400/114728000)*(1-((401715000-VELOCITY)/(401715000-22.54))^114728000))
Brook stickleback adult D	=(((300-DEPTH)/(300-24.507))^26.99)*2.718^((26.99/22.438)*(1-((300-DEPTH)/(300-24.507))^22.438))
Brook stickleback adult V	=(((764213000-VELOCITY)/(764213000-3.922))^48309300)*2.718^((48309300/1953480000)*(1-((764213000-VELOCITY)/(764213000-3.922))^1953480000))
Brook stickleback young-of-year D	=(((363216000-DEPTH)/(363216000-34.063))^30521200)*2.718^((30521200/14990900)*(1-((363216000-DEPTH)/(363216000-34.063))^14990900))
Brook stickleback young-of-year V	=(((1474740000-VELOCITY)/(1474740000-0))^219260000)*2.718^((219260000/95621600000)*(1-((1474740000-VELOCITY)/(1474740000-0))^95621600000))
Brown trout adult D	=0.505+(1.075/3.1416)*ATAN(3.1416*0.037*(DEPTH -80.547))

Species-life stage	Formula
Brown trout adult V	=(((1020000000-VELOCITY)/(1020000000-41.6))^25900000)*2.718^ ((25900000/91100000)*(1-((1020000000-VELOCITY)/(1020000000-41.6))^91100000))
Brown trout ju-venile D	=(((300- DEPTH)/(300-118.736))^1.873)*2.718^((1.873/5.274)*(1-((300-DEPTH)/(300-118.736))^5.274))
Brown trout juve-nile V	=(((1088.249-VELOCITY)/(1088.249-22.573))^87.658)*2.718^((87.658/30.719)*(1-((1088.249-VELOCITY)/(1088.249-22.573))^30.719))
Brown trout spawning D	=(((3095.527-DEPTH)/(3095.527-44.06))^2827.414)*2.718^ ((2827.414/33.159)*(1-((3095.527-DEPTH)/(3095.527-44.06))^33.159))
Brown trout spawning V	=(((150-VELOCITY)/(150-54.712))^29.64)*2.718^((29.64/1.352)*(1-((150-VELOCITY)/(150-54.712))^1.352))
Brown trout young-of-year D	=(((-66.8-DEPTH)/(-66.8-34.3))^34.197)*2.718^((34.197/1.239)*(1-((-66.8-DEPTH)/(-66.8-34.27))^1.239))
Brown trout young-of-year V*	=(((132-VELOCITY)/(132--30.04))^55.7)*2.718^((55.7/0.033)*(1-((132-VELOCITY)/(132--30.04))^0.033))
Central stone-roller adult D	=(((499-DEPTH)/(499-25.3))^22)*2.718^((22/38.7)*(1-((499-DEPTH)/(499-25.3))^38.7))
Central stone-roller adult V	=(((195-VELOCITY)/(195-79.2))^61.9)*2.718^((61.9/0.269)*(1-((195-VELOCITY)/(195-79.2))^0.269))
Central stone-roller juvenile D	=(((300-DEPTH)/(300-19.755))^16.433)*2.718^((16.433/45.925)*(1-((300-DEPTH)/(300-19.755))^45.925))
Central stone-roller juvenile V	=(((150.45-VELOCITY)/(150.45-51.011))^55.776)*2.718^((55.776/0.674)*(1-((150.45-VELOCITY)/(150.45-51.011))^0.674))
Central stone-roller spawning D	=(((300.001-DEPTH)/(300.001-26.684))^47.817)*2.718^((47.817/11.252)*(1-((300.001-DEPTH)/(300.001-26.684))^11.252))
Central stone-roller spawning V	=(((150-VELOCITY)/(150-49.943))^19.369)*2.718^((19.369/3.311)*(1-((150-VELOCITY)/(150-49.943))^3.311))
Central stone-roller young-of-year D	=(((355-DEPTH)/(355-11.5))^21.2)*2.718^((21.2/82.4)*(1-((355-DEPTH)/(355-11.5))^82.4))
Central stone-roller young-of-year V	=(((146-VELOCITY)/(146-55.7))^65)*2.718^((65/0.565)*(1-((146-VELOCITY)/(146-55.7))^0.565))
Channel catfish adult D	=(((1098410000-DEPTH)/(1098410000-92.113))^3056716.905)*2.718^ ((3056716.905/65326300)*(1-((1098410000-DEPTH)/(1098410000-92.113))^65326300))
Channel catfish adult V*	=(((150-VELOCITY)/(150+3.303))^3.836)*2.718^((3.836/42.783)*(1-((150-VELOCITY)/(150+3.303))^42.783))

Species-life stage	Formula
Channel catfish juvenile D	=(((2555810000-DEPTH)/(2555810000-133.007))^3553032.739)*2.718^((3553032.739/87335500)*(1-((2555810000-DEPTH)/(2555810000-133.007))^87335500))
Channel catfish juvenile V	=(((150.001-VELOCITY)/(150.001-0.855))^3.709)*2.718^((3.709/1024.131)*(1-((150.001-VELOCITY)/(150.001-0.855))^1024.131))
Channel catfish young-of-year D	=(((838415000-DEPTH)/(838415000-22.016))^4160628.858)*2.718^((4160628.858/185959000)*(1-((838415000-DEPTH)/(838415000-22.016))^185959000))
Channel catfish young-of-year V	=(((155-VELOCITY)/(155-28.9))^9.37)*2.718^((9.37/4.76)*(1-((155-VELOCITY)/(155-28.9))^4.76))
Common carp adult D	=(((2450310000-DEPTH)/(2450310000-73.164))^11326300)*2.718^((11326300/144226000)*(1-((2450310000-DEPTH)/(2450310000-73.164))^144226000))
Common carp adult V	=(((6706310000-VELOCITY)/(6706310000-0))^92029500)*2.718^((92029500/2921370000)*(1-((6706310000-VELOCITY)/(6706310000-0))^2921370000))
Common carp juvenile D	=(((207190.661-DEPTH)/(207190.661-51.024))^1471.844)*2.718^((1471.844/25318.352)*(1-((207190.661-DEPTH)/(207190.661-51.024))^25318.352))
Common carp juvenile V	=(((150-VELOCITY)/(150-25.04))^27.369)*2.718^((27.369/0.854)*(1-((150-VELOCITY)/(150-25.04))^0.854))
Common carp young-of-year D	=(((581235000-DEPTH)/(581235000-19.436))^42620700)*2.718^((42620700/71218100)*(1-((581235000-DEPTH)/(581235000-19.436))^71218100))
Common carp young-of-year V	=(((294375.049-VELOCITY)/(294375.049-6.425))^30193.896)*2.718^((30193.896/12265.085)*(1-((294375.049-VELOCITY)/(294375.049-6.425))^12265.085))
Common shiner adult D	=(((300-DEPTH)/(300-91.521))^1.144)*2.718^((1.144/8.716)*(1-((300-DEPTH)/(300-91.521))^8.716))
Common shiner adult V	=(((155-VELOCITY)/(155-41.6))^2.12)*2.718^((2.12/4.6)*(1-((155-VELOCITY)/(155-41.6))^4.6))
Common shiner juvenile D	=(((1951030000-DEPTH)/(1951030000-26.782))^11470200)*2.718^((11470200/360212000)*(1-((1951030000-DEPTH)/(1951030000-26.782))^360212000))
Common shiner juvenile V	=(((155-VELOCITY)/(155-15.6))^2.75)*2.718^((2.75/29.3)*(1-((155-VELOCITY)/(155-15.6))^29.3))
Common shiner spawning D	=(((74791300-DEPTH)/(74791300-35.167))^5551696.476)*2.718^((5551696.476/4504372.744)*(1-((74791300-DEPTH)/(74791300-35.167))^4504372.744))
Common shiner spawning V	=(((151.722-VELOCITY)/(151.722-52.143))^60.118)*2.718^((60.118/0.703)*(1-((151.722-VELOCITY)/(151.722-52.143))^0.703))
Common shiner young-of-year V	=(((155-VELOCITY)/(155-19.269))^12.563)*2.718^((12.563/6.165)*(1-((155-VELOCITY)/(155-19.269))^6.165))

Species-life stage	Formula
Common shiner young-of-year D	=(((305-DEPTH)/(305-10.5))^2.05)*2.718^((2.05/234)*(1-((305-DEPTH)/(305-10.5))^234))
Creek chub adult D	=(((300-DEPTH)/(300-37.856))^3.87)*2.718^((3.87/25.783)*(1-((300-DEPTH)/(300-37.856))^25.783))
Creek chub adult V	=(((150-VELOCITY)/(150-23.675))^2.202)*2.718^((2.202/10.642)*(1-((150-VELOCITY)/(150-23.675))^10.642))
Creek chub juve-nile D	=(((300.428-DEPTH)/(300.428-23.369))^10.671)*2.718^((10.671/57.441)*(1-((300.428-DEPTH)/(300.428-23.369))^57.441))
Creek chub juve-nile V	=(((1510.925-VELOCITY)/(1510.925-11.278))^42.91)*2.718^((42.91/244.665)*(1-((1510.925-VELOCITY)/(1510.925-11.278))^244.665))
Creek chub young-of-year D	=(((300-DEPTH)/(300-12.684))^9.562)*2.718^((9.562/82.547)*(1-((300-DEPTH)/(300-12.684))^82.547))
Creek chub young-of-year V	=(((518659000-VELOCITY)/(518659000-0))^18762000)*2.718^((18762000/60950500)*(1-((518659000-VELOCITY)/(518659000-0))^60950500))
Eastern blacknose dace adult D	=(((1574320000-DEPTH)/(1574320000-40.104))^35523200)*2.718^((35523200/121267000)*(1-((1574320000-DEPTH)/(1574320000-40.104))^121267000))
Eastern blacknose dace adult V	=(((189.408-VELOCITY)/(189.408-56.161))^4.873)*2.718^((4.873/3.343)*(1-((189.408-VELOCITY)/(189.408-56.161))^3.343))
Eastern blacknose dace young-of -year D	=(((321.527-DEPTH)/(321.527-9.043))^15.015)*2.718^((15.015/127.469)*(1-((321.527-DEPTH)/(321.527-9.043))^127.469))
Eastern blacknose dace young-of -year V	=(((1088.249-VELOCITY)/(1088.249-22.573))^87.658)*2.718^((87.658/30.719)*(1-((1088.249-VELOCITY)/(1088.249-22.573))^30.719))
Emerald shiner adult D	=(((531430000-DEPTH)/(531430000-21.588))^18753400)*2.718^((18753400/64374100)*(1-((531430000-DEPTH)/(531430000-21.588))^64374100))
Emerald shiner adult V	=(((135-VELOCITY)/(135-19.8))^1.08)*2.718^((1.08/2.25)*(1-((135-VELOCITY)/(135-19.8))^2.25))
Emerald shiner young-of-year D	=(((2199160000-DEPTH)/(2199160000-0.848))^75882000)*2.718^((75882000/19101900000)*(1-((2199160000-DEPTH)/(2199160000-0.848))^19101900000))
Emerald shiner young-of-year V	=(((406-VELOCITY)/(406-0))^12.45)*2.718^((12.45/18.21)*(1-((406-VELOCITY)/(406-0))^18.21))
Fantail darter adult D	=(((300-DEPTH)/(300-17.8))^13.9)*2.718^((13.9/42.3)*(1-((300-DEPTH)/(300-17.8))^42.3))
Fantail darter adult V	=(((568685000-VELOCITY)/(568685000-91.36))^32302800)*2.718^((32302800/13844200)*(1-((568685000-VELOCITY)/(568685000-91.36))^13844200))

Species-life stage	Formula
Fantail darter spawning D	=(((300-DEPTH)/(300-13.324))^8.324)*2.718^((8.324/86.179)*(1-((300-DEPTH)/(300-13.324))^86.179))
Fantail darter spawning V	=(((157.575-VELOCITY)/(157.575-54.827))^76.4)*2.718^((76.4/0.863)*(1-((157.575-VELOCITY)/(157.575-54.827))^0.863))
Fantail darter young-of-year D	=(((300-DEPTH)/(300-9.399))^12.527)*2.718^((12.527/116.059)*(1-((300-DEPTH)/(300-9.399))^116.059))
Fantail darter young-of-year V	=(((356863000-VELOCITY)/(356863000-55.052))^13515400)*2.718^((13515400/9615927.239)*(1-((356863000-VELOCITY)/(356863000-55.052))^9615927.239))
Fathead minnow adult D	=(((1027220000-DEPTH)/(1027220000-19.485))^29622200)*2.718^((29622200/213446000)*(1-((1027220000-DEPTH)/(1027220000-19.485))^213446000))
Fathead minnow adult V	=(((642034-VELOCITY)/(642034-9.96))^17610)*2.718^((17610/75521)*(1-((642034-VELOCITY)/(642034-9.96))^75521))
Fathead minnow spawning D	=(((504645000-DEPTH)/(504645000-28.611))^45510300)*2.718^((45510300/27459400)*(1-((504645000-DEPTH)/(504645000-28.611))^27459400))
Fathead minnow spawning V	=(((161.473-VELOCITY)/(161.473-22.786))^101.951)*2.718^((101.951/1.202)*(1-((161.473-VELOCITY)/(161.473-22.786))^1.202))
Fathead minnow young-of-year D	=(((300.02-DEPTH)/(300.02-10.15))^14.39)*2.718^((14.39/100.15)*(1-((300.02-DEPTH)/(300.02-10.15))^100.15))
Fathead minnow young-of-year V	=(((150-VELOCITY)/(150-0))^70)*2.718^((70/0.87)*(1-((150-VELOCITY)/(150-0))^0.87))
Freshwater drum young-of-year D	=(((2071480000-DEPTH)/(2071480000-51.772))^47999900)*2.718^((47999900/125784000)*(1-((2071480000-DEPTH)/(2071480000-51.772))^125784000))
Freshwater drum young-of-year V	=(((300-VELOCITY)/(300-17.8))^13.9)*2.718^((13.9/42.3)*(1-((300-VELOCITY)/(300-17.8))^42.3))
Gizzard shad adult D	=(((321.536-DEPTH)/(321.536-61.804))^172.583)*2.718^((172.583/2.131)*(1-((321.536-DEPTH)/(321.536-61.804))^2.131))
Gizzard shad adult V	=(((150.003-VELOCITY)/(150.003-22.547))^92.285)*2.718^((92.285/1.145)*(1-((150.003-VELOCITY)/(150.003-22.547))^1.145))
Gizzard shad young-of-year D	=(((301.535-DEPTH)/(301.535-58.77))^102.883)*2.718^((102.883/1.274)*(1-((301.535-DEPTH)/(301.535-58.77))^1.274))
Gizzard shad young-of-year V	=(((288069.704-VELOCITY)/(288069.704-21.535))^21202.425)*2.718^((21202.425/18892.48)*(1-((288069.704-VELOCITY)/(288069.704-21.535))^18892.48))
Golden redhorse adult D	=(((655.308-DEPTH)/(655.308-148.25))^2.872)*2.718^((2.872/15.441)*(1-((655.308-DEPTH)/(655.308-148.25))^15.441))

Species-life stage	Formula
Golden redhorse adult V	=(((501240000-VELOCITY)/(501240000-15.107))^9781599.261)*2.718^((9781599.261/79432800)*(1-((501240000-VELOCITY)/(501240000-15.107))^79432800))
Golden redhorse juvenile D	=(((300-$A12)/(300-96.689))^33.65)*2.718^((33.65/2.049)*(1-((300-$A12)/(300-96.689))^2.049))
Golden redhorse juvenile V	=(((599.505-$A12)/(599.505-17.332))^21.913)*2.718^((21.913/52.238)*(1-((599.505-$A12)/(599.505-17.332))^52.238))
Golden redhorse young-of-year D	=(((305-DEPTH)/(305-15.6))^11.8)*2.718^((11.8/51.8)*(1-((305-DEPTH)/(305-15.6))^51.8))
Golden redhorse young-of-year V	=(((156-VELOCITY)/(156-17.6))^9.42)*2.718^((9.42/4.12)*(1-((156-VELOCITY)/(156-17.6))^4.12))
Greater redhorse adult D	=(((300-DEPTH)/(300-111.76))^27.596)*2.718^((27.596/1.565)*(1-((300-DEPTH)/(300-111.76))^1.565))
Greater redhorse adult V	=(((180.429-VELOCITY)/(180.429-80.123))^71.598)*2.718^((71.598/0.098)*(1-((180.429-VELOCITY)/(180.429-80.123))^0.098))
Greater redhorse juvenile D	=(((626789.778-DEPTH)/(626789.778-107.836))^16578.525)*2.718^((16578.525/7811.388)*(1-((626789.778-DEPTH)/(626789.778-107.836))^7811.388))
Greater redhorse juvenile V	=(((991894.746-VELOCITY)/(991894.746-26.261))^13265.514)*2.718^((13265.514/104976.607)*(1-((991894.746-VELOCITY)/(991894.746-26.261))^104976.607))
Greater redhorse spawning D	=(((857310000-DEPTH)/(857310000-33.312))^68948400)*2.718^((68948400/61185600)*(1-((857310000-DEPTH)/(857310000-33.312))^61185600))
Greater redhorse spawning V	=(((157.575-VELOCITY)/(157.575-54.827))^76.4)*2.718^((76.4/0.843)*(1-((157.575-VELOCITY)/(157.575-54.827))^0.843))
Greater redhorse young-of-year D	=(((300-DEPTH)/(300-19.267))^12.774)*2.718^((12.774/56.01)*(1-((300-DEPTH)/(300-19.267))^56.01))
Greater redhorse young-of-year V	=(((1582440000-VELOCITY)/(1582440000-21.301))^130685000)*2.718^((130685000/290489000)*(1-((1582440000-VELOCITY)/(1582440000-21.301))^290489000))
Green sunfish adult D	=(((15380800000-DEPTH)/(15380800000-18.789))^86278700)*2.718^((86278700/4980590000)*(1-((15380800000-DEPTH)/(15380800000-18.789))^4980590000))
Green sunfish adult V	=(((1143820000-VELOCITY)/(1143820000-0))^61581100)*2.718^((61581100/10695900000)*(1-((1143820000-VELOCITY)/(1143820000-0))^10695900000))
Green sunfish young-of-year D	=(((2794.953-DEPTH)/(2794.953-27.048))^39.57)*2.718^((39.57/351.309)*(1-((2794.953-DEPTH)/(2794.953-27.048))^351.309))
Green sunfish young-of-year V	=(((150-VELOCITY)/(150-0))^7.636)*2.718^((7.636/31733.825)*(1-((150-VELOCITY)/(150-0))^31733.825))

Species-life stage	Formula
Hornyhead chub adult D	=(((300-DEPTH)/(300-101.902))^11.252)*2.718^((11.252/2.352)*(1-((300-DEPTH)/(300-101.902))^2.352))
Hornyhead chub adult V	=(((231.002-VELOCITY)/(231.002-41.52))^105.895)*2.718^((105.895/0.264)*(1-((231.002-VELOCITY)/(231.002-41.52))^0.264))
Hornyhead chub juvenile D	=(((300-DEPTH)/(300-24.006))^1.87)*2.718^((1.87/66.252)*(1-((300-DEPTH)/(300-24.006))^66.252))
Hornyhead chub juvenile V	=(((150-VELOCITY)/(150-38.807))^18.218)*2.718^((18.218/0.607)*(1-((150-VELOCITY)/(150-38.807))^0.607))
Hornyhead chub spawning D	=(((300-DEPTH)/(300-24.1))^6.45)*2.718^((6.45/107)*(1-((300-DEPTH)/(300-24.1))^107))
Hornyhead chub spawning V	=(((150-VELOCITY)/(150-27.7))^17)*2.718^((17/5.59)*(1-((150-VELOCITY)/(150-27.7))^5.59))
Hornyhead chub young-of-year D	=(((300-DEPTH)/(300-8.246))^6.855)*2.718^((6.855/169.823)*(1-((300-DEPTH)/(300-8.246))^169.823))
Hornyhead chub young-of-year V	=(((224.548-VELOCITY)/(224.548-9.056))^10.175)*2.718^((10.175/59.032)*(1-((224.548-VELOCITY)/(224.548-9.056))^59.032))
Iowa darter adult D	=(((3423970000-DEPTH)/(3423970000-26.774))^20042300)*2.718^((20042300/584977000)*(1-((3423970000-DEPTH)/(3423970000-26.774))^584977000))
Iowa darter adult V	=(((1779090000-VELOCITY)/(1779090000-0))^106924000)*2.718^((106924000/443782000)*(1-((1779090000-VELOCITY)/(1779090000-0))^443782000))
Johnny darter adult D	=(((760000000-DEPTH)/(760000000-30.95))^33300000)*2.718^((33300000/46500000)*(1-((760000000-DEPTH)/(760000000-30.95))^46500000))
Johnny darter adult V	=(((150-VELOCITY)/(150-30.5))^2.3)*2.718^((2.3/10.6)*(1-((150-VELOCITY)/(150-30.5))^10.6))
Johnny darter young-of-year D	=(((582100000-DEPTH)/(582100000-14.82))^18220000)*2.718^((18220000/138000000)*(1-((582100000-DEPTH)/(582100000-14.82))^138000000))
Johnny darter young-of-year V	=(((150.999-VELOCITY)/(150.999-0))^24.571)*2.718^((24.571/0.183)*(1-((150.999-VELOCITY)/(150.999-0))^0.183))
Lake sturgeon adult D	=(((18.017-DEPTH)/(18.017-10.09))^77.566)*2.718^((77.566/0.182)*(1-((18.017-DEPTH)/(18.017-10.09))^0.182))
Lake sturgeon adult V	=(((5.1- VELOCITY)/(5.1-0.429))^5.696)*2.718^((5.696/40.271)*(1-((5.1-VELOCITY)/(5.1-0.429))^40.271))
Lake sturgeon spawning D	=(((312-DEPTH)/(312-125))^62.8)*2.718^((62.8/0.65)*(1-((312-DEPTH)/(312-125))^0.65))

Species-life stage	Formula
Lake sturgeon spawning V	=(((150-VELOCITY)/(150-25.3))^2.67)*2.718^((2.67/13.8)*(1-((150-VELOCITY)/(150-25.3))^13.8))
Largemouth bass juvenile D	=(((174044000-DEPTH)/(174044000-54.586))^15291200)*2.718^((15291200/3770789.759)*(1-((174044000-DEPTH)/(174044000-54.586))^3770789.759))
Largemouth bass juvenile V	=(((1253930000-VELOCITY)/(1253930000-2.524))^120097000)*2.718^((120097000/477201000)*(1-((1253930000-VELOCITY)/(1253930000-2.524))^477201000))
Largemouth bass young-of-year D	=(((329.046-DEPTH)/(329.046-47.57))^160.353)*2.718^((160.353/1.967)*(1-((329.046-DEPTH)/(329.046-47.57))^1.967))
Largemouth bass young-of-year V	=(((7687.839-VELOCITY)/(7687.839-0))^561.959)*2.718^((561.959/18974.081)*(1-((7687.839-VELOCITY)/(7687.839-0))^18974.081))
Largescale stone-roller adult D	=(((300-DEPTH)/(300-20.434))^21.255)*2.718^((21.255/39.852)*(1-((300-DEPTH)/(300-20.434))^39.852))
Largescale stone-roller adult V	=(((1080.181-VELOCITY)/(1080.181-47.378))^38.614)*2.718^((38.614/44.079)*(1-((1080.181-VELOCITY)/(1080.181-47.378))^44.079))
Largescale stone-roller juvenile D	=(((300-DEPTH)/(300-14.643))^42.143)*2.718^((42.143/132.659)*(1-((300-DEPTH)/(300-14.643))^132.659))
Largescale stone-roller juvenile V	=(((150.4-VELOCITY)/(150.4-51.924))^49.927)*2.718^((49.927/0.596)*(1-((150.4-VELOCITY)/(150.4-51.924))^0.596))
Largescale stone-roller young-of-year D	=(((330.268-DEPTH)/(330.268-13.925))^73.524)*2.718^((73.524/39.317)*(1-((330.268-DEPTH)/(330.268-13.925))^39.317))
Largescale stone-roller young-of-year V	=(((150-VELOCITY)/(150-51.592))^14.527)*2.718^((14.527/0.965)*(1-((150-VELOCITY)/(150-51.592))^0.965))
Larval fish D	=(((546.067-DEPTH)/(546.067-6.72))^18.449)*2.718^((18.449/379.574)*(1-((546.067-DEPTH)/(546.067-6.72))^379.574))
Larval fish V	=(((771566000-VELOCITY)/(771566000-0))^52198300)*2.718^((52198300/43571000)*(1-((771566000-VELOCITY)/(771566000-0))^43571000))
Logperch adult D	=(((8988218.561-DEPTH)/(8988218.561-58.88))^358629.456)*2.718^((358629.456/285024.561)*(1-((8988218.561-DEPTH)/(8988218.561-58.88))^285024.561))
Logperch adult V	=(((150-VELOCITY)/(150-100.709))^18.786)*2.718^((18.786/0.574)*(1-((150-VELOCITY)/(150-100.709))^0.574))
Logperch spawning D	=(((300-DEPTH)/(300-64.243))^131.169)*2.718^((131.169/2.402)*(1-((300-DEPTH)/(300-64.243))^2.402))
Logperch spawning V	=(((150-VELOCITY)/(150-100.709))^18.786)*2.718^((18.786/0.574)*(1-((150-VELOCITY)/(150-100.709))^0.574))

Species-life stage	Formula
Logperch young-of-year D	=(((302.631-DEPTH)/(302.631-37.075))^2.572)*2.718^((2.572/29.806)*(1-((302.631-DEPTH)/(302.631-37.075))^29.806))
Logperch young-of-year V	=(((150.015-VELOCITY)/(150.015-54.794))^60.327)*2.718^((60.327/0.748)*(1-((150.015-VELOCITY)/(150.015-54.794))^0.748))
Longnose dace adult D	=(((453694000-DEPTH)/(453694000-9.036))^8594488.372)*2.718^((8594488.372/236434000)*(1-((453694000-DEPTH)/(453694000-9.036))^236434000))
Longnose dace adult V	=(((299.584-VELOCITY)/(299.584-92.751))^217.527)*2.718^((217.527/0.18)*(1-((299.584-VELOCITY)/(299.584-92.751))^0.18))
Longnose dace spawning D	=(((300-DEPTH)/(300-19.35))^147.8)*2.718^((147.8/10.11)*(1-((300-DEPTH)/(300-19.35))^10.11))
Longnose dace spawning V	=(((150.6-VELOCITY)/(150.6-53.1))^68.9)*2.718^((68.9/0.844)*(1-((150.6-VELOCITY)/(150.6-53.1))^0.844))
Longnose dace young-of-year D	=(((355-DEPTH)/(355-5.53))^12.6)*2.718^((12.6/1000)*(1-((355-DEPTH)/(355-5.53))^1000))
Longnose dace young-of-year V	=(((2410000-VELOCITY)/(2410000-13.3))^33700)*2.718^((33700/225000)*(1-((2410000-VELOCITY)/(2410000-13.3))^225000))
Mimic shiner adult D	=(((300-DEPTH)/(300-9.102))^8.377)*2.718^((8.377/142.502)*(1-((300-DEPTH)/(300-9.102))^142.502))
Mimic shiner adult V	=(((1079.337-VELOCITY)/(1079.337-9.736))^42.98)*2.718^((42.98/664.096)*(1-((1079.337-VELOCITY)/(1079.337-9.736))^664.096))
Mimic shiner young-of-year D	=(((300-DEPTH)/(300-7.736))^12.725)*2.718^((12.725/153.545)*(1-((300-DEPTH)/(300-7.736))^153.545))
Mimic shiner young-of-year V	=(((270.384-VELOCITY)/(270.384-25.439))^197.097)*2.718^((197.097/1.73)*(1-((270.384-VELOCITY)/(270.384-25.439))^1.73))
Muskellunge spawning D	=(((869950000-DEPTH)/(869950000-61.784))^31898600)*2.718^((31898600/76534900)*(1-((869950000-DEPTH)/(869950000-61.784))^76534900))
Muskellunge spawning V	=(((406.25-VELOCITY)/(406.25-0))^605.168)*2.718^((605.168/7.242)*(1-((406.25-VELOCITY)/(406.25-0))^7.242))
Northern hog-sucker adult D	=(((3165570000-DEPTH)/(3165570000-80.192))^13634800)*2.718^((13634800/210842000)*(1-((3165570000-DEPTH)/(3165570000-80.192))^210842000))
Northern hog-sucker adult V	=(((104101.085-VELOCITY)/(104101.085-61.377))^12754.58)*2.718^((12754.58/1130.159)*(1-((104101.085-VELOCITY)/(104101.085-61.377))^1130.159))
Northern hog-sucker juvenile D	=(((1947170000-DEPTH)/(1947170000-14.78))^74096200)*2.718^((74096200/385240000)*(1-((1947170000-DEPTH)/(1947170000-14.78))^385240000))

Species-life stage	Formula
Northern hog-sucker juvenile V	=(((54484400-VELOCITY)/(54484400-50.628))^4920608.037)*2.718^((4920608.037/923547.963)*(1-((54484400-VELOCITY)/(54484400-50.628))^923547.963))
Northern hog-sucker spawning D	=(((300-DEPTH)/(300-54.455))^70.759)*2.718^((70.759/1.562)*(1-((300-DEPTH)/(300-54.455))^1.562))
Northern hog-sucker spawning V	=(((150.273-VELOCITY)/(150.273-81.72))^34.603)*2.718^((34.603/0.375)*(1-((150.273-VELOCITY)/(150.273-81.72))^0.375))
Northern hog-sucker young-of-year D	=(((300.003-DEPTH)/(300.003-23.754))^5.776)*2.718^((5.776/37.673)*(1-((300.003-DEPTH)/(300.003-23.754))^37.673))
Northern hog-sucker young-of-year V	=(((1662.765-VELOCITY)/(1662.765-22.52))^118.684)*2.718^((118.684/66.444)*(1-((1662.765-VELOCITY)/(1662.765-22.52))^66.444))
Northern pike adult D	=(((416-DEPTH)/(416-70.1))^2.35)*2.718^((2.35/30)*(1-((416-DEPTH)/(416-70.1))^30))
Northern pike adult V	=(((800000000-VELOCITY)/(800000000-2.7))^55400000)*2.718^((55400000/877000000)*(1-((800000000-VELOCITY)/(800000000-2.7))^877000000))
Orangespotted sunfish adult D	=(((485523000-DEPTH)/(485523000-38.175))^14663400)*2.718^((14663400/33193300)*(1-((485523000-DEPTH)/(485523000-38.175))^33193300))
Orangespotted sunfish adult V	=(((411211000-VELOCITY)/(411211000-3.686))^33337800)*2.718^((33337800/255682000)*(1-((411211000-VELOCITY)/(411211000-3.686))^255682000))
Orangespotted sunfish spawning D	=(((300.353-DEPTH)/(300.353-56.015))^171.292)*2.718^((171.292/2.125)*(1-((300.353-DEPTH)/(300.353-56.015))^2.125))
Orangespotted sunfish spawning V	=(((150-VELOCITY)/(150-28.594))^74.604)*2.718^((74.604/0.926)*(1-((150-VELOCITY)/(150-28.594))^0.926))
Orangespotted sunfish young-of-year D	=(((300.017-DEPTH)/(300.017-30.575))^37.943)*2.718^((37.943/10.631)*(1-((300.017-DEPTH)/(300.017-30.575))^10.631))
Orangespotted sunfish young-of-year V	=(((150.005-VELOCITY)/(150.005-0))^103.983)*2.718^((103.983/1.291)*(1-((150.005-VELOCITY)/(150.005-0))^1.291))
Quillback adult D	=(((77872300-DEPTH)/(77872300-139.419))^6327778.027)*2.718^((6327778.027/290532.051)*(1-((77872300-DEPTH)/(77872300-139.419))^290532.051))
Quillback adult V	=(((150-VELOCITY)/(150-15.555))^2.581)*2.718^((2.581/2.581)*(1-((150-VELOCITY)/(150-15.555))^2.581))
Quillback carp-sucker young-of-year D	=(((708360000-DEPTH)/(708360000-25.683))^25067400)*2.718^((25067400/71119500)*(1-((708360000-DEPTH)/(708360000-25.683))^71119500))
Quillback carp-sucker young-of-year V	=(((150-VELOCITY)/(150-5.608))^13.568)*2.718^((13.568/68.515)*(1-((150-VELOCITY)/(150-5.608))^68.515))

Species-life stage	Formula
Rainbow darter adult D	=(((300-DEPTH)/(300-19.099))^10.057)*2.718^((10.057/41.939)*(1-((300-DEPTH)/(300-19.099))^41.939))
Rainbow darter adult V	=(((9249.785-VELOCITY)/(9249.785-91.314))^529.816)*2.718^((529.816/100.514)*(1-((9249.785-VELOCITY)/(9249.785-91.314))^100.514))
Rainbow darter spawning D	=(((300-DEPTH)/(300-24.989))^10.647)*2.718^((10.647/34.161)*(1-((300-DEPTH)/(300-24.989))^34.161))
Rainbow darter spawning V	=(((580014000-VELOCITY)/(580014000-63.539))^3630456.34)*2.718^((3630456.34/55130100)*(1-((580014000-VELOCITY)/(580014000-63.539))^55130100))
Rainbow darter young-of-year D	=(((1093.399-DEPTH)/(1093.399-13.468))^631.051)*2.718^((631.051/65.139)*(1-((1093.399-DEPTH)/(1093.399-13.468))^65.139))
Rainbow darter young-of-year V	=(((150-VELOCITY)/(150-54.821))^23.147)*2.718^((23.147/0.422)*(1-((150-VELOCITY)/(150-54.821))^0.422))
River carpsucker young-of-year D	=(((300-DEPTH)/(300-29.174))^6.64)*2.718^((6.64/29.9)*(1-((300-DEPTH)/(300-29.174))^29.9))
River carpsucker young-of-year V	=(((193.897-VELOCITY)/(193.897-9.403))^8.909)*2.718^((8.909/64.638)*(1-((193.897-VELOCITY)/(193.897-9.403))^64.638))
River shiner adult D	=(((300-DEPTH)/(300-21.737))^27.904)*2.718^((27.904/21.973)*(1-((300-DEPTH)/(300-21.737))^21.973))
River shiner adult V	=(((150-VELOCITY)/(150-46.709))^16.204)*2.718^((16.204/0.779)*(1-((150-VELOCITY)/(150-46.709))^0.779))
River shiner young-of-year D	=(((4763130000-DEPTH)/(4763130000-9.909))^77182700)*2.718^((77182700/2694900000)*(1-((4763130000-DEPTH)/(4763130000-9.909))^2694900000))
River shiner young-of-year V	=(((156.3-VELOCITY)/(156.3-21.491))^2.222)*2.718^((2.222/17.71)*(1-((156.3-VELOCITY)/(156.3-21.491))^17.71))
Rock bass adult D	=(((133000000-DEPTH)/(133000000-39.8))^897368)*2.718^((897368/12200000)*(1-((133000000-DEPTH)/(133000000-39.8))^12200000))
Rock bass adult V*	=(((155-VELOCITY)/(155--31.3))^17)*2.718^((17/0.719)*(1-((155-VELOCITY)/(155--31.3))^0.719))
Rock bass young-of-year D	=(((384-DEPTH)/(384-119))^2.48)*2.718^((2.48/13.6)*(1-((384-DEPTH)/(384-119))^13.6))
Rock bass young-of-year V	=(((164-VELOCITY)/(164-0.647))^275)*2.718^((275/3.41)*(1-((164-VELOCITY)/(164-0.647))^3.41))
Sand shiner adult D	=(((300.001-DEPTH)/(300.001-13.086))^8.081)*2.718^((8.081/84.81)*(1-((300.001-DEPTH)/(300.001-13.086))^84.81))

Species-life stage	Formula
Sand shiner adult V	=(((150-VELOCITY)/(150-32.108))^3.646)*2.718^((3.646/7.559)*(1-((150-VELOCITY)/(150-32.108))^7.559))
Sand shiner spawning D	=(((1363980000-DEPTH)/(1363980000-24.144))^58403200)*2.718^((58403200/210668000)*(1-((1363980000-DEPTH)/(1363980000-24.144))^210668000))
Sand shiner spawning V	=(((159.095-VELOCITY)/(159.095-60.787))^43.616)*2.718^((43.616/0.223)*(1-((159.095-VELOCITY)/(159.095-60.787))^0.223))
Sand shiner young-of-year D	=(((329.871-DEPTH)/(329.871-10.202))^22.214)*2.718^((22.214/95.304)*(1-((329.871-DEPTH)/(329.871-10.202))^95.304))
Sand shiner young-of-year V	=(((150-VELOCITY)/(150-23.765))^2.545)*2.718^((2.545/6.179)*(1-((150-VELOCITY)/(150-23.765))^6.179))
Shorthead red-horse adult D	=(((2392240000-DEPTH)/(2392240000-86.852))^18028100)*2.718^((18028100/120445000)*(1-((2392240000-DEPTH)/(2392240000-86.852))^120445000))
Shorthead red-horse adult V	=(((151.848-VELOCITY)/(151.848-94.145))^0.277)*2.718^((0.277/2.651)*(1-((151.848-VELOCITY)/(151.848-94.145))^2.651))
Shorthead red-horse juvenile D	=(((677783000-DEPTH)/(677783000-57.044))^20478700)*2.718^((20478700/35143800)*(1-((677783000-DEPTH)/(677783000-57.044))^35143800))
Shorthead red-horse juvenile V	=(((153.048-VELOCITY)/(153.048-56.724))^0.471)*2.718^((0.471/4.811)*(1-((153.048-VELOCITY)/(153.048-56.724))^4.811))
Shorthead red-horse spawning D	=(((1084190000-DEPTH)/(1084190000-37.378))^42392200)*2.718^((42392200/107790000)*(1-((1084190000-DEPTH)/(1084190000-37.378))^107790000))
Shorthead red-horse spawning V	=(((150-VELOCITY)/(150-78.607))^44.194)*2.718^((44.194/0.529)*(1-((150-VELOCITY)/(150-78.607))^0.529))
Shorthead red-horse young-of-year D	=(((739.818- DEPTH)/(739.818-11.709))^15.977)*2.718^((15.977/275.107)*(1-((739.818- DEPTH)/(739.818-11.709))^275.107))
Shorthead red-horse young-of-year V	= (((150- VELOCITY)/(150-31.201))^13.244)*2.718^((13.244/1.052)*(1-((150-VELOCITY)/(150-31.201))^1.052))
Silver redhorse adult D	=(((300-DEPTH)/(300-95.115))^13.206)*2.718^((13.206/2.688)*(1-((300-DEPTH)/(300-95.115))^2.688))
Silver redhorse adult V	=(((150-VELOCITY)/(150-36.802))^2.225)*2.718^((2.225/7.538)*(1-((150-VELOCITY)/(150-36.802))^7.538))
Silver redhorse young-of-year D	=(((300-DEPTH)/(300-27.479))^9.591)*2.718^((9.591/24.543)*(1-((300-DEPTH)/(300-27.479))^24.543))
Silver redhorse young-of-year V	=(((345.546-VELOCITY)/(345.546-5.771))^13.377)*2.718^((13.377/33.946)*(1-((345.546-VELOCITY)/(345.546-5.771))^33.946))

Species-life stage	Formula
Slenderhead darter adult D	=(((7295.278-DEPTH)/(7295.278-23.153))^265.983)*2.718^((265.983/944.741)*(1-((7295.278-DEPTH)/(7295.278-23.153))^944.741))
Slenderhead darter adult V	=(((242.237-VELOCITY)/(242.237-110.329))^30.61)*2.718^((30.61/0.375)*(1-((242.237-VELOCITY)/(242.237-110.329))^0.375))
Slenderhead darter spawning D	=(((572819000-DEPTH)/(572819000-33.067))^172058000)*2.718^((172058000/15667800)*(1-((572819000-DEPTH)/(572819000-33.067))^15667800))
Slenderhead darter spawning V	=(((150-VELOCITY)/(150-74.602))^0.942)*2.718^((0.942/8.843)*(1-((150-VELOCITY)/(150-74.602))^8.843))
Slenderhead darter young-of-year D	=(((9307480000- DEPTH)/(9307480000-10.114))^146323000)*2.718^((146323000/5308850000)*(1-((9307480000-DEPTH)/(9307480000-10.114))^5308850000))
Slenderhead darter young-of-year V	= (((153.336-VELOCITY)/(153.336-54.487))^0.905)*2.718^((0.905/5.342)*(1-((153.336--VELOCITY)/(153.336-54.487))^5.342))
Smallmouth bass adult D	=(((303.809-DEPTH)/(303.809-124.103))^1.136)*2.718^((1.136/6.237)*(1-((303.809-DEPTH)/(303.809-124.103))^6.237))
Smallmouth bass adult V	=(((150-VELOCITY)/(150-19.838))^1.363)*2.718^((1.363/19.724)*(1-((150-VELOCITY)/(150-19.838))^19.724))
Smallmouth bass fingerling D	=(((350-DEPTH)/(350-30))^1.97)*2.718^((1.97/52.5)*(1-((350-DEPTH)/(350-30))^52.2))
Smallmouth bass fingerling V	=(((130-VELOCITY)/(130-33.8))^0.755)*2.718^((0.755/6.71)*(1-((130-VELOCITY)/(130-33.8))^6.71))
Smallmouth bass fry D	=(((342.468-DEPTH)/(342.468-9.958))^3.561)*2.718^((3.561/191.049)*(1-((342.468-DEPTH)/(342.468-9.958))^191.049))
Smallmouth bass fry V	=(((616860000-VELOCITY)/(616860000-3.564))^82898900)*2.718^((82898900/67410900)*(1-((616860000-VELOCITY)/(616860000-3.564))^67410900))
Smallmouth bass juvenile D	=(((502-DEPTH)/(502-54.8))^6.57)*2.718^((6.57/30.4)*(1-((502-DEPTH)/(502-54.8))^30.4))
Smallmouth bass juvenile V	=(((135-VELOCITY)/(135-23.8))^1.59)*2.718^((1.59/11.4)*(1-((135-VELOCITY)/(135-23.8))^11.4))
Smallmouth bass spawning D	=(((300-DEPTH)/(300-64.801))^89.923)*2.718^((89.923/1.906)*(1-((300-DEPTH)/(300-64.801))^1.906))
Smallmouth bass spawning V	=(((2016760000-VELOCITY)/(2016760000-0))^1484200000)*2.718^((1484200000/10008100000)*(1-((2016760000-VELOCITY)/(2016760000-0))^10008100000))
Spotfin shiner adult D	=(((4554640000-DEPTH)/(4554640000-20.029))^60398800)*2.718^((60398800/889817000)*(1-((4554640000-DEPTH)/(4554640000-20.029))^889817000))

Species-life stage	Formula
Spotfin shiner adult V	=(((1303130000-VELOCITY)/(1303130000-22.375))^51332200)*2.718^((51332200/72528600)*(1-((1303130000-VELOCITY)/(1303130000-22.375))^72528600))
Spotfin shiner spawning D	=(((5689250000-DEPTH)/(5689250000-15.061))^96532100)*2.718^((96532100/1703000000)*(1-((5689250000-DEPTH)/(5689250000-15.61))^1703000000))
Spotfin shiner spawning V	=(((150-VELOCITY)/(150-36.361))^14.371)*2.718^((14.371/0.457)*(1-((150-VELOCITY)/(150-36.361))^0.457))
Spotfin shiner young-of-year D	=(((300-DEPTH)/(300-12.005))^8.33)*2.718^((8.33/98.988)*(1-((300-DEPTH)/(300-12.005))^98.988))
Spotfin shiner young-of-year V	=(((150-VELOCITY)/(150-25.457))^17.305)*2.718^((17.305/2.31)*(1-((150-VELOCITY)/(150-25.457))^2.31))
Spottail shiner adult D	=(((2955370000-DEPTH)/(2955370000-44.055))^62562600)*2.718^((62562600/242602000)*(1-((2955370000-DEPTH)/(2955370000-44.055))^242602000))
Spottail shiner adult V	=(((95316100-VELOCITY)/(95316100-25.767))^8592534.292)*2.718^((8592534.292/2141716.89)*(1-((95316100-VELOCITY)/(95316100-25.767))^2141716.89))
Spottail shiner young-of-year D	=(((375786000-DEPTH)/(375786000-27.533))^15850300)*2.718^((15850300/30827700)*(1-((375786000-DEPTH)/(375786000-27.533))^30827700))
Spottail shiner young-of-year V	=(((150-VELOCITY)/(150-20.197))^6.557)*2.718^((6.557/9.254)*(1-((150-VELOCITY)/(150-20.197))^9.254))
Stonecat adult D	=(((300-DEPTH)/(300-27.981))^9.281)*2.718^((9.281/23.583)*(1-((300-DEPTH)/(300-27.981))^23.583))
Stonecat adult V	=(((150.723-VELOCITY)/(150.723-89.121))^0.164)*2.718^((0.164/4.357)*(1-((150.723-VELOCITY)/(150.723-89.121))^4.357))
Stonecat juvenile D	=(((300-DEPTH)/(300-13.429))^8.99)*2.718^((8.99/77.832)*(1-((300-DEPTH)/(300-13.429))^77.832))
Stonecat juvenile V	=(((173.927-VELOCITY)/(173.927-99.567))^0.586)*2.718^((0.586/3.264)*(1-((173.927-VELOCITY)/(173.927-99.567))^3.264))
Stonecat young-of-year D	=(((300-DEPTH)/(300-4.939))^11.583)*2.718^((11.583/513.374)*(1-((300-DEPTH)/(300-4.939))^513.374))
Stonecat young-of-year V	=(((150-VELOCITY)/(150-67.498))^28.248)*2.718^((28.248/0.458)*(1-((150-VELOCITY)/(150-67.498))^0.458))
Tadpole madtom adult D	=(((2516740000-DEPTH)/(2516740000-42.063))^26253600)*2.718^((26253600/263747000)*(1-((2516740000-DEPTH)/(2516740000-42.063))^263747000))
Tadpole madtom adult V	=(((150-VELOCITY)/(150-29.768))^14.803)*2.718^((14.803/1.661)*(1-((150-VELOCITY)/(150-29.768))^1.661))

Species-life stage	Formula
Tadpole madtom young-of-year D	=(((62050.355-DEPTH)/(62050.355-30.948))^1008.68)*2.718^((1008.68/6665.67)*(1-((62050.355-DEPTH)/(62050.355-30.948))^6665.67))
Tadpole madtom young-of-year V	=(((3235420000-VELOCITY)/(3235420000-3.411))^109985000)*2.718^((109985000/2762060000)*(1-((3235420000-VELOCITY)/(3235420000-3.411))^2762060000))
Topeka shiner adult D	=(((300-DEPTH)/(300-29.93))^11.736)*2.718^((11.736/22.101)*(1-((300-DEPTH)/(300-29.93))^22.101))
Topeka shiner adult V	=(((150-VELOCITY)/(150-2.293))^6.02)*2.718^((6.02/123.876)*(1-((150-VELOCITY)/(150-2.293))^123.876))
Topeka shiner spawning D	=(((300-DEPTH)/(300-44.226))^116.094)*2.718^((116.094/2.309)*(1-((300-DEPTH)/(300-44.226))^2.309))
Topeka shiner spawning V	=(((150-VELOCITY)/(150-31.06))^32.831)*2.718^((32.831/2.41)*(1-((150-VELOCITY)/(150-31.06))^2.41))
Walleye adult D	=(((2641.492-DEPTH)/(2641.492-202.051))^25.026)*2.718^ ((25.026/22.704)*(1-((2641.492-DEPTH)/(2641.492-202.051))^22.704))
Walleye adult V	=(((150-VELOCITY)/(150-16.151))^5.107)*2.718^((5.107/21.512)*(1-((150-VELOCITY)/(150-16.151))^21.512))
Walleye juvenile D	=(((300-DEPTH)/(300-113.837))^37.516)*2.718^((37.516/0.834)*(1-((300-DEPTH)/(300-113.837))^0.834))
Walleye juvenile V	=(((1828890000-VELOCITY)/(1828890000-6.315))^64704900)*2.718^((64704900/7151390000)*(1-((1828890000-VELOCITY)/(1828890000-6.315))^7151390000))
Walleye spawning D	=(((300.002-DEPTH)/(300.002-54.226))^22.269)*2.718^((22.269/9.417)*(1-((300.002-DEPTH)/(300.002-54.226))^9.417))
Walleye spawning V	=(((7590.933-VELOCITY)/(7590.933-53.579))^6104.739)*2.718^((6104.739/12.473)*(1-((7590.933-VELOCITY)/(7590.933-53.579))^12.473))
Walleye young-of-year D	=(((4413900000-DEPTH)/(4413900000-128.38))^26769600)*2.718^((26769600/309477000)*(1-((4413900000-DEPTH)/(4413900000-128.38))^309477000))
Walleye young-of-year V	(((243.736- VELOCITY)/(243.736-55.743))^137.814)*2.718^((137.814/0.515)*(1-((243.736- VELOCITY)/(243.736-55.743))^0.515))
White bass young-of-year D	=(((5467120000-DEPTH)/(5467120000-56.637))^183150000)*2.718^((183150000/254840000)*(1-((5467120000-DEPTH)/(5467120000-56.637))^254840000))
White bass young-of-year V	=(((561648000-VELOCITY)/(561648000-9.487))^15078300)*2.718^((15078300/243508000)*(1-((561648000-VELOCITY)/(561648000-9.487))^243508000))
White sucker adult D	=(((302.511-DEPTH)/(302.511-154.388))^0.312)*2.718^((0.312/6.634)*(1-((302.511-DEPTH)/(302.511-154.388))^6.634))

Species-life stage	Formula
White sucker adult V	=(((150-VELOCITY)/(150-47.476))^19.475)*2.718^((19.475/0.228)*(1-((150-VELOCITY)/(150-47.476))^0.228))
White sucker juvenile D	=(((598-DEPTH)/(598-17.3))^9.67)*2.718^((9.67/138)*(1-((598-DEPTH)/(598-17.3))^138))
White sucker juvenile V	=(((150-VELOCITY)/(150-34.05))^1.842)*2.718^((1.842/7.265)*(1-((150-VELOCITY)/(150-34.05))^7.265))
White sucker young-of-year D	=(((1994870000-DEPTH)/(1994870000-23.175))^192463000)*2.718^((192463000/305829000)*(1-((1994870000-DEPTH)/(1994870000-23.175))^305829000))
White sucker young-of-year V	=(((150-VELOCITY)/(150-37.306))^18.731)*2.718^((18.731/1.311)*(1-((150-VELOCITY)/(150-37.306))^1.311))
Yellow perch adult D	=(((5407000000-DEPTH)/(5407000000-51.54))^116900000)*2.718^((116900000/1924000000)*(1-((5407000000-DEPTH)/(5407000000-51.54))^1924000000))
Yellow perch adult V	=(((150.48-VELOCITY)/(150.48-25.34))^61.84)*2.718^((61.84/0.756)*(1-((150.48-VELOCITY)/(150.48-25.34))^0.756))
Yellow perch juvenile D	=(((2286890000-DEPTH)/(2286890000-71.982))^26548500)*2.718^((26548500/121573000)*(1-((2286890000-DEPTH)/(2286890000-71.982))^121573000))
Yellow perch juvenile V	=(((150.54-VELOCITY)/(150.54-2.06))^5.12)*2.718^((5.12/7.75)*(1-((150.54-VELOCITY)/(150.54-2.06))^7.75))
Yellow perch young-of-year D	=(((300-DEPTH)/(300-8.987))^1.464)*2.718^((1.464/386.996)*(1-((300-DEPTH)/(300-8.987))^386.996))
Yellow perch young-of-year V	=(((150.042-VELOCITY)/(150.042-63.48))^26.982)*2.718^((26.982/0.301)*(1-((150.042-VELOCITY)/(150.042-63.48))^0.301))
Black sandshell D	=(((350.463- DEPTH)/(350.463-113.911))^5.335)*2.718^((5.335/8.243)*(1-((350.463- DEPTH)/(350.463-113.911))^8.243))
Black sandshell V	=(((500232.106- VELOCITY)/(500232.106-32.739))^28133.608)*2.718^((28133.608/31415.241)*(1-((500232.106-VELOCITY)/(500232.106-32.739))^31415.241))
Creeper D	=(((349.672- DEPTH)/(349.672-69.878))^4.056)*2.718^((4.056/31.451)*(1-((349.672- DEPTH)/(349.672-69.878))^31.451))
Creeper V	=(((565388.152- VELOCITY)/(565388.152-22.444))^11709.861)*2.718^((11709.861/81879.431)*(1-((565388.152-VELOCITY)/(565388.152-22.444))^81879.431))
Fat mucket D	=(((349.713- DEPTH)/(349.713-76.934))^15.731)*2.718^((15.731/11.817)*(1-((349.713- DEPTH)/(349.713-76.934))^11.817))
Fat mucket V	=(((249.953- VELOCITY)/(249.953-33.891))^11.653)*2.718^((11.653/10.499)*(1-((249.953- VELOCITY)/(249.953-33.891))^10.499))

Species-life stage	Formula
Fluted shell D	=(((345.782- DEPTH)/(345.782-130.384))^74.172)*2.718^((74.172/0.488)*(1-((345.782- DEPTH)/(345.782-130.384))^0.488))
Fluted shell V	=(((150.641- VELOCITY)/(150.641-24.585))^3.595)*2.718^((3.595/15.535)*(1-((150.641- VELOCITY)/(150.641-24.585))^15.535))
Mucket D	=(((348.792- DEPTH)/(348.782-113.264))^29.679)*2.718^((29.679/1.611)*(1-((348.792- DEPTH)/(348.792-113.264))^1.611))
Mucket V	=(((249.811- VELOCITY)/(249.811-32.088))^8.639)*2.718^((8.639/20.184)*(1-((249.811- VELOCITY)/(249.811-32.088))^20.184))
Plain pocket book D	=(((327.21- DEPTH)/(327.21-158.192))^1.785)*2.718^((1.785/3.762)*(1-((327.21-DEPTH)/(327.21-158.192))^3.762))
Plain pocket book V	=(((150- VELOCITY)/(150-45.021))^15.006)*2.718^((15.006/2.684)*(1-((150-VELOCITY)/(150-45.021))^2.684))
Wabash pigtoe D	=(((349.487- DEPTH)/(349.487-72.332))^7.566)*2.718^((7.566/36.746)*(1-((349.487- DEPTH)/(349.487-72.332))^36.746))
Wabash pigtoe V	=(((150- VELOCITY)/(150-39.548))^16.362)*2.718^((16.362/3.407)*(1-((150-VELOCITY)/(150-39.548))^3.407))
Spike D	=(((346.311- DEPTH)/(346.311-141.975))^91.282)*2.718^((91.282/0.733)*(1-((346.311- DEPTH)/(346.311-141.975))^0.733))
Spike V	=(((150- VELOCITY)/(150-24.987))^11.168)*2.718^((11.168/8.683)*(1-((150-VELOCITY)/(150-24.987))^8.683))
Threeridge D	=(((562.422- DEPTH)/(562.422-81.473))^3.416)*2.718^((3.416/71.135)*(1-((562.422- DEPTH)/(562.422-81.473))^71.135))
Threeridge V	=(((182.95- VELOCITY)/(182.95-75.37))^75.023)*2.718^((75.023/0.166)*(1-((182.95- VELOCITY)/(182.95-75.37))^0.166))

*Curves were normalized to get a preference value of 1.