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Distribution and Habitat Use of the Crystal Darter (*Crystallaria asprella*) and Spotted Darter (*Etheostoma maculatum*) in the Elk River, West Virginia

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Abstract

Distribution and Habitat Use of the Crystal Darter (*Crystallaria asprella*) and Spotted Darter (*Etheostoma maculatum*) in the Elk River, West Virginia

Elizabeth A. Osier

Crystal darters (Crystallaria asprella) and spotted darters (Etheostoma maculatum) have disjunct distributions within the Mississippi River drainage. In West Virginia, both species are restricted to a single drainage (the Elk River). Little information exists on the distribution and habitat use of crystal and spotted darters in the Elk River. I surveyed the Elk River between Sutton and Charleston, West Virginia, and documented distributions of crystal and spotted darters, as well as habitat use and habitat availability data. Two crystal darters were collected during 20 sampling occasions from 2002 to 2004. Spotted darters were documented at 9 sites; habitat use data were collected at 3 sites via snorkeling. Spotted darters primarily used glide habitats (transitional areas between tails of pools and heads of riffles) with large unembedded substrate (> 20 cm) and moderate velocities (13 to 51 cm sec-1). My observations support the rarity of crystal darters within the Elk River, but good habitat (based on habitat commonly used by crystal darters in other river systems) is available in the Elk River. Previous studies found large rocks and fast riffles as important spotted darter habitat. Spotted darters in the Elk River were associated with large rocks within glide habitats and were rarely found in riffles. Crystal and spotted darters are benthic habitat specialists; population persistence of these Elk River darters may be linked to stream sedimentation.

Dedication

I would like to dedicate the work represented by this thesis to my parents. It goes without saying that I could not have made it here were it not for your support. I am truly grateful for the drive and determination you instilled in me through out my upbringing. Thank you for always encouraging me to work harder and to be a better person. I love you.

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I would also like to acknowledge my friends and family for their support. Chris Moats was a pillar of strength for me and a source of continuous encouragement. Finally, I could not have accomplished so much in my life were it not for the continued loving support of numerous friends. Their support, through moves across the country and back again, has helped me keep my eye on the future and a smile on my face.

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Chapter 1:

Literature Review

Introduction

This thesis documents the geographic distribution and habitat use of two rare darters and includes three chapters: 1. an introduction and literature review of habitat use with emphasis on darters; 2. a study on the distribution and habitat of the Elk River crystal darter (*Crystallaria asprella*); and 3. a study on distribution and microhabitat use of spotted darters (*Etheostoma maculatum*). Crystal darters and spotted darters are distributed disjunctly within the Mississippi River watershed and inhabit a single drainage in West Virginia. Prior to my studies, Elk River crystal darters were known from only two locations representing eight individuals, and spotted darters were known from only two locations in the Elk River. A broader understanding of distributions and habitat use will enhance management and conservation of these rare species.

Habitat Use by Stream Fishes

Habitat use of stream fishes is influenced synergistically by abiotic factors (e.g., depth, velocity, temperature, substrate composition), biotic factors (competition, predation, foraging, resting and spawning), and phylogenetic constraints. Darters, a specious group of North American percids, exhibit diverse uses of habitat (Page 1983). As in most fishes, morphology and foraging behavior play complex roles in darter habitat use (Page and Swofford 1984). Some species of darters are habitat generalists, but most use one or more specific habitats (Page 1983). Abiotic and biotic factors can override habitat preferences by restricting habitat availability (Gorman 1988, Grossman et al. 1998).

Environmental and habitat variables across a range of spatial scales affect stream fish habitat use (Crook et al. 2001, Jackson et al. 2001). Stream habitat features consist of nested hierarchies, where small scale features nest within larger features (Hawkins et al. 1993). Several authors have defined spatial scales important to the study of stream fish habitat (Hawkins et al.

1993, Kramer et al. 1997). Generally, large scales consist of a geographic region or an entire watershed and encompass a range of habitat variables that take into account geomorphic processes and major environmental conditions. At large scales, riffle/pool patterns can be semi-replicated and biogeographic constraints can be considered (Jackson et al. 2001). Intermediate scales describe the habitat type or channel unit, such as a riffle or pool. Habitat units are relatively homogeneous and can be qualitatively determined (Hawkins et al. 1993, Kramer et al. 1997). Finer scales describe microhabitats that are typically differentiated quantitatively using habitat variables (Kramer et al. 1997). Microhabitats are considered to be the space used by an organism within its "normal daily range" (Kramer et al. 1997). The resolution of microhabitats may be determined by the researcher; however as scale decreases, habitat and environmental heterogeneity also decrease. Therefore, the effects of environmental differences are not easily detected (Jackson et al. 2001). This review will primarily address habitat use on intermediate and fine scales.

Abiotic factors

Stream fishes use habitat on many interrelated dimensions. Fish ecologists commonly perceive depth, current velocity and substrate as important habitat features (Schlosser 1982). Water temperature is also an important influence on fish habitat use (Whiteside and McNatt 1972). Variations among these factors interact to determine abiotic habitat characteristics. Additionally, other physiochemical factors that approach or exceed tolerance limits influence fish habitat use.

Water depth and current velocity are interrelated factors that influence fish habitat use and are determined, in part, by channel morphometry and substrate deposition (Allan 1995). The influence of water depth and current velocity on habitat use is, in part, linked to fish morphology

(Matthews 1985, Power et al. 1988, Winemiller 1992, Allan 1995). Many darter species inhabit shallow riffles, though some larger bodied species, including members of the genus *Percina*, use deeper pool habitats (Page 1983). Body morphologies of riffle-dwelling darters are adapted to swift velocities (Page and Swofford 1984, Matthews 1985). Bain et al. (1988) found that depth and velocity were the primary habitat variables affecting fish distribution in a river with variable flow. Matthews et al. (1982) found that current velocity was the largest overlapping microhabitat feature among three darter species in the Upper Roanoke River drainage. However, the roles of water depth and current velocity in stream fish habitat use cannot be clearly separated due to the interrelatedness of these variables.

Substrate provides habitats for foraging, reproduction, and shelter from predators and velocity. Variability in substrate creates habitat heterogeneity and available habitats for benthic darters. Darters are morphologically adapted to use a wide range of substrates (Page and Swofford 1984) and many species have specific requirements for the substrate particle size (Page 1983, Stauffer et al. 1996), such as *Ammocrypta's* use of sand. Substrate heterogeneity also creates areas of low velocity which fish, especially darters, use as “velocity shelters” (Harding et al. 1998).

Stream water temperature is affected by many factors including substrate, water depth and current velocity which create small scale temperature gradients that influence habitat of stream fishes (Whiteside and McNatt 1972). Fishes are affected physiologically by water temperature (Jobling 1981) and often alter habitat use in response to temperature changes. Hlohowskyj and Wissing (1985) found that critical thermal maximum of darters can shift seasonally. Interspecific variation in thermal tolerance, in addition to seasonal shifts, results in longitudinal separation of the distribution of darters along a stream gradient (Ingersoll and

Claussen 1984). Variation in temperature acclimation rates can also determine whether darters use riffles or pools (Hlohowskyj and Wissing 1985, Ingersoll and Claussen 1984).

Biotic factors

Fishes often use different habitats for spawning, foraging and resting. Fish species, especially darters, have adapted behaviorally and morphologically to exploit habitat characteristics and allow for coexistence (Smart and Gee 1979, Page and Swofford 1984). However, interspecific interactions, such as competition and predation, also determine fish habitat use (Ross 1986). Limiting resources create competition, causing species' to alter habitat use (Scheoner 1974). Also, avoidance of predation strongly influences the behavior and habitat use of stream fishes (Werner et al. 1983, Schlosser 1987).

Habitats used during spawning periods often differ from those used during other periods. Because darters live in close association with the bottom, most spawn on substrate or vegetation (Winn 1958). Substrate type (for egg attachment; Page 1985) and current velocity (for egg aeration and stability; e.g. *Etheostoma maculatum*, Raney and Lachner 1939, Winn 1958) are important factors influencing spawning habitat. Darters use substrate by either burying eggs (exhibited by all *Percina* and *Ammocrypta*) or by attaching adhesive eggs to substrate including rocks, plants or woody debris (Page 1985). Winn (1958) noted that species with complex reproductive behavior use slower current than those with generalized behavior.

Foraging habitats, in part, are determined by body morphology (Winemiller 1992) and prey availability (Petty and Grossman 1996). Because darters feed primarily on benthic insects (Forbes 1880), their foraging habitat does not generally differ from other habitats. Darters with small body size forage under and between rocks (Page and Swofford 1984). Head morphology and mouth position differ among darters allowing for differential foraging mechanisms (Page

1985) and optimal foraging efficiency in riffles (Page and Swofford 1984). Darters eat from the top, sides and bottom of rocks, and by over turning rocks (Page 1983, Welsh and Perry 1998).

The use of habitat for "resting" by stream fishes is a means of energy conservation. Facey and Grossman (1992) found that energetic constraints of habitat were more important for water column species than for benthic fish, such as darters. They hypothesized that morphological features reduce the importance of energetic cost of habitat for benthic species. Harding et al. (1998) showed that microhabitat velocity shelters created by heterogeneous substrate acts as refugia for darters. Daniels (1989) suggested that energy conservation could be one reason eastern sand darters (*Ammocrypta pellucida*) exhibit burrowing behavior (though it may not be the only reason).

Competition, for both space and food resources, can greatly alter habitat use by stream fishes. Competition occurs when two species interact for the use of a resource and one species impedes another species' use of the same resource (interference) or when the interaction reduces the fitness of one of the species (exploitative, Schlosser 1987, Grossman and Freeman 1987). Interference competition, in conjunction with other factors, usually results in resource partitioning (Schoener 1969). However darters' use of benthic habitats is due, in part, to phylogenetic history (Grossman and Freeman 1987). Resource partitioning among stream fishes is often based on food resources (Ross 1986), however Grey et al. (1997) concluded that resource partitioning in a guild of darters was due to other spatial requirements. Additionally, Ingersoll and Claussen (1984) found that interspecific avoidance was the overriding factor in selection of thermal habitat when fantail darters (*Etheostoma flabellare*) and johnny darters (*Etheostoma nigrum*) co-occurred. Darters' high diversity of foraging mechanisms reduces competition for prey (Page 1983), but because some species are generalists, while others are specialists, interspecific interactions result in competition for space. Additionally, many species of darters exhibit territoriality (Winn 1958) and aggressive behavior does influence habitat use in some darter communities (e.g. Kessler and Thorp 1993).

Predation risk influences habitat use of stream fishes, often forcing potential prey species into suboptimal foraging habitat (e.g. Power 1984). Predators also influence the use of depth and substrate of prey species (Schlosser 1987, Schlosser 1988). Schlosser (1987) reported that largemouth bass forced small species, including darters, from pool to riffle habitat. Small darters, whose major predators are often centrarchids (Page 1983, Greenberg 1991), hide within the substrate and avoid predators (Page and Swofford 1984). Despite the threat of avian predation in shallow waters (Schlosser 1987), small-bodied darters avoid both avian and aquatic predation through the use of substrate. Within deeper pool habitats, larger bodied *Percina*, avoid predation by remaining near the bottom (Greenberg 1991).

Seasonal habitat shifts of stream fishes are due to behavior (e.g. spawning) or environmental variables (e.g. temperature and flow). Additionally ontological changes, such as juvenile to adult, typically result in habitat shifts. Winn (1958) noted that most darters exhibit reproductive migration, but otherwise use a relatively small area. Deep water species move to shallower regions, while riffle species move to deeper, slower habitats (Winn 1958). Mundahl and Ingersoll (1983) found that johnny darters (*E. nigrum*) moved little outside of the reproductive season, but fantail darters (*E. flabellare*) exhibited considerable early autumn upstream movement, possibly seeking better quality habitat. Stream flow changes, which occur seasonally or within smaller time frames, can be highly variable and unpredictable (Bain et al. 1988) and can drastically change the physical habitat of fishes (Harding et al 1998). Stauffer et al. (1996) found that seasonal shifts in darter habitat use were related to environmental fluctuations, such as high water levels. However, some darter species may exhibit habitat shifts based on endogenous circannual rhythms rather than environmental conditions (e.g., photo period, Ingersoll and Claussen 1984). Ross et al. (1992) found that bayou darters (*Etheostoma rubrum*) increased use of cover during cold water conditions possibly because low temperatures reduce a fish's ability to withstand variable water velocities. Additionally, the absence of vegetation in winter months could result in the use of different foraging habitat (White and Aspinwall 1984). Ontological shifts are, in part, related to flow because juvenile fish are more highly affected by the high between-year flow variability than adults (Schlosser 1985). Habitats of juvenile darters are typically shallower and slower than those of adults (Winn 1958, Page 1983).

Darters are a complex, highly specialized group of fishes. Multiple mechanisms typically influence habitat use of darters. Because many darters exhibit specific habitat requirements, several species are threatened by habitat alterations (Connelly et al. 1999, Mattingly and Galat 2002, Wood and Raley 2000). For instance, sedimentation associated with land use practices threaten darter habitat as it fills interstitial spaces (Mattingly and Galat 2002) and chokes aquatic vegetation (Connelly et al. 1999). Management actions can reduce negative impacts to sensitive darter species such as protection of riparian areas (Jones et al. 1999) or entire watersheds (Freeman and Freeman 1994). Studying and defining habitat use can help researchers and managers develop effective darter conservation programs.

Life History and Habitat Use of the Crystal Darter (*Crystallaria asprella*)

Introduction

The crystal darter, *Crystallaria asprella*, is a rare species known to inhabit medium to large rivers. For a darter, it is moderately sized and it is physically distinctive due to its translucent body with three to four dorsal saddles and a mid-lateral stripe of fused ovoid blotches (Page 1983, Etnier and Starnes 1993, Keuhne and Barbour 1983). David Starr Jordan first described the crystal darter in 1878 from a tributary of the Mississippi River in Illinois, naming it *Pleurolepis asprellus* (Jordan 1878). It was later analyzed with sand darters (genus *Ammocrypta*) because of an elongate shape, translucent skin and musculature, and a single anal spine characteristic of the genus (Simons 1991). Presently, the crystal darter comprises the monotypic genus *Crystallaria* based on Simons' (1991) sister relationship between *Crystallaria asprella* and a larger monophyletic group of *Percina*, *Etheostoma* and the *Ammocrypta*.

Distribution and Status

In the late 1800s and early 1900s, the crystal darter, was distributed widely within Mississippi River drainage from Mississippi west to southeastern Oklahoma, north to southern Minnesota and southeast to Ohio; and in Gulf Coast drainages from the western panhandle of Florida to Mississippi (Page 1980, Keuhne and Barbour 1983, Grandmaison et al. 2003). The crystal darter's distribution has decreased dramatically during the last century (Hatch 1997, Etnier and Starnes 1993). Stable populations occur in Alabama, Louisiana and Arkansas (George et al. 1996, Sheppard et al. 1999, Hatch 1997) while populations in Minnesota and Wisconsin are restricted (Becker 1983, Hatch 1997). Populations within Indiana, Ohio, Illinois, Kentucky and Tennessee are considered extirpated (Hatch 1997).

The only recently documented crystal darter population in the Ohio River drainage occurs in the Elk River, West Virginia. It was first collected 1.6 river km below Mink Shoals in November of 1980 (Cincotta and Hoeft 1987). Previous to 2002, a total of eight individuals were collected during sampling efforts at or near Mink Shoals and another site approximately 18 river km upstream near Clendenin, West Virginia.

Wood and Raley (2000) and Morrison et al. (2004) reported that the crystal darter population within the Elk River, WV, is genetically distinct from populations in the Saline River, AR; Zumbro River, MN; Cahaba River, AL/Pearl River, MS. Action is required to protect this evolutionarily significant lineage from continued anthropogenic impacts to the Elk River drainage (Morrison et al. 2004, Wood and Raley 2000). The authors suggest that the Elk River crystal darter be protected by the Endangered Species Act due to its unique genetic status.

Biology and Life History

While ecological descriptions of the crystal darter are numerous (Etnier and Starnes 1993, Robison and Buchanan 1988, Keuhne and Barbour 1983, Becker 1983, Clay 1975, Trautman 1981, Miller and Robison 1973, Page 1983; Grandmaison et al. 2003), most are based on pre-1940 data (Clay 1975, Etnier and Starnes 1993, Trautman 1981). Due to its rarity, little research exists on the natural history of this species (Lutterbie 1979, Hatch 1997, Etnier and Starnes 1993, Keuhne and Barbour 1983). Few direct observations exist of the crystal darter in its native habitat (George et al. 1996, Becker 1983). Crystal darters are often collected at night (Cincotta and Hoeft 1987, Shepard et al. 1999), but George et al. (1996) successfully collected crystal darters during the day. Becker (1983) speculates that they remain in deeper pools during the day, which makes sampling difficult. They probably move into shallow riffles at night where they are more easily detected (Becker 1983). However, they may inhabit riffles during the day, but are able to evade capture; therefore night sampling is more successful (D. Cincotta, pers. comm.). Currently, we know little about diurnal habits of crystal darters.

Adult crystal darters range in maximum standard length from 99 mm (George et al. 1996) to 144 mm (Lutterbie 1979). Lutterbie (1979) concludes that crystal darters in Wisconsin have a life expectancy of three years, while George et al. (1996) found the maximum age of crystal darters in the Saline River, Arkansas to be two years. Etnier and Starnes (1993) reported a life expectance of 2 to 4 years. George et al. (1996) suggested that the disparity in size and life expectancy between individuals from southern and northern populations may be due to environmental differences. He suggested that Saline River populations might mature before age one and begin reproducing at an earlier age than northern populations, resulting in shorter life spans.

Habitat

While there are few documented observations of *Crystallaria asprella* habitat use, it is typically collected from 0.5 to 1.5 m depths in moderate to strong velocities over sand and gravel substrate (Becker 1983, Robison and Buchanan 1988, Shepard et al. 1999, Simon et al. 1992). Current velocities in crystal darter habitat range from an average of 30 cm/sec in the Mississippi River (Hatch 1997) to an average of 70 cm/sec from the Saline River, Arkansas (George et al. 1996; see Table 1 of Chapter 2). George et al. (1996) collected crystal darters in the Saline River, Arkansas, over predominantly gravel substrate, with small cobble and patches of sand, while Hatch (1997) collected individuals over coarse sand and gravel with 30% to 40% embedded cobble and boulder in the Mississippi River. Swift currents in crystal darter habitat account for the reported "clean swept" substrate and lack of silt (Etnier and Starnes 1993, Simon et al. 1992). Additionally, crystal darters are not associated with debris or vegetation (George et al. 1996, Shepard et al. 1999).

In captivity, crystal darters burrow into sand, where only their eyes protrude (Miller and Robison 1992). Crystal darters may exhibit similar habitat use in natural environments. Similar burrowing behavior was documented for the genus *Ammocrypta* (Page 1983). Darters may burrow to avoid predation or as an ambush foraging tactic (Trautman 1981). However, Daniels (1989) suggested that sand darters burrow in sandy substrates for stability in turbulent velocities.

Reproduction

Little is known about reproductive habits of crystal darters. Breeding tubercles occur on the anal and pelvic fin rays of mature males (George et al. 1996, Page 1983, Lutterbie 1979). Crystal darters in the Mississippi River developed breeding tubercles from late autumn to winter suggesting a spring spawn (Lutterbie 1979, Keuhne and Barbour 1983). George et al. (1996) reported that crystal darters in the Saline River, Arkansas, developed tubercles as early as late October. The reproductive season occurs in the late winter or early spring (January through mid-April), based on both tubercle and testicular development. Additionally, George et al. (1996) reported minute breeding tubercles on females. George et al. (1996) also reported evidence of two different size classes of ova in female crystal darters, suggesting multiple spawnings per reproductive cycle.

Only one account of crystal darter spawning has been documented. Simon et al. (1992) reported that crystal darters left the mainstem Tallapoosa River, Alabama, in late February and moved into a "moderately swift" 60 to 90 cm deep side channel riffle with gravel substrate. Spawning occurred over the course of a week in water temperatures from 1.6 to 12.8°C. During spawning and egg deposition, the female was partially submerged in sand and "mounted" by one or several males.

Foraging

With few direct observations of crystal darters, foraging behavior and use of habitat are poorly understood; however diet data provides insights on foraging habitat. Miller and Robison (1992) suggested that crystal darters burrow as an ambush foraging tactic. Daniels (1989) concluded that ambush foraging is not supported for sand darters (*Ammocrypta* sp.) based on body shape, mouth shape and diet. Though crystal darter morphology differs slightly from sand darters, their diets are very similar. Midge larvae and caddisfly larvae are most abundant in crystal darter diets (Lutterbie 1976, Hatch 1997). Lutterbie (1976) reported that midges comprised the largest proportion of biomass. Hatch (1997) found that caddisflies contributed the greatest amount of biomass, but midges were more abundant in the diet. Hatch (1997) also noted that water mites (Hydrachnidae) were consumed in substantial quantities, though the contribution to biomass was negligible. Daniels (1989) suggests that these items originate from drift or sandy substrate and are defenseless against fish predators, therefore, there is no need for ambush predation. Hatch (1997) likewise suggested that, rather than remaining stationary to ambush prey, crystal darters actively forage in a variety of habitats. While embedded in sand, however, crystal darters may enjoy a velocity break adjacent to macroinvertebrate drift, a strategy similar to salmonids in eddy edges.

Life History and Habitat Use of the Spotted Darter *(Etheostoma maculatum)*

Introduction

The spotted darter, *Etheostoma maculatum*, is a rare species with a disjunct distribution within the Ohio River drainage. This member of the sub-genus *Nothonotus* originally included populations from the Upper Ohio River, Cumberland River and Tennessee River systems. However, three geographically separated sub-species (*E. m. maculatum*, *E. m. sanguifluum*, and *E. m. vulneratum*) described by Zorach and Raney (1967) were elevated to species status by Etnier and Williams (1989).

Distribution

The spotted darter’s disjunct distribution ranges from northwest Pennsylvania and southwest New York to central Kentucky, and north to north-central Indiana (Etnier 1980). Populations occur in Pennsylvania and New York in the French Creek drainage of the Allegheny River watershed (Raney and Lachner 1939, Etnier 1980, Stauffer et al. 1996). In Ohio, a spotted darter population occurs in Big Darby Creek (Trautman 1981). Etnier (1980) noted that the population in the Wabash River drainage in Indiana is probably extirpated. Baker et al. (1985) reported collections of spotted darters between 1976 and 1984 in the Blue River, a tributary of the Ohio River in southern Indiana. In Kentucky, the spotted darter occurs in Russell Creek of the Green River watershed (Kessler 1994, Kessler and Thorp 1993) and the North Fork of the Kentucky River (Burr and Warren 1986). In West Virginia, spotted darters are restricted to the Elk River drainage of the lower Kanawha River system (Cincotta et al. 1986).

Biology and Life History

The spotted darter, drab olive in color with horizontal lines along the sides, has a narrow head, sharp snout and rounded caudal fin (Zorach and Raney 1967). Males have red spots encircled in black on the side of the body and, during spawning, develop a bluish-green breast and anal and pelvic fins with white margins (Raney and Lachner 1939, Zorach and Raney 1967, Page 1983). Fins and lateral body of females are primarily dusky with faint horizontal lines along sides (Zorach and Raney 1967).

Habitat

Spotted darters are typically collected from riffles containing gravel or cobble substrate (Kessler and Thorp 1993, Stauffer et al. 1996, Trautman 1981). Kessler and Thorp (1993) postulated that laterally-compressed bodies of spotted darters promoted use of imbricate substrates. Spotted darters are often associated with large loose substrate with interstitial spaces

(Kessler and Thorp 1993). Spotted darters used large pebble (2-16 mm) in Russell Creek, Kentucky (Kessler et al. 1995) and cobble/boulder substrate (25 to 100 cm^2) in French Creek, Pennsylvania (Stauffer et al. 1996). Kessler et al. (1995) noted a shift in habitat use from rough substrate (high size variability) to smoother substrates (lower size variability) from July to October. Additionally, Kessler and Thorp (1993) observed that spotted darters were "never found in areas with silt covered rocks and only rarely occurred where substrates were packed."

Spotted darters in Russell Creek, Kentucky, and French Creek, Pennsylvania, were found in water approximately 20 cm deep with a mean velocity (at 60% of depth) ranging from 40 to 60 cm/sec and a bottom velocity of approximately 14 cm/sec (Kessler and Thorp 1993, Kessler et al. 1995, Stauffer et al. 1996). Water velocities associated with spotted darters in Russell Creek and French Creek were swifter (Kessler et al. 1995) and as deep as average available habitat (Kessler et al. 1995, Stauffer et al. 1996). Kessler et al. (1995) found spotted darters in Russell Creek used deeper habitat with greater velocity in July than in October. Due to higher water levels, available habitat in July was deeper with greater velocity than in October, resulting in an apparent shift in habitat use (Kessler et al. 1995). Stauffer et al. (1996) reported spotted darters as generalists in the use of depth.

Reproduction

In Pennsylvania, spawning occurred between late May and late June at water temperatures of approximately 17.8°C (Raney and Lachner 1939). While facing upstream, males guarded nests under stacked or overlapping cobble and large gravel. Nests were spaced approximately 1.2 m apart at 15 to 60 cm depths. Eggs were deposited in a wedge shape on the underside of the rock. Not all eggs were deposited in one spawning episode. Likewise, eggs in ovaries of females differed in stage of maturity, suggesting multiple spawning per season (possibly as many as four). Nesting males and spawning females foraged during the spawning period. Though nest predation was not observed, eggs found in male stomachs support cannibalization. Raney and Lachner (1939) did not report incubation period or parental care.

Age & Growth

Limited research exists on age and growth of spotted darters. Raney and Lachner (1939) did not determine maximum age, but found that males and females spawn at age 2. Males grow faster than females and are consequently larger. On average males at age 2 were 48 mm standard length (SL) while females were 44 mm SL (Raney and Lachner 1939).

Food

The head shape and mouth orientation allow spotted darters to feed off rock surfaces (Kessler 1994, Kessler et al. 1995). With a laterally compressed body, narrow pointed snout and terminal mouth, spotted darters fit into crevices under and between rocks (Kessler and Thorp 1993). Kessler (1994) notes that the spotted darters' ability to feed from numerous rock surfaces suggests that it feeds opportunistically. Diet studies also support opportunistic foraging. Diet items of spotted darters are similar to other species in the sub-genus *Nothonotus*, where primary items include Chironomidae and Simuliidae larvae (Kessler 1994, Gray et al. 1997) as well as water mites, mayflies, stoneflies and caddisflies (Kessler 1994).

Grey et al. (1997) and Hansen et al. (1986) reported seasonal preferences in spotted darter diets. Seasonal shifts in spotted darter diets are associated with shifts in habitat use and prey availability (Kessler 1994, Grey et al. 1997). Kessler (1994) found that spotted darters consumed more food items in October than in July; however, in July, a greater diversity of taxa was consumed. An increase in chironomids and stoneflies in spotted darter diets in October probably resulted from a seasonal decrease of mayfly and caddisfly abundance (Kessler 1994).

Additionally, the dramatic differences in flow between July and October may explain differences in prey availability and abundance (Kessler 1994). Hansen et al. (1986) also found a higher diversity of prey items later in the summer season. Gray et al. (1997) found that female spotted darters consumed significantly more prey than males during the spawning period. Females and males differ in habitat use during the spawning period (Raney and Lachner 1939, Kessler and Thorp 1993) which could explain dietary differences. Additionally, male nest guarding and territoriality (Raney and Lachner 1939) reduce foraging time.

Community

Stauffer et al. (1996) found that microhabitat segregation is "critically" important in darter niche divergence. Gray et al. (1997) observed that resource partitioning among darters is due to spatial requirements rather than foraging. Stauffer et al. (1996) found that spotted darters occupied significantly different habitat than *Etheostoma zonale*, *Etheostoma caeruleum, Etheostoma camurum* and *Percina caprodes*, but not significantly different habitat than *E. flabellare*, *Etheostoma blennioides*, *Etheostoma tippecanoe* and *Etheostoma variatum*. In Kentucky and Pennsylvania, primary differences between *E. maculatum* and co-existing species are water velocities and substrate size (Kessler et al. 1995, Stauffer et al. 1996). Inflexibility in resource use may create microhabitat limitations for spotted darters, as was evident in territoriality between *E. maculatum* and *Etheostoma bellum* (Kessler and Thorp 1993).

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Chapter 2:

Distribution and habitat of Elk River crystal darters (*Crystallaria asprella*)

Introduction

In the late 1800s and early 1900s, the crystal darter, *Crystallaria asprella,* was distributed widely within the Mississippi River drainage from Mississippi west to southeastern Oklahoma, north to southern Minnesota and southeast to Ohio; and in Gulf Coast drainages from the western panhandle of Florida to Mississippi (Page 1980, Keuhne and Barbour 1983, Grandmaison et al. 2003). The crystal darter's distribution decreased dramatically during the last century (Hatch 1997, Etnier and Starnes 1993). Stable populations occur in Alabama, Louisiana and Arkansas (George et al. 1996, Shepard et al. 1999, Hatch 1997) while populations in Minnesota, Wisconsin, Iowa, Indiana, and Oklahoma are restricted (Becker 1983, Taylor et al. 1993, Hatch 1997, Bowler 2001, Grandmaison et al. 2003). Populations within Ohio, Illinois, Kentucky and Tennessee are considered extirpated (Hatch 1997). Population declines of crystal darters are likely linked to losses of large river habitat. While there are few documented observations of crystal darter habitat use, many researchers generalize crystal darter habitat as areas of clean sand and gravel, and moderate to strong currents within the lower reaches of medium to large rivers (Table 1).

The crystal darter population in the Ohio River drainage is currently restricted to the Elk River of the lower Kanawha River system, West Virginia (Grandmaison et al. 2003). Wood and Raley (2000) and Morrison et al. (2004) reported that the crystal darter population in the Elk River, WV, is genetically distinct from populations in the Saline River, AR; Zumbro River, MN; Cahaba River, AL; and Pearl River, MS. Based on genetic results of Wood and Raley (2000), Warren et al. (2000) recognized the Elk River population as a distinct taxon (*Crystallaria asprella* spp., the Elk River crystal darter).

The Elk River crystal darter was first collected in 1980, 1.6 rkm below Mink Shoals in Kanawha County (Cincotta and Hoeft 1987). Seven crystal darters were subsequently collected from 1991 to 1999, including collections at Mink Shoals in August 1993 (1 individual) and near Clendenin, WV, in July 1991 (2 individuals), August 1993 (1 individual), September 1995 (2 individuals) and August 1999 (1 individual). All collections of Elk River crystal darters have occurred near Mink Shoals and Clendenin; Mink Shoals is 7.4 km from the mouth of Elk River, and Clendenin is 28.9 km upstream of Mink Shoals (Figure 1). Elk River crystal darters were collected from six of a total of 37 fish surveys on the lower 51 km of Elk River (King Shoals to the mouth) from 1936 through 2001 (Figure 1; Table 2).

Several scientists have recommended protection for the Elk River crystal darter (Wood and Raley 2000, Morrison et al. 2004, Boschung and Mayden 2004). Given few observations, however, little is known about distribution, population size, or habitat use of Elk River crystal darters. Any additional ecological information of Elk River crystal darters will aid management and protection of this rare species. Therefore, primary study objectives were to 1) determine the distribution of the crystal darter in the Elk River, and 2) document general characteristics of habitat use of crystal darters and habitat availability in the lower Elk River. Additionally, I documented sampling efforts from previous Elk River collections based on data from published and unpublished literature.

Methods

Study Area

The Elk River originates in Pocahontas County, flows 290 km west through central West Virginia, drops 631 meters in elevation, and converges with the Kanawha River in Charleston, West Virginia. The lower 51 river kilometers (rkm) of Elk River (King Shoals, WV, to

Charleston, WV) has a relatively low gradient and low sinuosity, whereas the 111 rkm section from King Shoals upstream to the flood control dam at Sutton, WV, has a higher gradient and higher sinuosity. Study areas were riffle/pool transitions within the lower 51 rkm of Elk River. Before this study, Bill Tolin (USFWS, unpublished data) identified 28 riffle/pool transition areas in the lower 51 rkm section (Figure 1; Table 3). Riffle/pool transition areas (typically about 100 m in length) follow a habitat sequence of shallow, high velocity tails of riffles, moderate depth and velocity runs, and deep, slow velocity heads of pools. The substrate transition within this habitat sequence ranges generally from gravel/cobble/boulder in riffles to sand/gravel/cobble in runs and sand in pools.

Data Collections

During 2002 through 2004, I sampled fishes and collected qualitative and quantitative habitat data from riffle/pool transition habitats within the lower Elk River. Fish sampling gear included backpack electrofisher (Smith-Root model 12-B), electrofishing boat, seine (3.1 m width x 1.2 m depth, and 0.32 cm mesh), and bag seines (4.6 or 6.1 m width and 1.8 m depth with a 1.2 x 1.2 x 1.2 m bag). Mesh size of bag seines was 0.64 cm in 2003 and 0.48 cm in 2004. Qualitative habitat data were collected at all sampling sites. At 10 sites, we also quantified habitat availability in addition to sampling fishes with bag seine.

During mid- to late summer of 2003 and 2004, I sampled 10 riffle/pool transitions in the lower Elk River (Figure 1; site 11 was sampled in 2003 and 2004) with bag seines. Fishes were sampled by hauling the seine downstream (typically for 15 meters), moving slightly faster than the water velocity. Approximate sample areas of each haul were summed to estimate the total sample area per site. Seine hauls of shorter distance occurred in areas of large boulders or other obstacles (e.g. tires, logs). Additional weights along the seine's lead line ensured contact with the river bottom. Sampling occurred just after dusk, from approximately 2000 until 2400 hours. In 2003, we also sampled with bag seine at two sites during daylight. Due to concerns of safety and sampling efficiency, I seined during low flows (<350 cfs [9.9 cms]; USGS stream gauge at Queen Shoals). Also, I kicked or backpack electrofished into a 3.1 x 1.2 m seine in areas of some sites, where obstacles or extremely high velocities hindered use of bag seines.

Habitat availability was quantified at 10 of the 28 riffle/pool sites on the same day as fish sampling. Habitat availability data were collected from 30 and 50 randomly-selected m^2 quadrats per site in 2003 and 2004, respectively. Water depth (cm), mean water velocity (60% of depth, cm sec^{-1}), bottom water velocity (2 cm above substrate, cm sec^{-1}), percent substrate composition (sand, gravel, cobble or boulder) and percent of embedded substrates were measured at each random location. Water velocity was measured with a flow meter (Marsh-McBirney Flowmate, model 2000).

Data Analysis

Site comparisons of habitat availability were examined with principal components analysis (PCA; McGarigal et al. 2000) and descriptive univariate statistics (means and standard errors). Before PCA, continuous habitat variables (depth, bottom velocity, and mean velocity) and percent variables of substrate composition were normalized with log (+1) and arcsin transformations, respectively. Two PCAs were conducted; one PCA included velocity, depth, and substrate data, whereas another included only data on substrate types. Separate plots of PC1 x PC2 were depicted for each PCA. For each PC1 x PC2 plot, we used multivariate analysis of variance (MANOVA) to determine if clusters of site groups were significantly ($P<0.05$) different. An ANOVA and Tukey-Kramer test were used to determine differences along each

PC axis, if clusters were significantly different along one axis independent of the second axis. All statistical tests were conducted with SAS software.

Results

During 2002 through 2004, I sampled on 20 occasions on the lower Elk River (Figure 1, Table 2), and quantified habitat availability at 10 sites (including sites of recent and previous crystal darter collections). Sampling with seines was restricted to warmer water temperatures of late summer and early fall during relatively low flows (Figures 2 and 3; Table 2). High flows prevented sampling until late August in 2003 (Figure 3). In 2004, sampling began in early July and continued through August (Table 2) until high water again hindered sampling (Figure 3). A bag seine produced two crystal darters at one site on August 29, 2003 (Site 11, Clendenin, WV, Table 4). No other crystal darters were collected or observed in 2003 or 2004, despite multiple efforts with bag seines, seines, electrofishing boat and backpack electrofishing. I also documented a total of 37 previous sampling efforts through a synthesis of fish collections on the lower Elk River (Table 2).

The two crystal darters were collected at site 11 (Clendenin, WV) near a sand bar off the toe of an island in approximately 0.5 to 0.75 meters of water over a mosaic of sand, large gravel, and cobble substrate. Mean water velocity within the general area of capture ranged from 10 to 45 cm/s. Based on measurements from randomly-selected quadrats at site 11 in 2003, depth ranged from 0.36 to 1.19 m and mean velocity (measured at 0.6 of depths) averaged 26.2 cm/sec. Mean values of substrate data were 31.6 % gravel (SE = 4.42), 25.8 % cobble (SE = 4.17) and 27.6 % sand (SE = 4.52) and percent embeddedness was 14.4 (SE = 3.51, Table 5). From a repeat sampling of Site 11 in 2004 (with no crystal darters collected), substrate composition consisted of a larger proportion of sand (42.2, SE = 4.34) and a greater proportion of embedded substrate (26.8, SE = 2.84) than in 2003 (Table 5).

In general, habitat availability data for most sites were consistent with crystal darter / habitat associations reported in the literature (Table 1) with relatively high percentages of sand (> 20%) and gravel (> 20%), and areas of moderate to strong velocities (mean velocity > 20 cm sec^{-1}; Table 5). Based on PCAs of the two datasets (all data and substrate data only), habitat availability was similar among sites, and confidence ellipses of site clusters of principal component scores overlapped among sites (Figure 4). The variation along PC1, influenced primarily by sand, gravel, and cobble, was intermediate for the Mink Shoals sites (27 and 28) and a Clendenin site (10) relative to that of other sites. Although 95% confidence ellipses overlapped for all sites (Figure 4), some significant differences occurred among sites (MANOVAs, $F_{(18, 978)} = 9.32$, $P<0.05$ and $F_{(18, 978)} = 7.76$, $P<0.05$, respectively). For the analysis of substrate data, a Tukey-Kramer test indicated that the principal component cluster of site 11 along PC1 was significantly ($P<0.05$) less than those of sites 21, 27, and 10. Also, along PC1, site 10 significantly exceeded that of sites 24 and 25 (Tukey-Kramer, $P<0.05$).

In 2004, I quantified habitat availability at the three sites of previous crystal darter collections, and compared these habitat data to those from the 2003 collection at site 11. At site 10 (at Clendenin water treatment plant), where crystal darters were collected in 1991, 1993, 1995 and 1999 (Table 2), the substrate in 2004 had a greater proportion of boulder (16.0, SE = 2.61) and cobble (38.7, SE = 2.44); and less sand (15.6, SE = 2.05) than site 11 in 2003 (Table 5). At site 27, where crystal darters were collected in 1993 (Table 2), substrate also had a higher proportion of cobble (45.9, SE = 3.14) and a lower proportion of sand (17.2, SE = 2.41) than site

11 in 2003 (Table 5). The percent of embedded substrates was also greater at sites 10 (36.9, SE = 2.16) and 27 (38.0, SE = 2.22) than it was at site 11 in 2003 (Table 5).

On average, 34 % of the area of bag seine sites were sampled in 2003 and 2004 (Table 4). At site 27, only 11.5% of the area was sampled with bag seine due to physical obstacles and shallow water. Sampling effort at site 27, and several others, was supplemented with kickseining and backpack shocking. In general, habitat availability data for most sites were consistent with crystal darter / habitat associations reported in the literature (Table 1) with relatively high percentages of sand (> 20%) and gravel (> 20%), and areas of moderate to strong velocities (mean velocity > 20 cm sec^{-1}; Table 5).

A compilation of 57 historic and recent sampling events in the lower Elk River indicated little sampling effort until the 1970s. The only pre-1970 collections occurred in 1936 (Addair 1944; J. Addair, unpublished field notes); 13 collections occurred between 1970 and 1990; and (including recent data) 41 collections have occurred between 1990 and 2004 (Table 2).

Discussion

Collection of Elk River crystal darters in 1980, 1991, 1993, 1995, 1999, and 2003 supports population persistence in the lower Elk River, West Virginia. Given a life expectancy of 2 - 4 years (George et al 1996, Page 1983, Lutterbie 1979) and the 24-year time series (1980-2003) of observations, at least some Elk River crystal darters have spawned successfully over a relatively long time period. Currently, based on survey data, the distribution of crystal darters within the lower Elk River is limited to two areas (Mink Shoals and Clendenin). Quantitative and qualitative examination of habitat availability supports adequate habitat (based on velocity and benthic substrates; Table 1) for crystal darters at the 28 riffle/pool transitions with the lower

51 rkm. Population size of the Elk River crystal darter is unknown, but the number of individuals is likely small given low catch per effort from our recent data and previous data.

The rareness of the Elk River crystal darter and its “species of concern” designation (WVDNR 2003) are supported by the low catch per effort from a total of 57 fish surveys on the lower 51 rkm of Elk River from 1936 through 2004 (Table 2; Figure 1). The earliest recorded fish collections on the lower 51 rkm of the Elk River occurred in 1936 (Addair 1944; J. Addair, unpublished field notes); however, most collections have occurred between 1971 and 2004. Although most efforts before this study did not target crystal darters, the low number of crystal darter observations from multiple gear types (seines, bag seines, boat elctrofishing and backpack electrofishing) supports a small population.

The recent survey efforts (2002-2004), during which only two crystal darters were collected from a total of 20 samples, further supports rareness of this species. Habitat data for these two specimens are consistent with previous information, i.e. moderate velocities over sand and gravel/cobble substrates. In addition to the 2003 observation, other collections of Elk River crystal darters were in areas of sand and gravel/cobble substrates (D. Cincotta, pers. comm.; S. Welsh, pers. comm.). Considerable effort (often hours of collecting within a relatively small area of stream) in some of the previous samples of Elk River crystal darters may have influenced habitat information. In 2003, the two individuals were collected during the first and third seine hauls; hence, the location (and associated habitat use information) of these individuals was unlikely influenced by the collectors.

Many records report small numbers of crystal darters per sampling site (Grandmaison et al. 2003). Gear avoidance may be one reason for low collection numbers. Crystal darters are reclusive in aquaria (Katula 2000), and may avoid sampling nets. However, others have successfully used bag seines to collect crystal darters (Hatch 1997, Shepard et al. 1999, Katula 2000). My bag seines were effective for many small benthic species, including eastern sand darters (A*mmocrypta pellucida*), a close-relative of *Crystallaria*. However, larger benthic fishes, such as adult suckers (*Moxostoma*), sauger (*Sander canadensis*), channel catfish (*Ictalurus punctatus*), and flathead catfish (*Pylodictis olivaris*) were rarely collected, despite a relatively high abundance within the lower Elk River. In addition to gear avoidance, sampling location may have influenced my catch rates. I sampled areas up to 1.5 m depths; hence, inference is not transferable to deeper waters. I did not use SCUBA for deepwater sampling because of turbidity and low sight distance.

The presence of moderate currents over cobble/gravel/sand substrates at sites near Clendenin and Mink Shoals (sites of previous collections of Elk River crystal darters) are consistent with the literature on crystal darter habitat (Table 1). These habitat characteristics in the lower Elk River, however, are not restricted to sites near Clendenin and Mink Shoals, but rather occur at all 28 riffle/pool transitions within the lower 51 rkm of the Elk River. My quantitative (10 sites including Clendenin and Mink Shoals) and qualitative (additional 18 sites) habitat data support adequate crystal darter habitat (based on substrate and velocity) at all 28 riffle/pool sites. Although sites exist with adequate habitat, the total length of river of these 28 riffle/pool sites is approximately 2800 meters, a relatively small amount (approximately 5.5 %) of the 51,000 m (51 rkm) of the lower Elk River (King Shoals to the mouth). Crystal darters, however, may use these riffle/pool habitats primarily during night and may occupy deeper pool habitats during the day.

The site of crystal darter collection in 2003 (site 10, Clendenin, WV) had higher amounts of sand and less embedded substrate than sites 11 and 27 where crystal darters were collected in previous years. However, drastic year-to-year changes in amounts of sand and embedded substrates have been observed at the Clendenin site (site 10) over the last 15 years (D. Cincotta, pers. comm.; S. Welsh, pers. comm.); consequently, habitat characteristics at Clendenin (site 10) or Mink Shoals (site 27) in 2004 may not be comparable to prior conditions in years of crystal darter observations.

Given the importance of clean sand and gravel to crystal darter habitat, population persistence of Elk River crystal darters will likely be linked to sedimentation from land use. Although sedimentation is a natural process, land use practices within the Elk River watershed, such as logging, coal mining and oil and gas extraction, contribute to excessive and unnatural sedimentation (WVDEP 1997). In addition to environmental perturbation, small populations, such as the populations of the Elk River crystal darter near Clendenin and near Mink Shoals, are susceptible to extirpation from demographic stochasticity and catastrophic events (Lande 1988). Given uncertainties of population status, additional monitoring of the Elk River crystal darter is needed (Warren et al. 2000, Grandmaison et al. 2003). Given that adequate habitat exists in the lower Elk River, future efforts should consider captive propagation and supplemental stocking as a strategy for conservation of Elk River crystal darters.

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Tables and Figures

Table 1. Summary of published descriptions of crystal darter habitat including current velocity and substrate composition.

State/Region	Current Velocity	Bottom Substrate	Citation
Alabama	moderate to swift runs	sand and gravel mix; Cahaba River	Shepard et al. 1999
Alabama	areas of higher current velocity	stable sand bars; cobble, gravel, and sand; Alabama River	Shepard et al. 1999
Alabama	strong current	gravel or sand bottom	Smith-Vaniz 1968; Boschung and Mayden 2004
Alabama	moderate to swift side channel riffle for spawning	spawn over course sand and gravel; Tallapoosa River	Simon et al. 1992
Arkansas	strong current	sand or fine gravel	Robison and Buchanan 1988
Arkansas	46-90 cm/s	primarily gravel, with some small cobble and patches of sand	George et al. 1996
entire range	strong current	clean sand and gravel	Page 1983
entire range	steady current	clean sand or gravel	Kuehne and Barbour 1983
Illinois		sandy stream (Little Wabash River); small rocky tributary of the Mississippi River	Jordan 1876
Iowa		sand; Pool 11 Mississippi River	Bowler 2001
Minnesota	moderate to strong currents; 60.8-37.6 cm/sec	coarse sand and gravel with 30-40% embedded cobble and boulder; main channel Mississippi River	Hatch 1997
Minnesota		driftwood and debris caught in shifting sand; Zumbrow River	J. Underhill, pers. comm. As cited in Becker (1983)
Mississippi	66 cm/s (range 25 - 100 cm/s)	clean sand and large gravel	Ross 2001
Missouri	slight current	sand or small gravel	Pflieger 1997
Ohio		sandy riffles, bars, and pool bottoms;	Trautman 1981
Oklahoma		sand or fine gravel	Miller and Robison 1973
Oklahoma		sand/gravel mix at pool/riffle interface; Kiamichi River	Taylor et al. 1993
Oklahoma		sandy backwater	Taylor et al. 1993
Oklahoma		riffle with gravel substrate	Taylor et al. 1993

Table 1. Continued.

State/Region	Current Velocity	Bottom Substrate	Citation
Tennessee	swifter portions of shoal areas	clean sand and gravel	Etnier and Starnes 1993
West Virginia		adjacent to submerged log in sandy run; 25% rubble, 50% gravel, 20% sand, 5% silt; Elk River	Cincotta and Hoeft 1987
Wisconsin	moderate to strong currents	sandy riffles, bars, and pool bottoms	Becker 1983
Wisconsin	moderate current	gravelly bar; Mississippi River at Cassville	Becker 1983
Wisconsin		10-25% sand and 90 to 75% gravel; Chippewa River	Becker 1983
Wisconsin	moderately flowing	extensive rock shelf; Wisconsin River	Becker 1983

Table 2. Summary of fish collections on the Elk River between King Shoals and Charleston, WV from 1936 to 2004. Crystal darter observations indicated with "Y" (yes).

YR	M	D	UTM EW	UTM NS	CRYSTAL DARTER	LOCATION DESCRIPTION
1936	7	4	456069	4251240		7 mi. above Clendenin, WV
1936	7	5	479132	4261873		at mouth of Little Sandy Creek, 15 mi above Charleston, WV
1936	7	5	448767	4249434		2.5 mi. above Charleston, WV
1971	10	20	475240	4257980		23.0 mi. above mouth - pool under & above Queen Shoals bridge (HWY 1)
1973	9	6	472200	4259560		23.5 mi. above mouth
1973	9	6	473980	4258600		22.5 mi. above mouth
1973	9	6	473680	4258900		22.0 mi. above mouth
1978	9	8	447220	4247320		3.0 mi. above mouth - stream section adj. to I-79 construction & Kanawha Airport
1979	4	20	479160	4261860		29.8 mi. above mouth - at mouth of King Shoals Run
1979	9	11	448940	4248700		4.24 mi. above mouth
1980	11	13	448993	4249845	Y	3.6 mi. above mouth to 5.1 mi. above mouth adjacent to Coonskin Park
1981	9	23	449559	4249982		from Mink Shoals to Garnett School at Big Chimney, WV near Coonskin Park
1982	11	16	465249	4257890		17.8 mi. above mouth, at mouth of Jordan Cr. near Falling Rock, WV
1983	2	22	475189	4257898		at mouth of Queen Shoals Cr.
1983	8	26	450720	4249400		Big Chimney, WV downstream to Mink Shoals
1986	6	2	465276	4257880		at mouth of Jordan Creek
1991	7	18	471076	4260078	Y	at Clendenin water treatment plant
1993	8	4	471076	4260078	Y	at Clendenin water treatment plant
1993	8	5	448783	4249360	Y	at Mink Shoals
1995	6	27	475078	4257960		at Queen Shoals
1995	6	27	471076	4260078		at Clendenin water treatment plant
1995	8	5	471076	4260078		at Clendenin water treatment plant
1995	8	5	448783	4249360		at Mink Shoals
1995	8	13	448783	4249360		at Mink Shoals
1995	8	13	471076	4260078		at Clendenin water treatment plant
1995	8	13	475078	4257960		at Queen Shoals
1995	9	20	471076	4260078	Y	at Clendenin water treatment plant
1995	10	21	471076	4260078		at Clendenin water treatment plant
1995	10	21	448783	4249360		at Mink Shoals
1996	6	20	448783	4249360		at Mink Shoals
1996	7	14	446590	4246241		from mouth upstream to Mink Shoals

Table 2. Continued.

YR	M	D	UTM EW	UTM NS	CRYSTAL DARTER	LOCATION DESCRIPTION
1996	10	19	471076	4260078		at Clendenin water treatment plant
1999	8	25	471076	4260078	Y	at Clendenin water treatment plant
2000	9	24	471076	4260078		at Clendenin water treatment plant
2000	9	24	448783	4249360		at Mink Shoals
2001	9	29	471076	4260078		at Clendenin water treatment plant
2001	9	29	448783	4249360		at Mink Shoals
2002	8	2	471076	4260078		at Clendenin water treatment plant
2002	8	2	461731	4257517		~1 road mi. S of Youngs Bottom, WV
2002	8	13	451401	4249721		~1.5 mi. SW of Big Chimney, WV
2002	8	13	452814	4250561		at foot of island in Elk River at Big Chimney, WV
2002	8	13	457361	4253602		< 1 mi. S of Elkview, WV; behind old Elkview Medical Center
2002	8	13	448858	4249675		Mink Shoals, ~ 3.5 mi. N of Charleston, WV
2002	8	15	467083	4258290		~1.5 mi. ENE of Falling Rock, WV
2002	9	20	461731	4257517		~1 road mi. S of Youngs Bottom, WV
2003	7	17	462798	4248136		~3 mi. NE of Charleston, WV (at mouth of Elk River)
2003	8	29	469387	4260164	Y	Site 11, 188 meters upstream of Rt. 4 bridge in Clendenin, WV
2003	8	30	457377	4253729		Site 22, ~1 mi. SW of Elkview, WV; behind old Elkview Medical Center
2004	7	5	466907	4258565		Site 12, ~2 mi. SW of Clendenin, WV; at mouth of Leatherwood Cr
2004	7	6	466905	4258569		Site 21, ~ 0.5 mi. SSW of Elkview, WV
2004	7	7	452608	4250851		Site 24, below Rt. 114 bridge in Big Chimney, WV
2004	7	9	451385	4249921		Site 25, ~ 1 mi. SW of Big Chimney, WV
2004	7	10	448774	4248665		Site 28, ~3.75 mi. NE of Charleston, WV (at mouth of Elk River); behind Yeager Airport
2004	7	11	469401	4260151		Site 11, 188 meters upstream of Rt. 4 bridge in Clendenin, WV
2004	7	19	461516	4257539		Site 18, ~ 1.3 mi. NE of Blue Creek, WV
2004	8	18	471076	4260078		Site 10, at Clendenin water treatment plant
2004	8	28	448773	4249642		Site 27, Mink Shoals, ~ 4.1 mi. NE of Charleston, WV (at mouth of Elk River); adjacent to Coonskin Park

Table 3. Site locations of 28 riffle/pool transition areas on the lower 51 km of Elk River.

SITE	UTM EW	UTM NS	Location description	Distance from mouth (km)
1	479040	4262080	3.2 km NW of Procious, WV	51
2	478336	4261911	1 km NNE of Porter, WV	50.2
3	478350	4260947	1.8 km NNE of Porter, WV	49.2
4	478174	4260412	1.1 km NE of Porter WV	48.6
5	477336	4259286	0.4 km SW of Porter, WV	47.1
6	474830	4258110	Queen Shoals	42
7	473697	4259110	0.9 km NW of Queen Shoals, WV	40.4
8	472740	4259567	1.4 km SE of Queen Shoals, WV	39.3
9	472113	4259779	1.3 km SE of Clendenin, WV	38.6
10	471079	4260299	0.9 km E of Clendenin, WV at Clendenin Water Treatment Facility	37.4
11	469460	4260166	Adjacent to Clendenin, WV upstream of Rt. 4 bridge	35.7
12	466989	4258504	3.2 km SW of Clendenin, WV; at mouth of Leatherwood Cr	32.7
13	465285	4258054	0.2 km E of Falling Rock, WV; mouth of Jordan Creek	30.9
14	465088	4257801	Adjacent to Falling Rock, WV; mouth of Falling Rock Creek	30.6
15	464574	4257167	0.4 km S of Falling Rock, WV	29.8
16	463504	4256850	0.3 km SE of Youngs Bottom, WV	28.7
17	463272	4256801	0.2 km SE of Youngs Bottom, WV; mouth of Sand Run	28.5
18	461794	4257639	2 km NE of Blue Creek, WV	26.7
19	459943	4255548	0.2 km SW of Blue Creek, WV; adjacent to island below mouth of Blue Creek	23.8
20	457887	4254767	Adjacent to town of Elkview, WV; mouth of Little Sandy Creek	21.5
21	457394	4253887	0.5 km SW of Elkview, WV	20.3
22	456937	4252120	0.7 km NW of Pinch, WV	18.4
23	455987	4251416	1 km W of Pinch, WV	16
24	452805	4250895	below Rt. 114 bridge in Big Chimney, WV	14.3
25	451453	4249966	0.2 km E of Creed, WV	11
26	449468	4250276	Adjacent to Elk Hills, WV	8.7
27	448807	4249656	Mink Shoals, 6.5 km NE of Charleston, WV; adjacent to Coonskin Park	7.6
28	448715	4248650	6 km NE of Charleston, WV; behind Yeager Airport	6.5

Table 4. Summary of bag seine sampling efforts by site. Sampling effort (*) was supplemented by kickseining in riffles and near obstacles. Sampling effort (**) was supplemented by backpack shocking into a 3.1 x 1.2 m seine in riffles and near obstacles.

Site	Date	Area of sample site (m^2)	Approximate % area sampled	Number of Seine hauls	Crystal darter observations Yes/no	Time of sampling
11	8/29/2003	13,724	10.0	15	N	Day
11	8/29/2003	13,724	11.0	17	Y	Night
22	8/30/2003	6000	23.0	15	N	Day
22	8/30/2003	6000	26.0	17*	N	Night
12	7/5/2004	4176	39.0	28	N	Night
21	7/6/2004	4588	35.0	27	N	Night
24	7/7/2004	1755	86.0	26	N	Night
25	7/9/2004	2451	47.2	26*	N	Night
28	7/10/2004	2520	47.9	26	N	Night
11	7/11/2004	4500	40.1	32*	N	Night
18	7/18/2004	3496	32.8	26**	N	Night
10	8/18/2004	1863	32.1	17*	N	Night
27	8/28/2004	2850	11.5	12**	N	Night

Table 5. Average habitat values by site with standard error (SE) in italics. Velocity values of “2 cm” and “mean” were measured at 2 cm above the substrate, and at 0.6 percent of depth, respectively.

	Sampling sites (year in parentheses)										
Habitat type	10 (2004)	11 (2004)	11 (2003)	12 (2004)	18 (2004)	21 (2004)	22 (2003)	24 (2004)	25 (2004)	27 (2004)	28 (2004)
% Sand	15.6	42.2	27.6	29.4	17.0	16.0	37.5	51.6	29.1	17.2	23.3
SE	*2.05*	*4.34*	*4.52*	*4.45*	*4.87*	*1.25*	*6.73*	*4.21*	*4.79*	*2.41*	*2.66*
% Gravel	27.8	31.4	31.6	23.2	31.3	37.0	24.7	17.5	21.0	26.1	24.5
SE	*2.15*	*3.20*	*4.42*	*4.47*	*4.24*	*2.81*	*4.38*	*2.49*	*3.93*	*3.09*	*2.30*
% Cobble	38.7	23.6	25.8	31.6	34.2	40.8	27.9	28.8	28.9	45.9	40.1
SE	*2.44*	*2.22*	*4.17*	*4.39*	*3.88*	*2.62*	*3.67*	*3.01*	*3.46*	*3.14*	*2.85*
% Boulder	16.0	2.0	3.5	13.9	15.2	5.3	9.8	2.2	15.0	9.0	11.9
SE	*2.61*	*1.03*	*1.27*	*3.02*	*4.18*	*1.58*	*3.18*	*0.86*	*2.75*	*2.09*	*2.96*
% Other	1.5	0.6	11.3	2.0	2.3	0.0	0.2	0.0	5.8	1.4	0.0
SE	*1.40*	*0.44*	*5.19*	*1.06*	*1.68*	*0.00*	*0.17*	*0.00*	*2.64*	*0.99*	*0.00*
Embedded	36.9	26.8	14.4	44.8	37.5	27.8	30.8	22.3	25.0	38.0	39.9
SE	*2.16*	*2.84*	*3.51*	*3.94*	*3.88*	*2.37*	*4.68*	*2.59*	*3.08*	*2.22*	*2.90*
Depth (cm)	46.27	54.32	75.46	61.4	52.32	39.75	72.31	36.82	67.79	50.29	44.99
SE	*2.95*	*1.11*	*3.18*	*3.9*	*4.08*	*1.34*	*4.32*	*2.58*	*3.72*	*3.96*	*3.12*
2 cm velocity (cm/s)	18.56	10.16	11.26	7.54	10.64	12.82	14.49	9.79	5.67	14.14	7.58
SE	*1.43*	*1.12*	*2.08*	*1.6*	*2.03*	*0.91*	*1.62*	*1.01*	*1.61*	*2.08*	*1.69*
Mean velocity (cm/s)	41.69	24.55	26.22	18.47	24.58	29.52	31.37	21.24	16.89	29.1	23.52
SE	*2.66*	*2.04*	*3.61*	*2.32*	*4.08*	*1.04*	*2.52*	*1.52*	*3.21*	*2.58*	*2.93*

Figure 1. Map of riffle/pool transition sites identified by Bill Tolin (USFWS, unpublished data) on the lower 51 rkm of the Elk River from King Shoals to Charleston, West Virginia. Closed symbols designate locations sampled during this study.

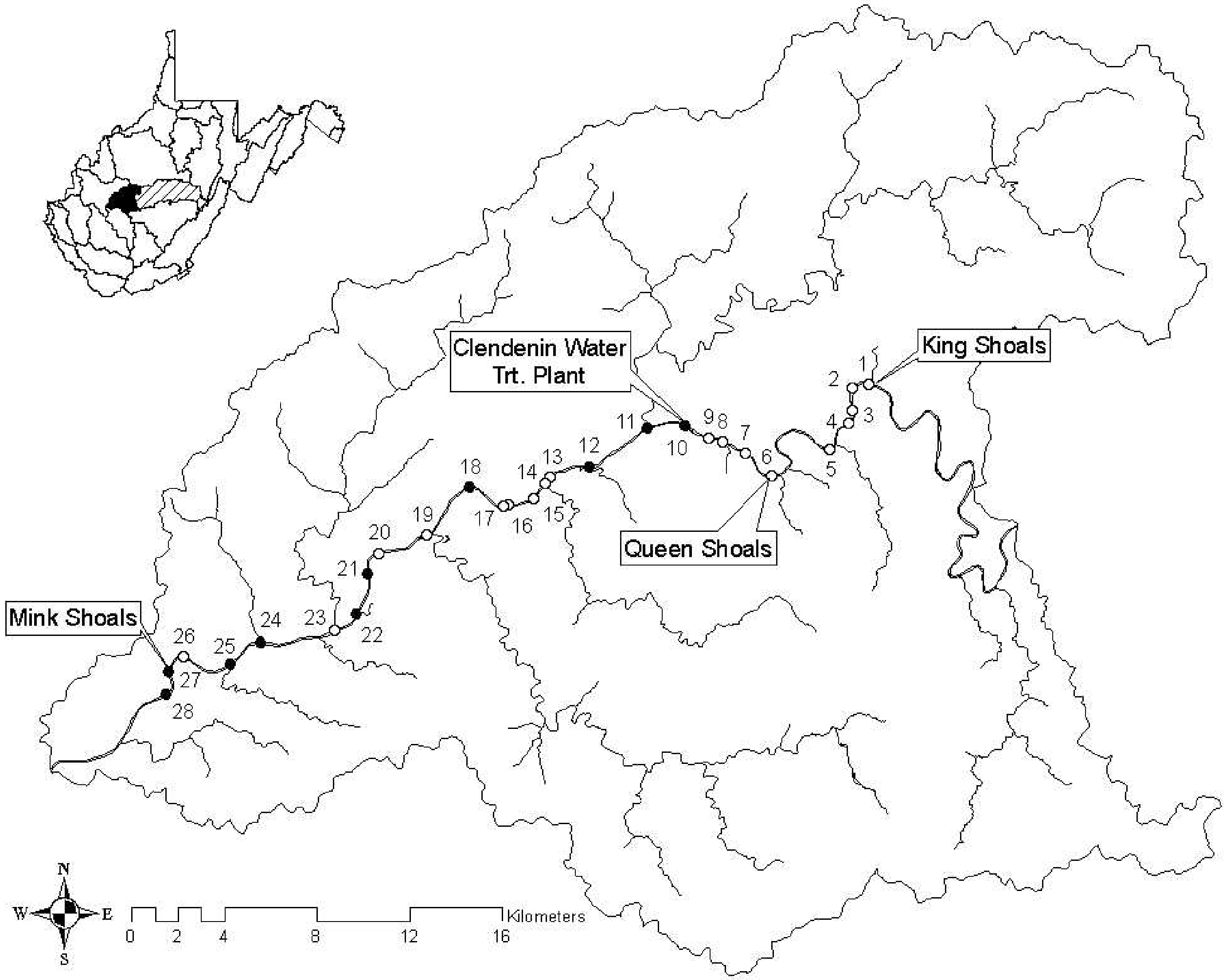


Figure 2. Daily water temperature (°C) of the Elk River at Queen Shoals (13 September 2002 until 3 July 2004).

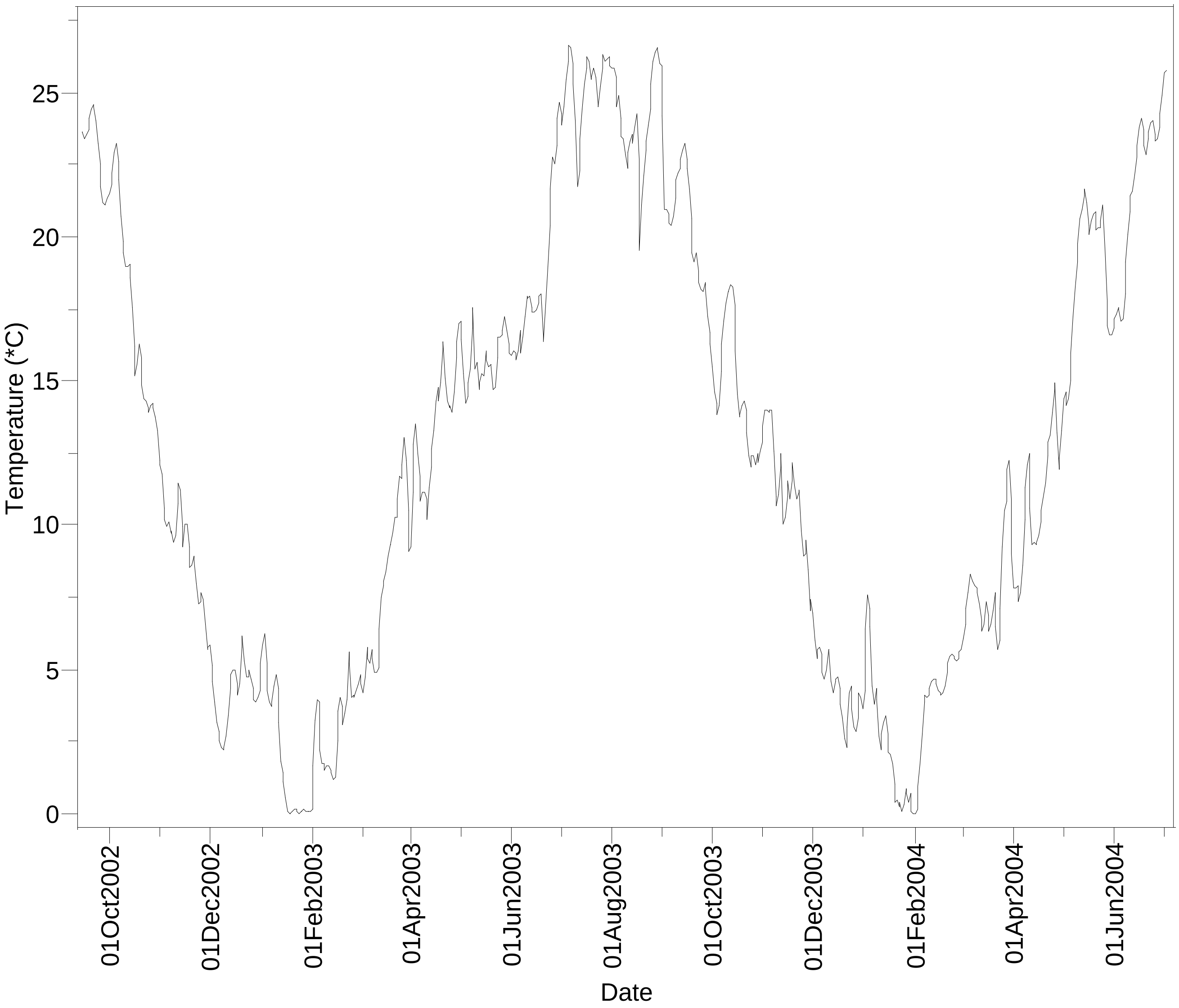


Figure 3. Mean daily discharge (m^3/s) of the Elk River from the USGS gauging station at Queen Shoals (1 August 2002 to 31 August 2004).

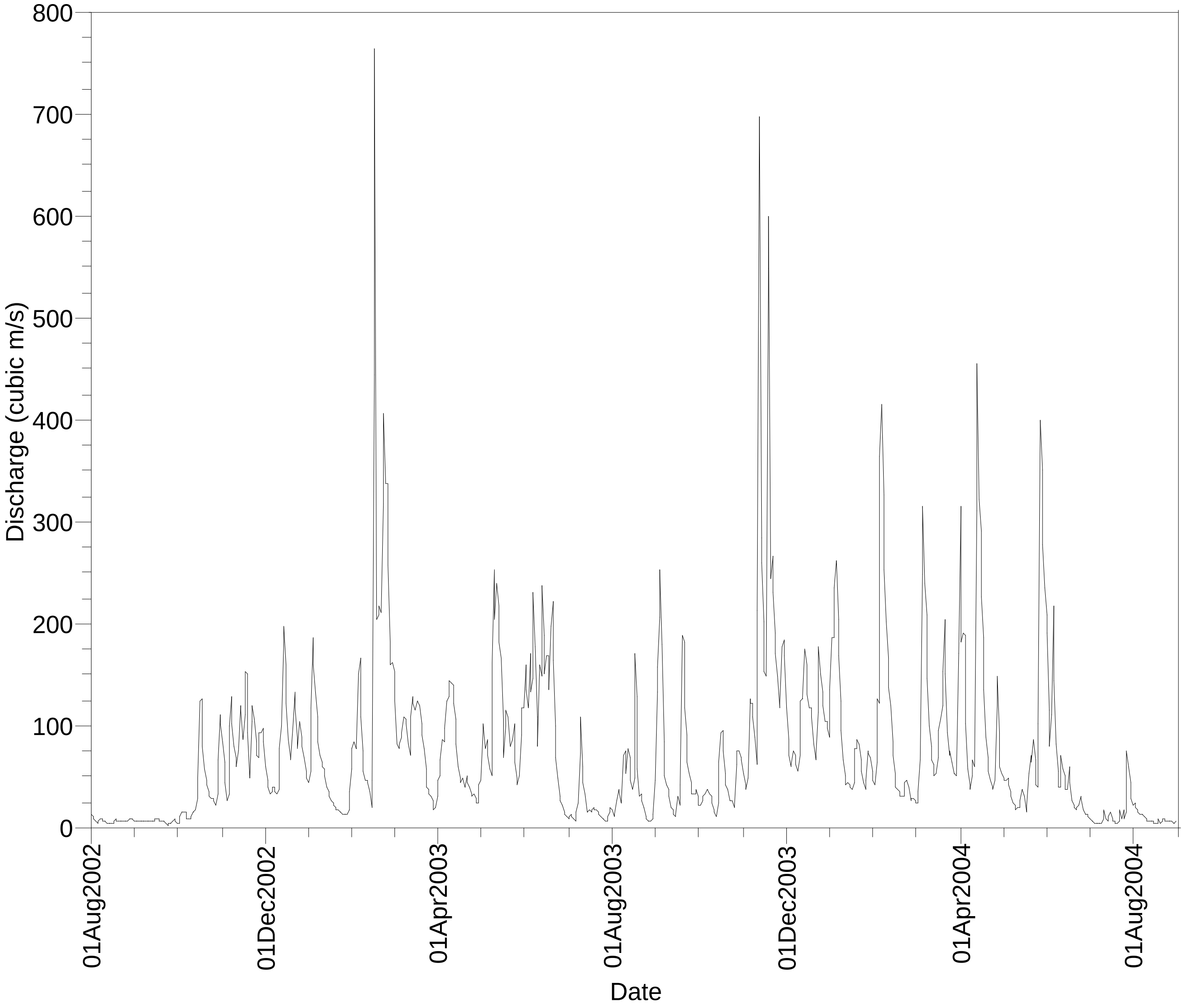
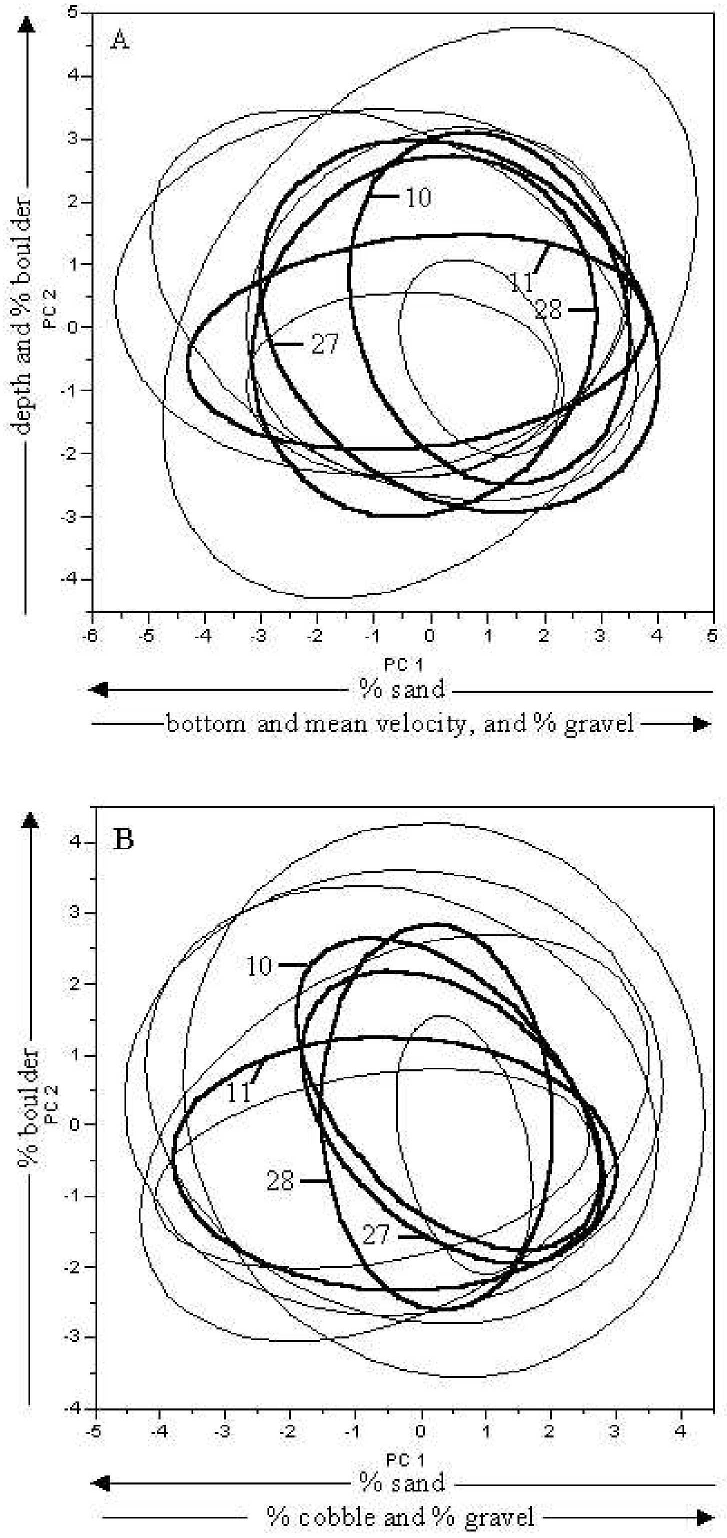


Figure 4. Habitat availability data of 10 sites on the lower Elk River depicted as confidence ellipses (95%) of principal component clusters; (A) PCA of all habitat data (velocity, depth, and substrate percents) and (B) PCA of substrate only. Bold ellipses depict previous crystal darter collection sites near Clendenin (10 and 11) and Mink Shoals (27 and 28).



Chapter 3:

Habitat use of the Elk River spotted darter, *Etheostoma maculatum*[*]

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[*] This chapter is formatted following the guidelines of the journal of Environmental Biology of Fishes.

Synopsis

The spotted darter, *Etheostoma maculatum*, is distributed disjunctly within the Ohio River drainage. Researchers have generalized spotted darter habitat as large rocks and swift riffles. In West Virginia, spotted darters occur only within the middle section of Elk River system, but information on habitat use is lacking. With direct observation (snorkeling), we examined microhabitat use of spotted darters in riffle and run habitats at three sites in the Elk River. Contrary to habitat use data from other populations, spotted darters in the Elk River were observed primarily in run habitats near large rocks and within moderate velocities. The Elk River spotted darter, a habitat specialist, is highly vulnerable to habitat alterations, such as sedimentation and substrate embeddedness. Given a small geographic range, further ecological studies are needed for conservation and management of Elk River spotted darters.

Introduction

Spotted darters, *Etheostoma maculatum*, are distributed disjunctly within the Ohio River drainage (Page & Burr 1991). Population isolates of the spotted darter occur in the Allegheny River watershed, Pennsylvania and New York (Raney & Lachner 1939, Stauffer et al. 1996), the Scioto River watershed, Ohio (Trautman 1981), the Blue River (Baker et al. 1985) and Wabash River watersheds (Etnier 1980), Indiana, and the Green River (Kessler & Thorp 1993, Kessler 1994, Kessler et al. 1995) and North Fork Kentucky River watersheds (Burr & Warren 1986), Kentucky. Range fragmentation of *E. maculatum* mirrors that of other regional species (such as *Erimystax dissimilis, Etheostoma tippecanoe, Etheostoma camurum*, and *Percina evides*) which is a geographic pattern attributed to recent degradation and fragmentation of habitat following post-Pleistocene dispersal (Simons 2004). Owing to small isolated populations, state agencies have listed spotted darters as threatened, endangered, or as “species of special concern.” In West Virginia, spotted darters occur only in the lower Kanawha River system in middle portions of the Elk River (Cincotta et al. 1986, Stauffer et al. 1995), where populations are known from ten sites (Appendix 1). The spotted darter population from Elk River differs morphologically from populations of other drainages (Welsh et al.[1]).

Spotted darters use riffle habitats with relatively fast velocities and large substrate in the Allegheny (Raney & Lachner 1939, Stauffer et al. 1996), Scioto (Trautman 1981) Green (Kessler & Thorp 1993, Kessler et al. 1995) and Kentucky (Burr & Warren 1986) river systems. Spotted darters are frequently observed under or near boulders or large cobbles (Raney

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[1] Welsh, S.A., D.A. Cincotta, R.L. Raesly, & R.M. Wood. 2002. Morphological variation among populations of the spotted darter (*Etheostoma maculatum*). From Program Book and Abstracts, Joint Meeting of Ichthyologists and Herpetologists, Kansas City, Missouri. 327 pp. Available from the internet URL http://www.asih.org/meetings/2002/Abstracts.pdf

& Lachner 1939, Kessler & Thorp 1993). Before this study, however, no information existed on habitat use of Elk River spotted darters. Therefore, our objective was to quantify microhabitat use of the spotted darter in the Elk River, West Virginia.

Materials and methods

Study Site

The Elk River, located in central West Virginia, flows west 290 km and drops 631 meters in elevation before entering the Kanawha River (Figure 1). The middle section of Elk River supports spotted darters, a section with relatively moderate gradients and high sinuosity (Appendix 1). In this study, we examined microhabitat use of Elk River spotted darters in riffle and run habitats at three sites adjacent to towns of Spread, Whetstone, and Ivydale. At Spread and Whetstone, run habitats were immediately upstream of the head of riffles, whereas at Ivydale, the run habitat paralleled the riffle habitat (separated by a narrow island). At each site, the size of the study area varied with available riffle or run habitat (Table 1).

Habitat availability

Random sampling was used to examine habitat availability of riffle and run habitats, where approximately 30 locations per site were selected randomly from a site grid of numbered 1 m^2 cells. At each random location, we measured mean water velocity (60% of depth, cm sec^{-1}), bottom water velocity (2 cm above substrate, cm sec^{-1}), water depth (cm) and substrate composition. Water velocity was measured with a flow meter (Marsh-McBirney Flowmate, model 2000). To measure substrate, a grid of 25 5 x 5-cm cells was centered over each location, and the dominant substrate size class for each cell was recorded. Substrate size, measured across the longest axis, was classed as the average value of 10 ranges: 0.032 mm (silt, range 0.004-0.06

mm silt); 1.0 mm (sand, range >0.06-2 mm); 0.5 cm (range >0.02-1 cm); 2 cm (range >1-3 cm); 4 cm (range >3-5 cm); 7.5 cm (range >5-10 cm); 12.5 cm (range >10-15 cm); 17.5 cm (range >15-20 cm); 22.5 cm (range >20-25 cm); and 30 cm (>25 cm). The mean of the 25 scores (from the 25 5 x 5-cm cell grid) produced a substrate size index for each location. Substrate heterogeneity at each location was determined using the standard deviation of the mean of the 25 substrate values (Bain 1985).

Habitat Use

Habitat use data were obtained from underwater observations (snorkeling) within run and riffle habitats at Spread (13 and 20 Sept 2002), Whetstone (11 Aug 2004) and Ivydale (1 Sept 2004). While snorkeling in an upstream direction during daylight hours (9:00-15:00 h), we marked spotted darter locations using numbered weighted tags. Darter locations were not marked if the presence of divers noticeably altered fish behavior. Mean water velocity (60% of depth, cm sec^{-1}), bottom water velocity (2 cm above substrate, cm sec^{-1}), water depth (cm) and substrate composition were measured at each fish location (as described above for habitat availability).

Data Analysis

We explored within- and among-site patterns of habitat availability and microhabitat use with principle components analysis (PCA). Specifically, we explored microhabitat availability within and among riffle and run habitats. Additionally, we examined relationships between microhabitat availability and microhabitat use within riffle and run habitats at each site. Before PCA, nonnormal data of habitat availability and habitat use were log (x+1) transformed. Separate plots of PC1 x PC2 depicted dissimilarities of: (1) habitat availability between riffle and run sites, among run sites, and between riffle sites; and (2) between habitat availability and habitat use within each site. Varimax rotation increased interpretation of principal components (McGarigal et al. 2000). For each PC1 x PC2 plot, we used multivariate analysis of variance (MANOVA) to determine if clusters of groups were significantly ($P<0.05$) different. An ANOVA and Tukey-Kramer test (for > 2 groups) or Student's t-test (for 2 groups) were used to determine differences along each PC axis, if clusters were significantly different along one axis independent of the second axis. Means and standard errors of habitat variables aided interpretation of PCA. All statistical tests were conducted with SAS software.

Results

Habitat availability

Habitat availability between riffle and run habitats differed significantly (MANOVA, $F_{(2, 168)} = 18.92$, $p<0.05$; Figure 2, Table 1) where water velocities within riffles exceeded those of run habitats (PC1, Student's t-test, $t_{(159)} = 5.19$, $p<0.05$) and substrate size and substrate heterogeneity within run habitats exceeded those of riffles (PC2, Student's t-test, $t_{(147)} = 4.16$, $p<0.05$). A PCA depicted significant differences in habitat availability among run habitats (MANOVA, $F_{(4, 222)} = 16.85$, $p<0.05$; Figure 3, Table 1). An ANOVA and Tukey-Kramer test indicated that water velocities at Whetstone and Spread were significantly faster than those of Ivydale (PC1, ANOVA, $F_{(2, 111)} = 22.89$, $p<0.05$), and substrate size and heterogeneity values at Ivydale were significantly larger than those at Whetstone and Spread (PC2, ANOVA, $F_{(2, 111)} = 11.67$, $p<0.05$); however, water depths were similar among run habitats (Table 1). For riffle habitats, water depth at Whetstone was shallower than that of Ivydale (Table 1). Based on PCA, substrate size and heterogeneity within the Whetstone riffle exceeded that of the Ivydale riffle (PC1, Student's t-test, $t_{(48)} = 3.96$, $p<0.05$, Figure 4).

Habitat use

At Ivydale and Whetstone, the number of spotted darter observations in run habitats (32 and 26) exceeded those in riffle habitats (10 and 7), respectively. At Spread, spotted darters were absent in the riffle, but 35 were observed in the run habitat. In addition to differences in habitat use between run and riffles, spotted darters were associated with larger rocks (>20 cm diameter), greater substrate heterogeneity, and faster velocities in run habitats. Large rocks were an important component of spotted darter habitat (Table 1); out of 111 total observations, 69 and 100 spotted darters were near or under rocks > 25 cm and > 20 cm diameter, respectively. Within the 25 cm^2 scale of observation, average rock sizes used by spotted darters among sites ranged from 12.4 to 18.2 cm (Table 1). Despite differences in available habitats among run and riffle sites, spotted darters were associated with rocks of similar size among sites, except for smaller rocks at the Ivydale riffle.

Within site habitat use versus habitat availability

For run habitats at Spread and Whetstone, the cluster of principal components of habitat use differed significantly from that of habitat availability (MANOVAs, $F_{(2,\ 89)} = 13.27$, $p<0.05$, and $F_{(2,\ 51)} = 35.65$, $p<0.05$, respectively) where substrate heterogeneity and substrate size associated with spotted darters exceeded that of habitat availability (PC1, Student's t-tests, $t_{(88)} = 5.11$, $p<0.05$, and $t_{(46)} = 5.36$, $p<0.05$, respectively; Figures 5 and 6). Spotted darters used deeper areas and faster velocities in the run at Whetstone (PC2, Student's t-test, $t_{(36)} = 3.96$, $p<0.05$; Figure 6). For the run habitat at Ivydale, clusters of habitat use and habitat availability did not differ significantly (MANOVAs, $F_{(2,\ 59)} = 2.09$, $p > 0.05$, Figure 7). Univariate analyses supported the interpretation of PCA; however, in addition to larger substrate sizes and higher substrate heterogeneity, mean water velocity and bottom velocity of habitat use data consistently exceeded that of availability within run habitats (Table 1). For riffle habitats at Whetstone and Ivydale, habitat use differed significantly from that of habitat availability (MANOVAs, $F_{(2,\ 33)} = 24.34$, $p<0.05$, and $F_{(2,\ 35)} = 50.05$, $p<0.05$, respectively) where substrate heterogeneity and substrate size associated with spotted darters exceeded that of habitat availability (PC1, Student's t-test, $t_{(33)} = 12.59$, $p<0.05$, and PC2, Student's t-test, $t_{(23)} = 3.94$, $p<0.05$, respectively; Figures 8 and 9). Also, water velocities associated with spotted darters within the Ivydale riffle were significantly slower than those of habitat availability data (PC1, Student's t-test, $t_{(11)} = 4.73$, $p<0.05$).

Discussion

Darters are adapted morphologically for a wide range of substrates and velocities (Page 1983, Page & Swofford 1984) and habitat use is documented for many species (Matthews 1985, Hlohowskyj & Wissing 1986, Chipps et al. 1994, Welsh & Perry 1998), including spotted darters (Kessler & Thorp 1993, Stauffer et al. 1996). Within run habitats of the middle section of Elk River, large unembedded substrate (> 20 cm) and moderate velocities (13 to 51 cm sec^{-1}) were important habitat for spotted darters. Few spotted darters were observed in riffle habitats, a finding inconsistent with most reports of spotted darter habitat use (Trautman 1981, Burr & Warren 1986, Kessler & Thorp 1993, Stauffer et al. 1996). Run habitats within our study area had lower bottom and mean velocities, larger rock size and higher substrate heterogeneity than riffle habitats. Use of slower velocity run habitats by spotted darters in the Elk River may be associated with availability of larger rocks, where individuals avoid riffles with smaller substrate.

Spotted darters in the Elk River were associated with large rocks (> 20 cm), a finding consistent among our results and those of previous studies (Kessler & Thorp 1993, Stauffer et al. 1996). Average sizes of rocks used by Elk River spotted darters were significantly larger than those of available habitat, except for the run at Ivydale where large rocks were distributed uniformly. We quantified habitat during low flows of summer and early fall; however, large substrate is also of primary importance to spotted darters for nest sites and egg attachment during spring spawning (Raney & Lachner 1939).

Although researchers have also documented swift riffles as primary habitat of spotted darters (Raney & Lachner 1939, Baker et al. 1985, Burr & Warren 1986, Kessler et al. 1995, Stauffer et al. 1996), we found most Elk River spotted darters in run habitat, and few in riffle habitat. Suitable run habitats within the middle section of Elk River were primarily located in the transition between slow pool and swift riffle habitat. Average velocity of spotted darter locations in run habitats was generally higher than that of available habitat. In the Elk River, spotted darters may associate with relatively high velocity areas of run habitats, in part, because of an absence of silt. Kessler & Thorp (1993) reported that spotted darters were not associated with silt-covered substrates, possibly because the substrates may also be used as spawning sites.

Management Implications

Many darters exhibit specific habitat requirements and are often threatened by habitat alterations (e.g.: Connelly et al. 1999, Mattingly and Galat 2002) because habitat specialists have higher vulnerability to habitat alterations. Specialization of habitat use of spotted darters often surpasses that of coexisting species (Kessler & Thorp 1993, Stauffer et al. 1996) thereby allowing spotted darters to be more easily displaced than habitat generalists. Kessler & Thorp (1993) noted that sedimentation reduces the availability of "large, loose, rough substrate" used by spotted darters. Clean cavities under large rocks are important spawning areas for spotted darters (Raney & Lachner 1939). Egg aeration uninhibited by large amounts of sediment is likely an important factor for recruitment. Large rocks also likely act as refuge from predation and velocity shelters (Harding et al. 1998), as spotted darters are observed under these substrates outside of reproductive seasons (Kessler & Thorp 1993).

Sedimentation associated with land use practices threatens darter habitat, including spotted darter habitat, as it fills interstitial spaces (Mattingly and Galat 2002). Within the Elk River watershed, sedimentation results from many sources, including logging, coal mining, and oil and gas extraction (WVDEP[2]) and may threaten spotted darter habitat. Management actions can reduce negative impacts to sensitive darter species such as protection of riparian areas (Jones et al. 1999) or entire watersheds (Freeman and Freeman 1994). Substrate specificity of Elk River spotted darters, supported by our observational study, not only imparts management and conservation implications, but also provides baseline for further experimental studies of spotted darter habitat use.

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[2] West Virginia Department of Environmental Protection (WVDEP). 1997. An Ecological Assessment of the Elk River Watershed. WVDEP, Division of Water Resources, Water Assessment Program website: http://www.wvdep.org/Docs/474_EAoftheElkRvrWatershed.pdf

Acknowledgements

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Tables and Figures

Table 1. Mean values of habitat availability (A) and habitat use (U) of spotted darters listed by site (standard errors in parentheses).

	Site dimensions L*W (m)	use/ available	sample size	depth (cm)	velocity @ 2cm (cm sec^{-1})	Mean velocity (cm sec^{-1})	Substrate size (cm)	Substrate heterogeneity
Run Sites								
Spread	60 x 60	A	56	37.06 (2.92)	14.58 (1.36)	35.78 (2.42)	11.20 (0.55)	6.54 (0.38)
		U	36	47.75 (2.90)	16.38 (1.81)	45.67 (3.11)	15.99 (0.51)	8.35 (0.44)
Ivydale	60 x 16	A	31	35.96 (2.81)	3.85 (0.83)	13.86 (1.36)	14.46 (0.99)	8.65 (0.41)
		U	32	33.29 (1.47)	3.40 (0.68)	16.41 (1.87)	15.93 (0.67)	9.52 (0.35)
Whetstone	53 x 50	A	28	33.09 (3.11)	12.16 (1.52)	31.12 (2.42)	9.85 (0.49)	5.44 (0.35)
		U	26	49.12 (1.37)	12.98 (1.94)	39.68 (1.19)	16.23 (0.76)	8.22 (0.42)
Riffle Sites								
Ivydale	44 x 24	A	28	34.40 (1.29)	17.80 (1.40)	40.41 (2.14)	7.79 (0.30)	4.37 (0.30)
		U	10	37.18 (1.19)	4.30 (1.44)	12.89 (3.06)	12.38 (0.59)	6.57 (0.40)
Whetstone	22 x 52	A	29	26.80 (2.56)	19.20 (2.13)	36.24 (3.09)	10.80 (0.06)	5.92 (0.41)
		U	7	31.78 (3.93)	19.20 (5.47)	51.51 (4.63)	18.17 (1.73)	11.01 (0.83)

Figure 1. Location of sampling sites (●) of spotted darter habitat use within the Elk River of the lower Kanawha River system, West Virginia

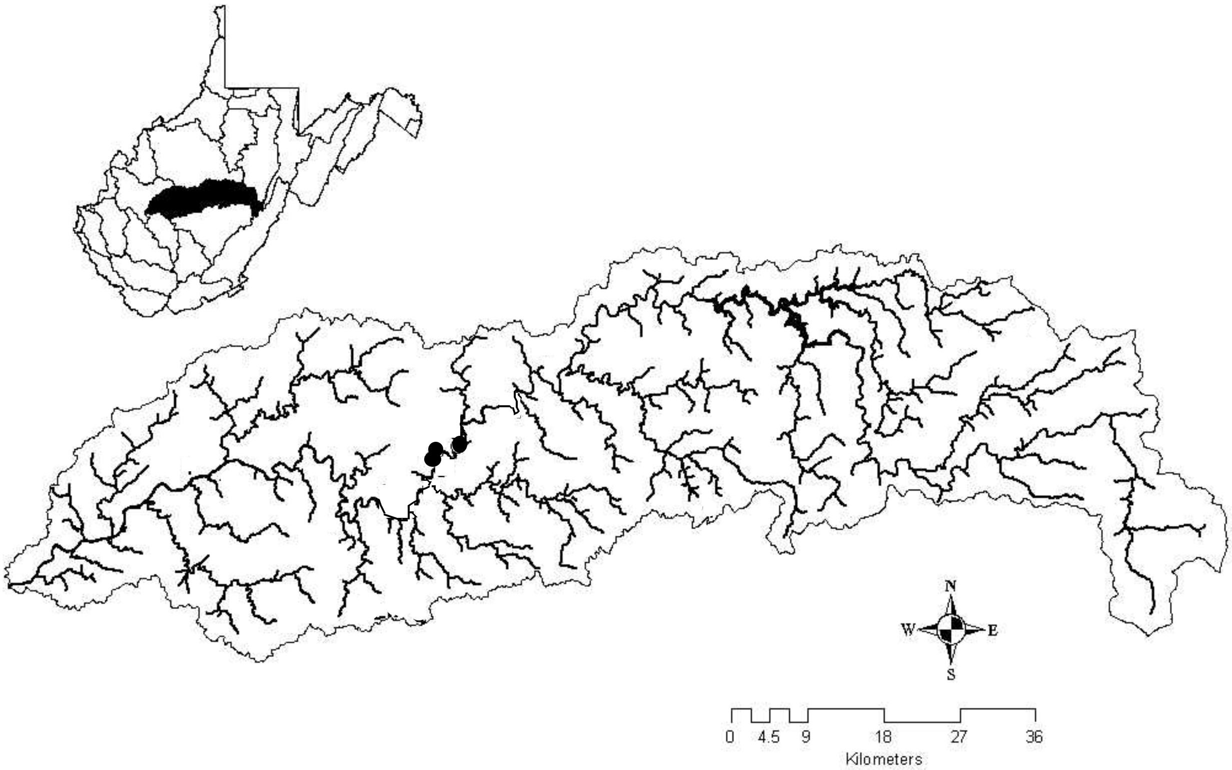


Figure 2. PCA-ordination diagram of habitat availability data from run (0) and riffle (•) habitats.

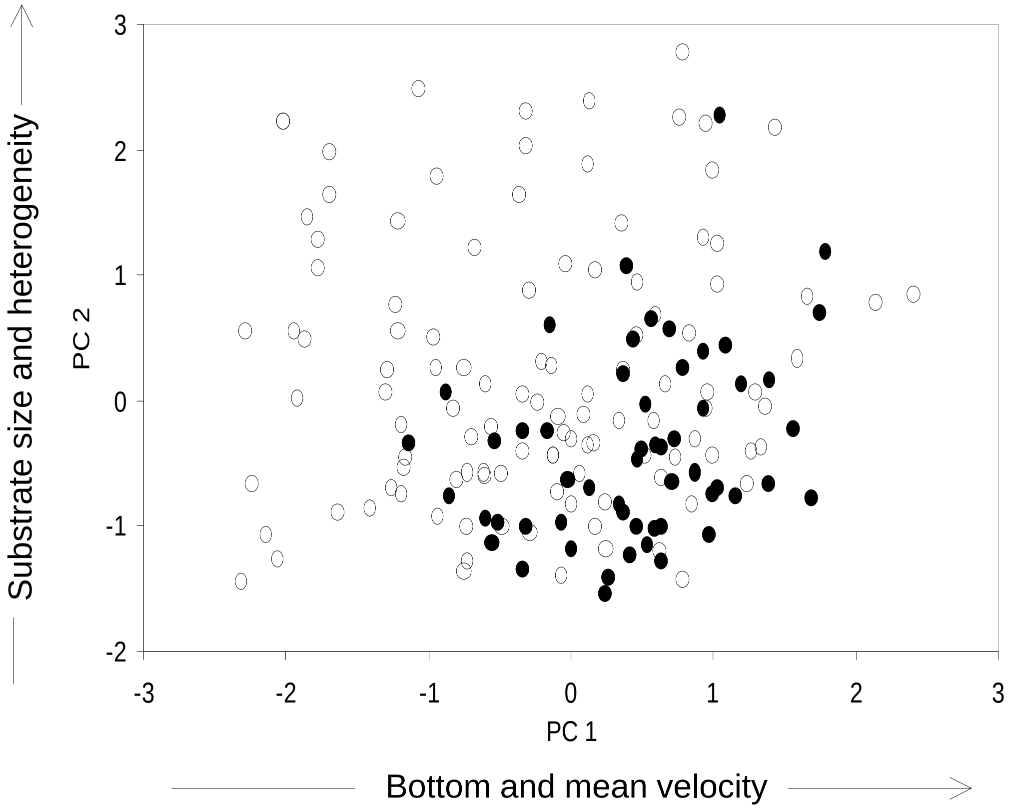


Figure 3. PCA-ordination diagram of habitat availability data from runs; Ivydale (0), Whetstone (•), and Spread (▲).

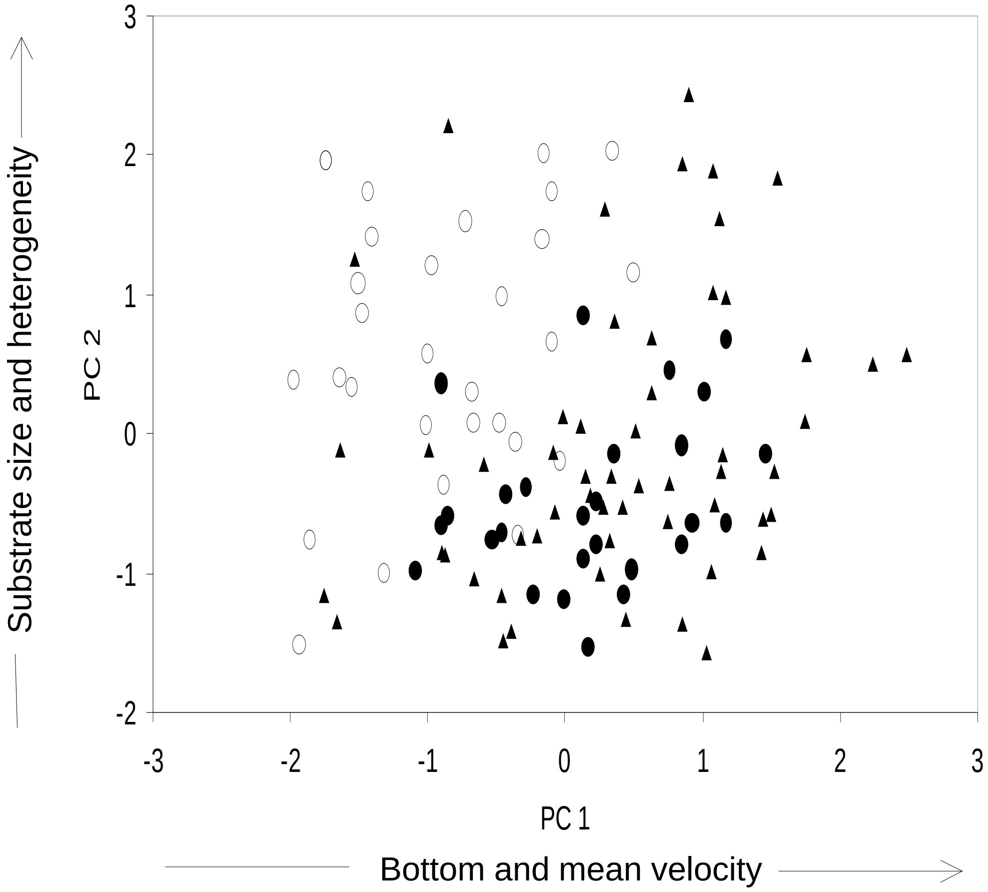


Figure 4. PCA-ordination diagram of habitat availability data from riffles; Ivydale (0), and Whetstone (•).

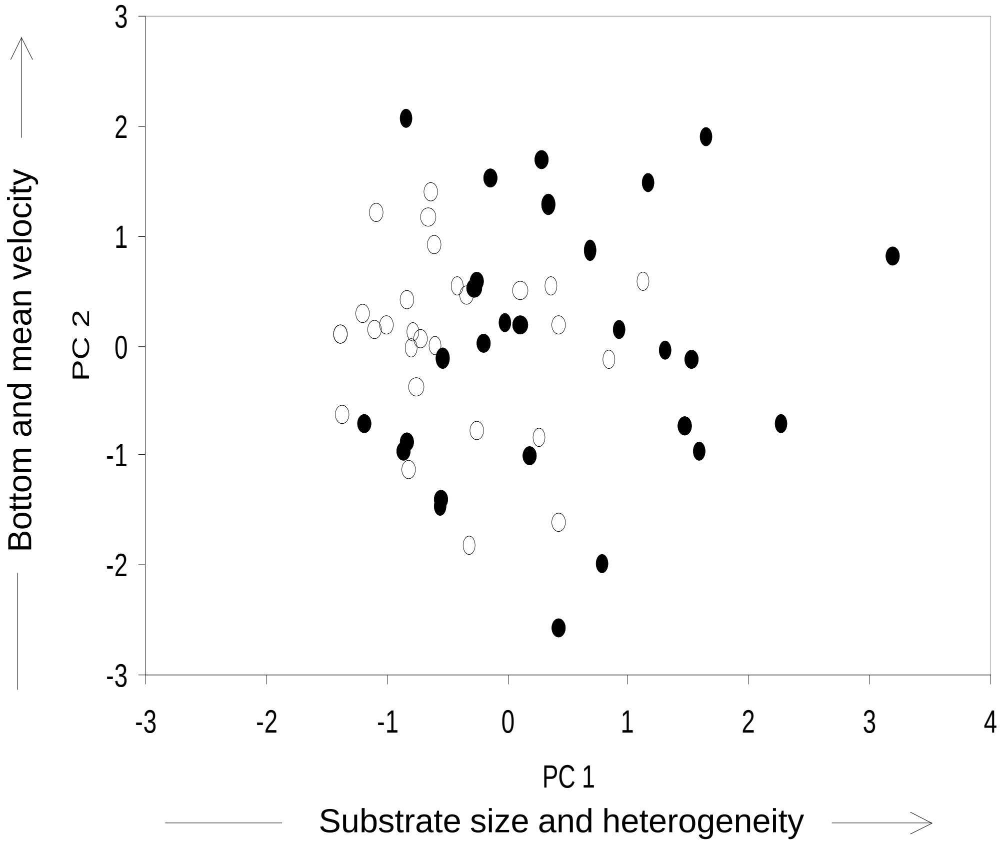


Figure 5. PCA-ordination diagram of habitat use (•) of spotted darters versus habitat availability (0) from the run habitat at Spread, West Virginia.

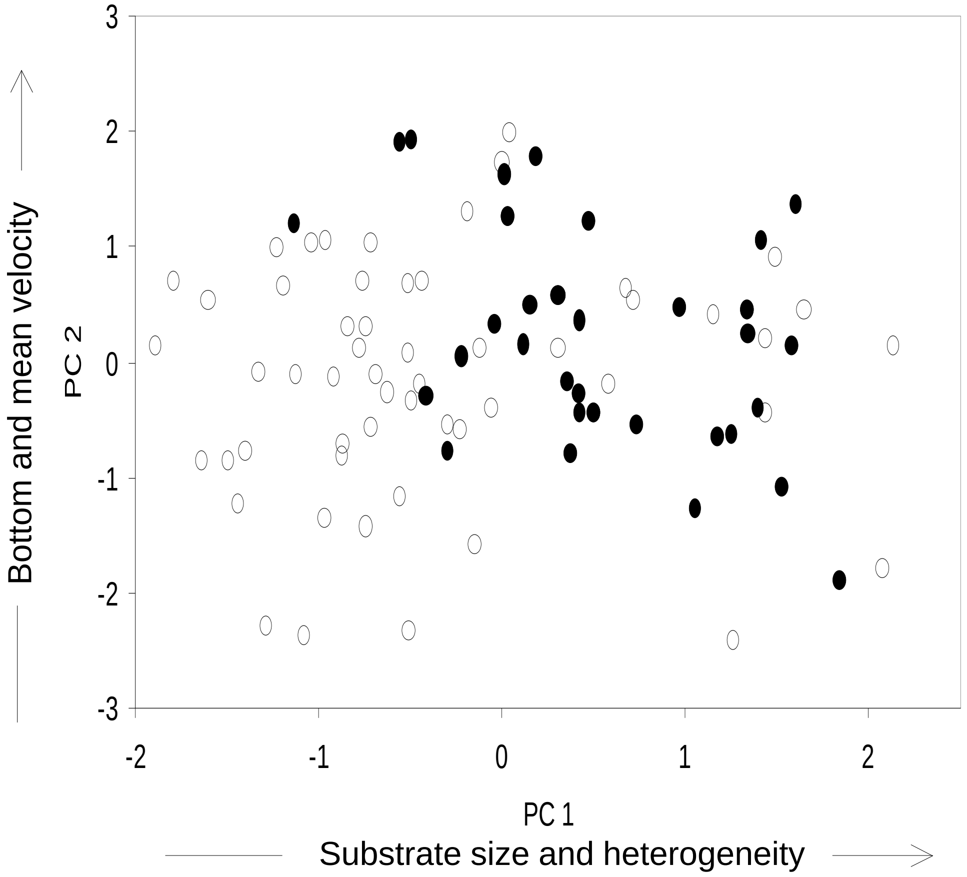


Figure 6. PCA-ordination diagram of habitat use (•) of spotted darters versus habitat availability (0) from the run habitat at Whetstone, West Virginia.

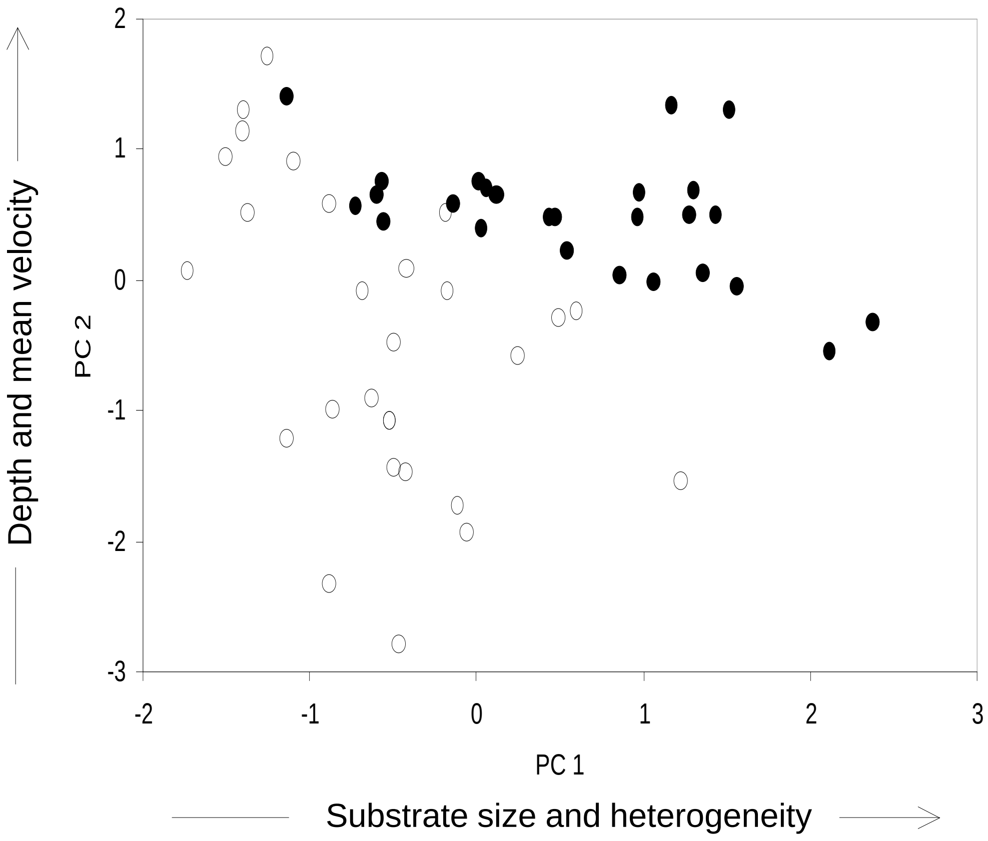


Figure 7. PCA-ordination diagram of habitat use (•) of spotted darters versus habitat availability (0) from the run habitat at Ivydale, West Virginia.

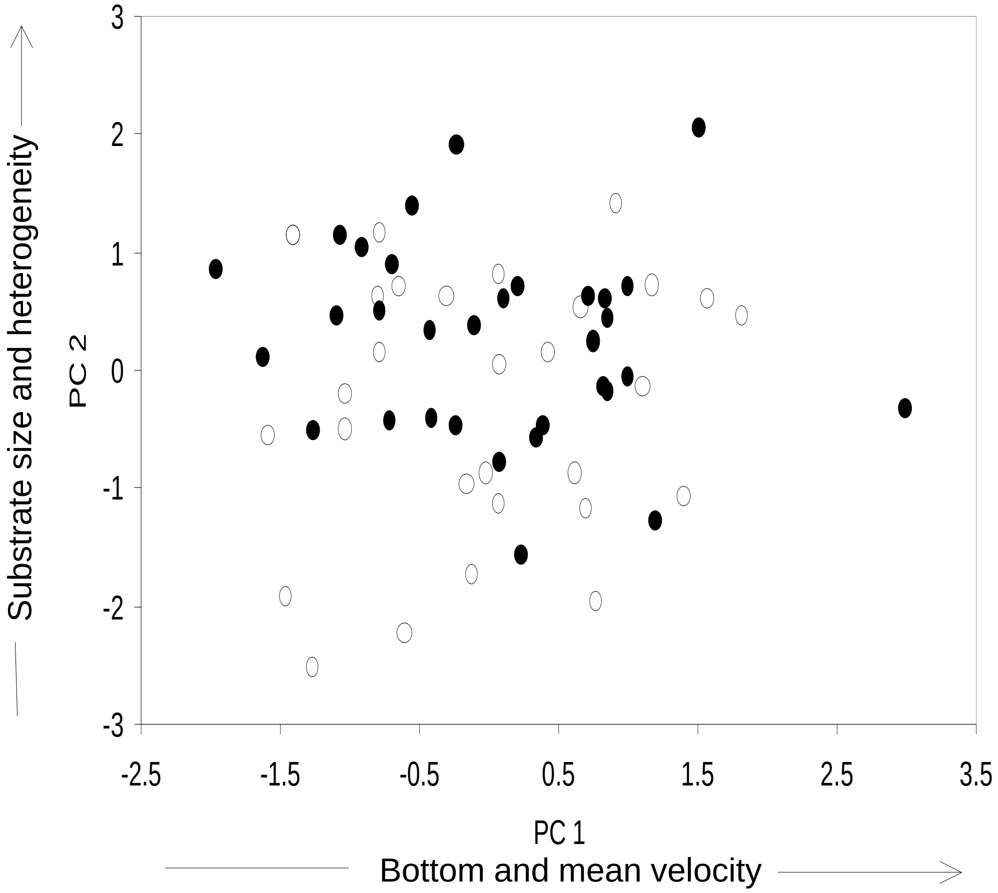


Figure 8. PCA-ordination diagram of habitat use (•) of spotted darters versus habitat availability (0) from the riffle habitat at Whetstone, West Virginia.

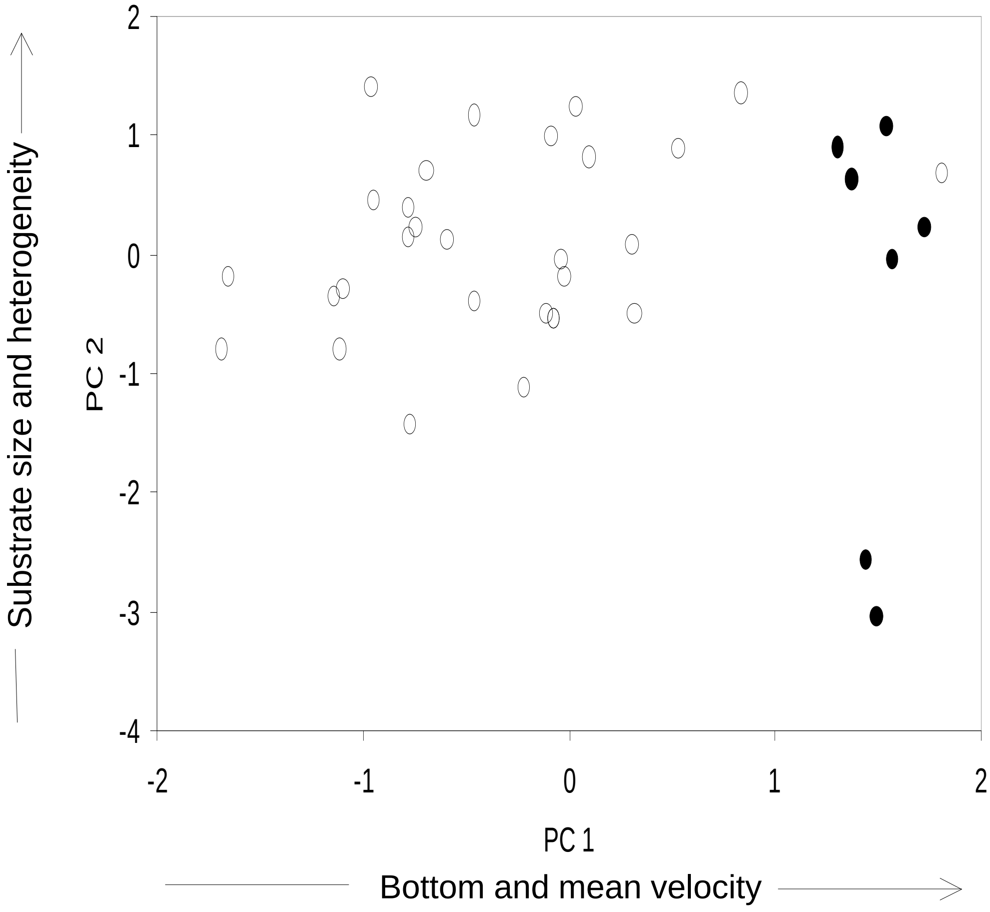
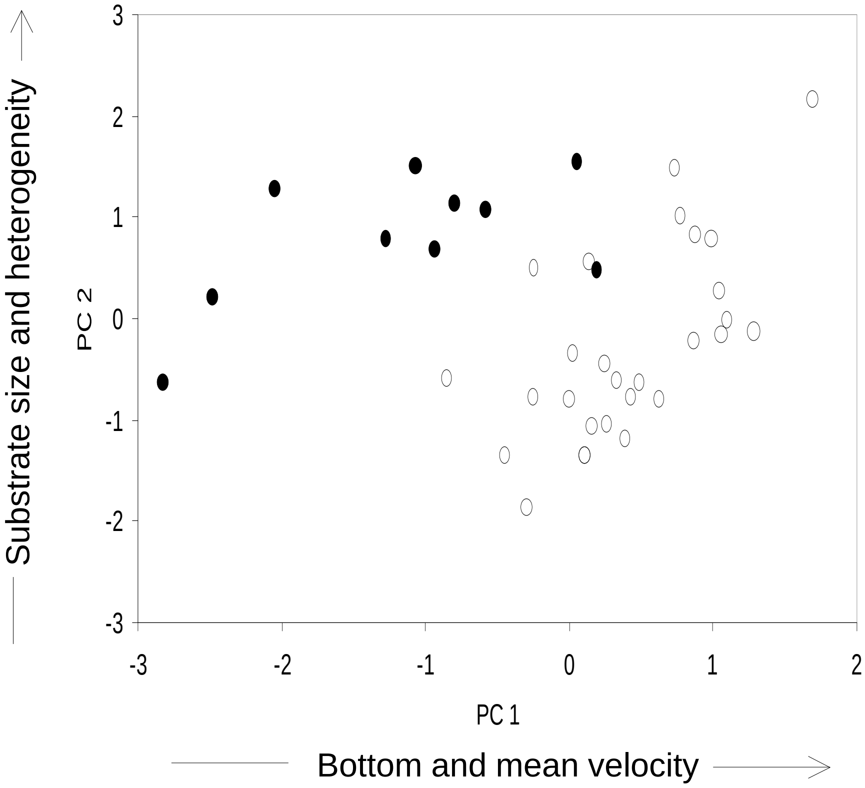


Figure 9. PCA-ordination diagram of habitat use (•) of spotted darters versus habitat availability (0) from the riffle habitat at Ivydale, West Virginia.



Appendix 1. Distribution of extant (circles) and possibly extirpated (square) populations of spotted darters in the Elk River, West Virginia. Open circles depict sites from the habitat use study.