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Resource Utilization and Life History of the Crystal Darter, *Crystallaria asprella* (Jordan), in the Lower Mississippi River, Minnesota

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Abstract

From July 1994 through August 1995, attempts were made to elucidate the life history of crystal darters (*Crystallaria asprella*) in Pools 4, 5, and 5a of the Upper Mississippi River and in the Zumbro River of southeastern Minnesota. Thirty-three collections from 14 sites on 18 dates produced a total of 27 crystal darters, all but two of which were taken from the navigation channel side of Island #36 in Pool 4. Another 9 specimens collected by state biologists from the Mississippi and Zumbro rivers were included in the analyses. One Zumbro River specimen was in its third year of growth and one Pool 4 specimen was in its second growth year when captured; all remaining specimens were young-of-the-year. The full spawning season could not be determined but included at least May and June in the Mississippi River. Growth was rapid with young-of-the-year reaching 80-100 mm total length (65-80 mm standard length) and 3-5 g total body mass by the end of their first growing season. Little energy was used for gonadal development during this time, leaving fall females with gonadosomatic indices of 0.03-0.04 and males with 0.005 or less. All Mississippi River specimens came from channel or channel-margin portions of the river in close proximity to islands where substrata were coarse sand and gravel with 30-40% embedded cobble and boulder and large amounts of dark silt particles. Most individuals occurred in water $\geq$ 1.8 m deep with near-bottom current velocities of 16-22 cm/sec. Two adults and 17 juveniles utilized 11 taxa of insects, 2 taxa of microcrustaceans and 1 taxon of water mites as food. The overall average number of items per stomach was 16.0 but was highly variable (0-80). Only small juveniles utilized microcrustaceans, otherwise both adults and juveniles primarily eat chironomid and hydropsychid larvae. Two hypotheses were developed to explain the extreme rarity of this species in the Upper Mississippi River: 1) crystal darters occur in deeper and swifter water than can be sampled by current techniques and, therefore, only appear to be rare or 2) they are, in fact, rare because navigation controls have reduced current velocities and caused excessive infusion of sand and gravel substrata with silt. These hypotheses need to be tested in the near future.

Introduction

The crystal darter, *Crystallaria asprella* (Jordan), is one of the more enigmatic of our native fish species. Because this darter lives in hard-to-sample areas of large rivers, we know very little about its biology and resource requirements (George et al. 1996) and are uncertain about its abundance historically and at present. Because human activities have greatly altered and degraded most large rivers in which they live (Smith 1971; Craig and Anderson 1991; Lubinski and Gutreuter 1993), we assume crystal darter populations have been adversely impacted, but we have only anecdotal evidence (Miller 1972; Trautman 1981; Kuehne and Barbour 1983; Robison and Buchanan 1988; Etnier and Starnes 1993). We are not even certain of this taxon's phylogenetic affinities (Simons 1991; Etnier and Starnes 1993), and some of its widely spaced, disjunct populations may represent separate species (Mayden et al. 1992). Clearly this is a taxon in need of careful study.

In 1878, David Starr Jordan described crystal darters from an Illinois tributary of the Mississippi River as *Pleurolepis asprellus* (Jordan 1878). In 1882, Jordan and Gilbert reassigned the crystal darter to the genus *Ammocrypta* (Jordan and Gilbert 1882) and finally to the genus *Crystallaria* three years later (Jordan 1885). Reeve Bailey (Bailey et al. 1954) relegated *Crystallaria* to a monotypic subgenus in the genus *Ammocrypta,* reaffirming this change the following year in a systematic study (Bailey and Gosline 1955). In a recent cladistic study, Simons (1991) elevated *Crystallaria* back to generic rank and placed it as the sister group to all other darters. He later subsumed the rest of the *Ammocrypta* species in the genus *Etheostoma* (Simons 1992). Simons' proposals has been accepted by many workers, yet others have called for additional data sets to be tested before accepting his phylogenetic scheme (Etnier and Starnes 1993; Jenkins and Burkhead 1994). Although *Crystallaria* long has been considered monotypic, some suggest it may not be (Mayden et al. 1992).

Since its description in 1878, the crystal darter has been reported from many locations including the Escambia River in the westernmost panhandle of Florida and at the border of Alabama (Gilbert 1992); the Coosa, Tallapoosa, Alabama, Cahaba, upper and lower Tombigbee rivers (Smith-Vaniz 1968), Uphapee and Alamuchee creeks of Alabama (MUSE); the Bogue Chitto, Ouachita and Pearl rivers of Louisiana (Douglas 1974); the Pearl, Tombigbee, Buttahatchie, and Homochitta rivers, Trim Cane Creek and Bayou Pierre of Mississippi (Cook 1959; Page 1983; MUSE); the Little River of Oklahoma (Miller and Robison 1973); the Little, Little Missouri, Ouachita, eastern Saline and lower White rivers (Robison and Buchanan 1988), and Indian Bayou of Arkansas (MUSE); drainage ditches of the Little River Drainage way and the St. Francis, Black, Meramec, Big and Gasconade rivers of Missouri (Pflieger 1971, 1975); the Cumberland and Roaring rivers of Tennessee (Etnier and Starnes 1993); the lower Cumberland (Page 1983), Big South Fork of the Cumberland (Etnier and Starnes 1993), Green and Ohio (at Ironton) rivers of Kentucky (Clay 1975); the Rock, Little Wabash and Wabash rivers, and an unnamed rocky tributary of the Mississippi (the type-locality) in Illinois (Smith 1979); the Wabash River (same as Illinois records) and Laughery Creek of Indiana (Gerking 1945); the Muskingum and Ohio (at Ironton, same as above) rivers in Ohio (Trautman 1981); the lower Wisconsin, lower Trempealeau, Chippewa, lower Red Cedar and lower St. Croix rivers in Wisconsin (Becker 1983; Fago and Hatch 1993); the Zumbro (Eddy and Underhill 1974) and St. Croix (same as Wisconsin records--Fago and Hatch 1993) rivers in Minnesota; and 17 locations in the Upper Mississippi River between pools 11 and 4 (Pitlo et al. 1995). The reference by Kuehne and Barbour (1983) to occurrence in the Perdido River of Florida and Alabama apparently is an error (Gilbert 1992), and crystal darters have not been collected within the borders of Iowa (Harlan et al. 1987). The recent study by Schmidt (1995) provides the most up-to-date information regarding its distribution in Minnesota.

Although clearly widespread at one time, the crystal darter was never shown to be common or abundant anywhere. At present, its most stable populations appear to be in Alabama and Arkansas. Additional, much smaller and rarer populations occur in the Upper Mississippi and St. Croix river boundary waters of Minnesota and Wisconsin. The taxon has not been collected since 1891 in Indiana, 1899 in Ohio, 1901 in Illinois, 1929 in Kentucky, and 1939 in

Tennessee, and it has been accorded endangered, threatened, or special concern status in all other states of occurrence (see citations above).

Until the recent work by George et al. (1996) in the Saline River of Arkansas, no systematic life history study of crystal darters had been reported. Prior to their study, the only age and growth information, which suggested rapid growth and a three-year life span, came from 16 specimens collected in three localities in Wisconsin (Lutterbie 1976). Anecdotal information provided by Becker (1983) suggested our populations may spawn in the spring, perhaps during a brief one-week period (Simon *et al.*, 1992). Spawning has not been observed, but Simon *et al.* (1992) believe a population in the Tallapoosa River, Alabama, spawned over gravel substrate in a "meandering side-channel riffle", which was 60-90 cm deep with a moderate to swift current. During the rest of the year, adults occupied "deeper, swifter riffles of the main channel," and larvae were found in a "small backwater pool." Page (1983), Becker (1983), Trautman (1981), and Miller and Robison (1973) all indicate that the species requires expanses of clean sand and gravel riffles in large rivers as a general habitat, and all but the last suggest that siltation of this habitat is responsible for the species' decline during this century.

We now know at least a small amount about the habitat utilization, age of maturity, ovarian cycle and fecundity of this species in Arkansas, but we know nothing about Minnesota populations. What we know about potential food use by our populations comes from four individuals from two locations in Wisconsin. Together they consumed 6 mayflies, 40 caddisflies, 28 crane flies, 45 black flies, 91 midges, and 3 water scavenger beetles (Becker 1983), which strongly suggests that they actively forage in a variety of habitats and do not remain buried in sand in order to ambush their prey as some have suggested (e.g., Miller and Robison, 1973).

The objectives of the present study were to determine: 1) which microhabitats are used for foraging by juveniles and adults, 2) what food resources are used by juveniles and adults, 3) the age structure of the population and the population's age-specific growth rates, 4) which microhabitats are used for spawning, 5) the age of sexual maturity, and 6) annual fecundity and its relationship to age and body size. Because so few individuals were found and none was in reproductive readiness, objectives 5 and 6 were not accomplished and the remaining objectives were only partially accomplished. In addition to presenting the results of objectives 1-4, this report summarizes in detail all that is known about the ecology of this species and makes specific recommendations about how Minnesota populations might be assessed in future.

Methods

Field Sampling—The study was conducted from 28 July 1994 through 11 August 1995 primarily in lower Pool 4 of the Mississippi River on the navigation channel sides of Hershey Island (Wabasha Co., MN, T110N, R10W, Sec. 34) and Island #36 (Buffalo, WI, T22N, R13W, Sec. 34). Additional collections were made in Pool 5a and the Zumbro River. Sampling was conducted primarily with 3 seines (20 x 1.8 m, 6.4-mm mesh beach seine; 10 x 1.8, 6.4 mm mesh bag seine with #15 chain attached to the lead line of the bag; 6 x 1.2 m, 3.2-mm mesh bag seine). The large bag seine was designed to sample the bottom 1.4 m of the water column in water as deep as 2.7 m. It was attached to 2.6-m poles made of 2.5 cm diameter metal conduit. The poles were pushed down to the bottom and pulled with a pole-vaulting type swimming action in order to move the seine in the direction of the current. This technique was very energy intensive but proved to be the only way crystal darters were recovered from deep water. Boomshocking and trawling with a 10-m otter trawl were also utilized but no crystal darters were captured by these techniques. On one occasion, sampling was conducted at the most promising site (Island #36) from midnight to 0300 hours.

A visual examination of the substrate at the two principal sites was carried out using SCUBA. One or two divers swam two longitudinal (parallel to the current) transects and 3-5 diagonal (cross-current) transects and qualitatively noted the substrates and their lines of discontinuity. A quantitative version of the technique was planned but not employed since viable populations were never found. Depth measurements were taken with a calibrated staff; and temperature (secondary standard thermometer-SCUBA assisted) and flow measurements

(General Oceanics Model 2030 flow meter) were made at near surface, center and near-bottom points in the water column at 2 sites where crystal darters were collected.

On the two occasions that several crystal darters were collected, they were held *in situ* in a flow-through minnow bucket until data collection began. At that point, one darter at a time was placed in a 100 mg/l solution of MS-222 until it lost its ability to maintain an upright (back up, belly down) position—known as the 4th plane or stage of anesthesia in fish (Summerfelt and Smith 1990). Exposure durations ranged from 1-2 minutes. The specimen's standard (SL) and total lengths (TL) were measured to the nearest 0.1 mm with a dial calipers and its total body mass (TBM) was measured to the nearest 0.01 g on a Sartorius digital, battery-powered balance (this measurement required the erection of a 360° windshield). Most specimens had to be returned to the MS-222 solution for 0.5 minutes in order to complete the above measures and the removal of 5-10 key scales. Key scales were taken from the two scale rows above the lateral line just below the junction of the spinous and soft dorsal fins. Another 0.5-1 minute exposure allowed a 24-ml stomach lavage following the procedure described in Appendix Report. Stomach contents were placed in a small, labeled vial of 5% formalin and returned to the laboratory for identification and enumeration.

Laboratory Analyses—Every food item from a stomach specimen was identified to the lowest practical taxon (usually genus, but occasionally family) and its body size measured according to the methods of Culver *et al.* (1985) for microcrustaceans and Smock (1980) for macroinvertebrates. Biomass for each taxon was determined using the length-weight regression equations in the two previously mentioned papers and in Hatch (1982). Food utilization was reported as percentage number and biomass, frequency of occurrence, and size frequency for specimens from Island #36.

Age of specimens was determined using the scale method. Scales were mounted in Sayer's medium on microscope slides and read with the aid of a Bausch and Lomb microprojector using the method of Hatch (1982). Individual growth histories of the two non-young-of-the-year specimens were determined by using the equation: $L_i = (S_i/s)\ (L)$, where L_i is the total length of the darter at the time of the i^{th} annulus formation, S_i is the length of the middle anterior scale radius at the i^{th} annulus (in mm at 150x), s is the length of the middle anterior scale radius at the time of capture, and L is the total length of the darter at the time of capture (Lagler, 1956). Because so few specimens were available the scale radius vs body length regression correction factor for the above equation could not be determined and statistical analyses could not be performed.

Results

Size, Age and Growth--Thirty-three collections from 14 sites on 18 dates produced a total of 27 crystal darters (Table 1). All but two of them came from the navigation channel side of Island #36 (Figure 1). During the study period, six additional specimens—four from Pool 4, 1 from Pool 5 and 1 from Pool 5a—were collected by Minnesota DNR biologists from Lake City. Three other specimens collected by these biologists came from the Zumbro River near Millville, MN, in 1984 and from Pool 4 of the Mississippi River in 1991 and 1993 (Table 1).

All of the specimens collected during the time period of this study were young-of-the-year. Only the 1991 Pool 4 specimen and the 1984 Zumbro River specimen had completed more than one growing season (Table 2). Despite the small number of specimens, it is clear that crystal darters grew very rapidly attaining total lengths of 80-100 mm TL (65-80 mm SL) and total body masses of 3-5 g by the end of their first growing season. Based on the few specimens for which we had measurements, little energy was transferred to gonadal development during that time. The two females reached GSIs (gonadosomatic index = GonM/ABM*100) of 0.03 and 0.04, while the males remained below 0.005. With only two confirmed females, sexual differences in growth could not be inferred.

The growth history (TL) of the oldest fish (Table 2) was 83.2 mm at one year, 123.4 mm at two years and probably close to its length at capture (139.5) at three years. The two-year-old's history was 76.8 mm at one year and probably close to its length at capture (119.2 mm) at two years. Although I could not perform a rigorous validation of the annular marks, the marks were

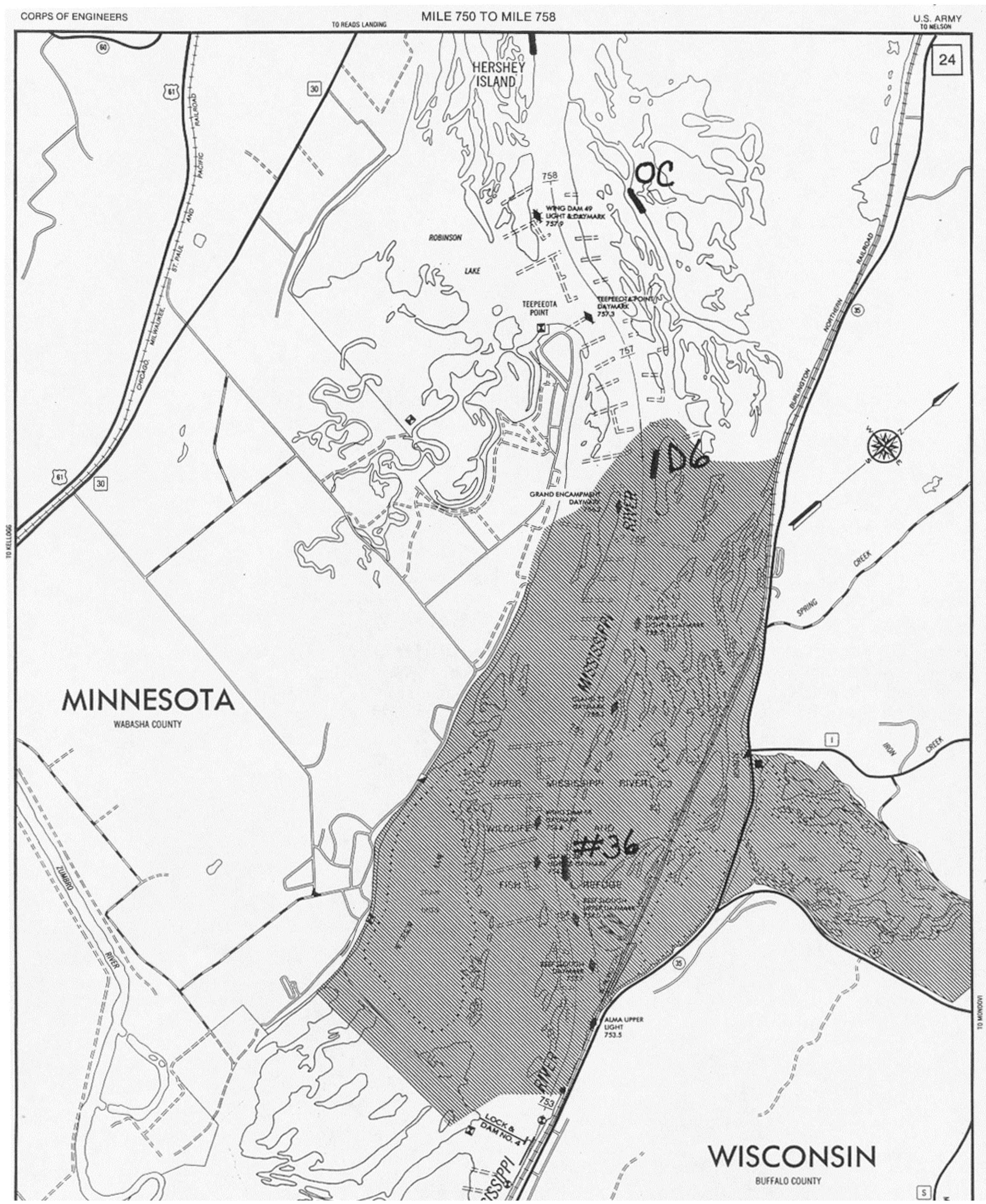

Figure 1. Map showing sites (solid black) where Crystallaria asprella was captured in Pool 4 of the Mississippi River, 1991-1995. These sites were channel-ward of Hershey Island, Island D6, Island #36 and at one off-channel (OC) location. Map is from U.S. Ary Corps of Engineers Upper Mississippi River Navigation Charts, Chart No. 24 (1984).

consistent with what one would hypothesize based on late August young-of-the-year scales, and they were consistent with one another.

Habitat Utilization--All specimens collected directly as a part of this study were found in channel or channel-margin portions of the Mississippi River in close proximity to islands. The substrata in these areas invariably were coarse sand and gravel with 30-40% embedded cobble and boulder (SCUBA qualitative observations). However, all substrata were blackened by large amounts of dark silt particles. Rooted aquatic vegetation was very sparse to absent. Two specimens were taken in water 1.0 m deep, the rest were taken in water ≥ 1.8m. Current velocity appeared moderate to strong in these areas, but measured velocities at the Hershey Island and Island #36 sites suggested these fish experienced only moderate current velocities. Velocities were higher in the shallow water at Island #36 than in the shallow water at Hershey Island, and velocities decreased substantially with depth of the water column at both sites (Table 3). Even these moderate velocities forced sampling (seines or trawls) to cover large areas so that locations of darters could only be attributed to depth contours rather than smaller areal extents.

Six hours (1.5 hrs nighttime) of SCUBA exploration on 5 dates at the Island #36 site produced zero occurrences of crystal darters. Visibility during these explorations was limited to 18-25 cm. Walleye, log perch, white bass and minnows of several species were observed on several occasions, but most of the underwater time produced no fish observations of any kind.

Food Utilization--The stomachs of the Zumbro River specimen and the specimen collected from Hershey Island on 13 October 1994 were empty. The remaining 19 stomachs yielded a total of 314 food items that included 11 taxa of insects, 2 taxa of microcrustaceans and 1 taxon of water mites (Table 4). The overall average number of items per stomach was 16.0 but was highly variable (0-80). Only small juveniles (June 1995 specimens) utilized microcrustaceans and this was true in both pools 4 and 5. Microcrustaceans were an important component of the diet of these animals both in terms of biomass and numbers consumed (Figures 2 and 3). Larvae of midges (Chironomidae) and caddisflies (Hydropsychidae: *Hydropsyche* and *Potomyia*) made up the majority of the diet for most older juveniles (July-October), with the former making a greater numerical contribution (Figure 3) and the latter making a greater biomass contribution (Figure 2). Older juveniles and the one adult (3 September 1991) also consumed substantial numbers of water mites (Hydrachnidae), although the biomass contribution was very small.

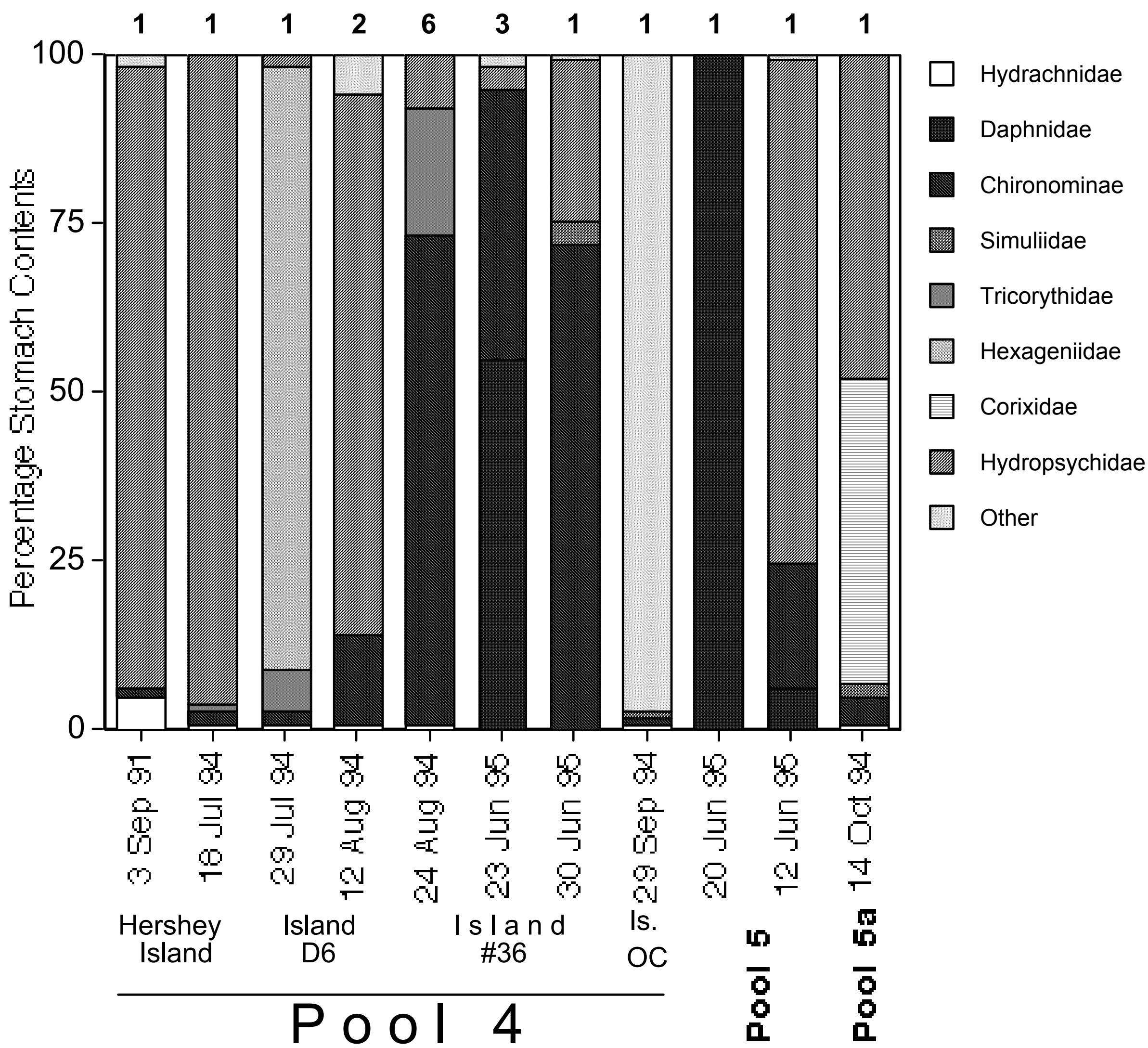

Figure 2. Composition of stomach contents by mass for 19 crystal darters from Pools 4, 5, and 5a of the Mississippi River. Sample size is given above each column.

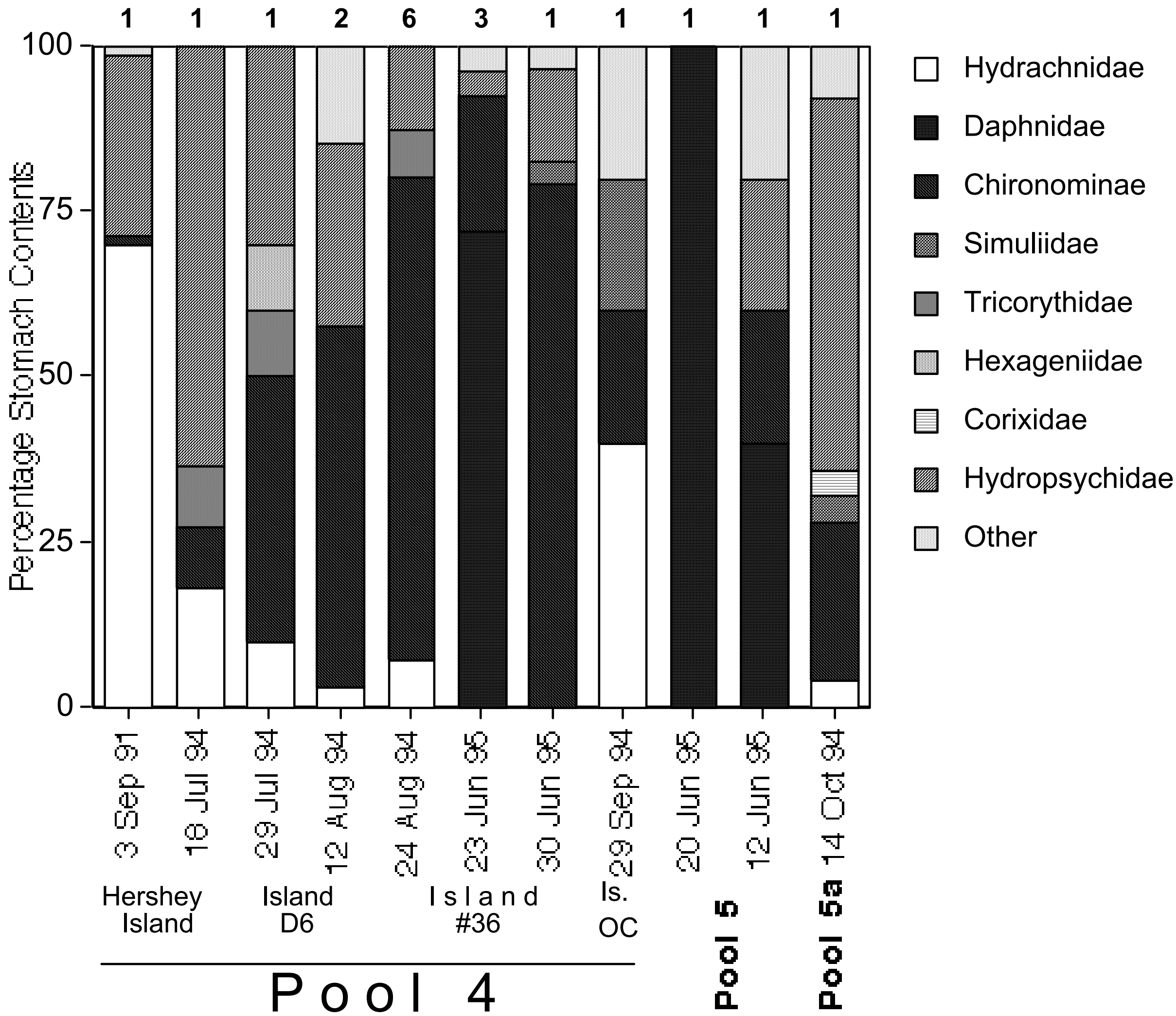

Figure 3. Composition of stomach contents by number for 19 crystal darters from Pools 4, 5, and 5a of the Mississippi River. Sample size is given above each column.

Discussion

Although the data from this study do not permit the usual type of age and growth analysis, it is clear that crystal darters in Pool 4 grew very quickly and reached rather large sizes by August. The mean TL of late August specimens (87.3 mm, N = 13) was similar to Lutterbie's back-calculated size for one-year olds in Wisconsin (86.7 mm, N = 11). The SL range of these same specimens (68.7-80.9 mm) was considerably larger than the young-of-the-year range reported by George et al (1996) for August-caught Saline River specimens (41-52 mm, N = 14). Based on 5 specimens, Lutterbie suggested two- and three-year-olds would reach about 138 mm and 160 mm TL, respectively. In sharp contrast, George et al. (1996) found no three-year-olds in their 1285 specimens, and their 14 late-season (September-November) two-year-olds ranged from 86-97 mm SL. The two older specimens (one from the Zumbro) from this study suggested sizes at age larger than those of the Saline River darters and smaller than those Lutterbie studied (Table 2). With the sample sizes involved, the differences between Minnesota and Wisconsin populations are not meaningful. However, the differences between the pooled MN-WI populations and those of the Saline River are substantial and probably real. The greater longevity, faster growth and larger ultimate size attained by these northern populations may be a reflection either of phenotypic plasticity by a wide-ranging species (variation in life-history tactics *sensu* Wootton 1984) or genetic divergence associated with speciation and a polytypic taxon (Mayden et al. 1992).

Very little can be concluded about reproduction from this study other than young-of-the-year males clearly (and probably females) do no begin a shift to gonadal growth until after October. George et al. (1996) very carefully documented seasonal gonadal development in Saline River males and females; but because of substantial differences in seasonal light periodicity and temperature between Arkansas and here, their work cannot be extrapolated to Minnesota. This study does show that well-developed juveniles (26.2-45.4 m TL) were present in Pools 4, 5 and 5a from 12-30 June in 1995. This observation suggests that some spawning occurred in at least May and June of that year. In the Saline River, crystal darters spawned from

January through April (George et al. 1996). Based on the present study and several others on Minnesota darters (Erickson 1977; Hatch 1982, 1986, 1987; Kollodge and Hatch 1989; Johnson and Hatch 1991), it is likely that the crystal darter exhibits a prolonged spawning season in Minnesota as well.

This study did not capture crystal darters in association with wing dams, but other studies have (Schmidt 1995). In this study, all specimens were found considerably downstream of wing dams in water 1-2 m deep between islands and the river's main navigation channel. On several occasions, it was the seine haul attempted at the deepest, most distant point from an island that produced the only or the most specimens of crystal darters. It may be that one reason so few crystal darters are found in this portion of the Mississippi River is that they occur in habitats that we cannot effectively sample and the only ones we typically encounter are the young or the strays that frequent the habitat that are less deep and less swift. At this time the preceding statement must be viewed as an untested hypothesis.

Another hypothesis that may explain the rarity of this species in the Upper Mississippi River centers on the reduction of current velocity and the increase in small substrate particle deposition associated with navigation controls. The fastest subsurface current measured where crystal darters were taken was 60.8 cm/sec, and the near-bottom velocities were 16.5-37.6 cm/sec. George et al. (1996) report that crystal darters in the Saline River of Arkansas were rarely collected at velocities < 32 cm/sec; they were collected at depths similar to ours (1.14-1.48 m) but at velocities of 46-90 cm/sec. In addition, they report substrata of mostly gravel with some cobble and patches of sand. Others have emphasized that crystal darters occur over silt-free substrata, which includes sand and fine gravel, in fast-flowing rivers (Becker 1983; Page 1983; Robison and Buchanan 1988; Etnier and Starnes 1993). The sand and gravel bottoms sampled in this study were deeply blackened by large amounts of silt infused throughout the substrate. Clay (1975) and Trautman (1981) blamed extirpations of this species on "accumulations of silt."

Perhaps one of the more important outcomes of this study was use of MS-222 as part of a stomach lavage procedure that retrieved stomach items without mortality to the specimens. The 6 lavaged stomachs—all from one date and location—yielded taxa similar to those taken from preserved stomachs collected near the same time. However, the count of 29 total items was quite small compared to numbers coming from stomachs of preserved specimens (Table 4). Although I cannot quantify the efficiency of food item removal in this species, subsequent laboratory experiments with logperch (*Percina caprodes*) suggested that a 70-98% recovery rate is possible in future with the new technique (see Appendix Report). In future studies, it should be possible to develop semi-quantitative food utilization patterns with this lavage technique.

The overall stomach analysis of this study suggests that crystal darters are probably as opportunistic in feeding as most other darter species. Although larvae of midges and hydropsychid caddisflies were the most important food items of older juveniles, watermites and a variety of other immature insects were utilized. Younger, smaller crystal darters relied heavily on microcrustaceans as well as chironomid larvae. The latter pattern in particular suggests an active, mobile search and attack approach to predation. The daphnids consumed are considered crawlers or clingers as opposed to being planktonic. Even if these animals became part of the drift, it is doubtful that small darters could resolve the image of a 1-mm translucent carapace, gage its distance and capture it as it drifted by at 16-37 cm/sec. I believe it is more likely that these darters forage from rock surfaces in a manner similar to that reported for other riffle dwelling species (Hatch 1982, 1985, 1987).

Recommendations

Future work on this species in Minnesota should center on finding areas of high velocity that are associated with and maintain clean substrate and carrying out extensive sampling that can determine the presence or likely absence (absence cannot be proven) of crystal darters. It is possible that these conditions are met further out from channel islands in deeper water than was sampled in this study. If so, it will be necessary to develop a new sampling technique that can be effective in deep (> 2.5 m), fast-flowing (> 60 cm/sec) water.

Judging from the work by George et al. (1996) and Lutterbie (1976), it would be useful to locate all preserved Minnesota specimens and extract whatever age, growth, food use and reproductive condition information from as many as possible.

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Table 1. Sites where sampling was conducted for *Crystallaria asprella*, 1994-1995. River miles in the Mississippi River are taken from U.S. Army Corps of Engineers Upper Mississippi River Navigation Charts.

Location	Collection number	Date sampled	Number of samples	Number of darters found
Mississippi River, Pool 4	JH94012	13 Oct 1994	2	1
Hershey Island, navigation channel side	JH95026	8 Jul 1995	1	0
south of Marina in Wabasha, MN, river mile 758.8	JH95029	21 Jul 1995	1	0
Wabash Co., T111N R10W Sec. 27-28				
Mississippi River, Pool 4	JH94010	13 Oct 1994	1	0
island immediately downstrm of Hershey Island,				
navigation channel side, river mile 758				
south of Marina in Wabasha, MN				
Wabash Co., T111N R10W Sec. 34				
Mississippi River, Pool 4	JH94013	13 Oct 1994	1	0
dredge spoil island downstrm of Hersey Island	JH95028	21 Jul 1995	1	0
and at east edge of navigation channel side,				
WI side, river mile 757.5				
Buffalo Co., T22N R13W Sec.20				
Mississippi River, Pool 4	JH94007	17 Aug 1994	1	7
Island No. 36 west of Alma Marina, Alma, WI	JH94008	24 Aug 1994	1	13
at east edge of navigation channel, river mile 754.4	JH94009	13 Oct 1994	1	0
Buffalo Co., T22N R13W Sec.35	JH95014	2 May 1995	1	0
	JH95018	30 May 1995	1	0
	JH95019	2 Jun 1995	1	0
	JH95023	21 Jun 1995	1	3
	JH95024	29 Jun 1995	1	0
	JH95025	30 Jun 1995	1	1
	JH95027	21 Jul 1995	1	0
	JH95035	11 Aug 1995	1	1
	JH95036	18 Aug 1995	1	0
Mississippi River, Pool 4	JH94005	17 Aug 1994	1	0
city beach at Alma Marina, Alma, WI				
river mile 754				
Buffalo Co., T22N R13W Sec.35				
Mississippi River, Pool 4	JH94003	11 Aug 1994	1	0
third set of islands upstrm of Lock and Dam 4				
at the east edge of Peterson Lake, river mile 754				
Wabash Co., T110N R09W Sec.18				
Mississippi River, Pool 4	JH94004	11 Aug 1994	1	0
first 3 islands upstrm of Lock and Dam 4	JH94006	17 Aug 1994	1	0
at the west edge of navigation channel, river mile 753.6				
Wabash Co., T110N R09W Sec. 17, 18				

Table 1 (continued).

Location	Collection number	Date sampled	Number of samples	Number of darters found
Mississippi River, Pool 5a Island No. 58 and WI side of navigation channel, river mile 734.8-732.2 Winona Co., T108N R08W Sec.26	JH94014 JH94015	14 Oct 1994	2	0
Mississippi River, Pool 5a first island downstrm from Island No. 58 navigation channel side, river mile 733.9 Winona Co., T108N R08W Sec.26	JH94016	14 Oct 1994	1	1
Mississippi River, Pool 5a Island No. 64, navigation channel side, river mile 732.5 Winona Co., T108N R07W Sec.30	JH94017	14 Oct 1994	1	0
Zumbro River 3 mi SE Mazeppa along cty rd 7 Wabasha Co., T109N R14W Sec 15	JH95030	26 Jul 1995	1	0
Zumbro River Millville city park canoe landing Wabasha Co., T109N R12W Sec 18	JH94018 JH95031	21 Oct 1994 26 Jul 1995	1 1	0 0
Zumbro River near Dumfries, mouth of Trout Brook Wabasha Co., T110N R11W Sec 14	JH94019	21 Oct 1994	1	0
Zumbro River near Kellogg, from old Hwy 61 to 3/4 mi. downstrm Wabasha Co., T110N R10W Sec 22, 23	JH94001 JH94002	28 Jul 1994	2	0

Table 2. Total length (TL), standard length (SL), total body mass (TBM), adjusted body mass (ABM), gonadal mass (GonM) and age of crystal darters from Pools 4, 5, and 5a of the Mississippi River, 1991-1995, and the Zumbro River, 1984.

Capture date		Sex	TL (mm)	SL (mm)	TBM (g)	ABM (g)	GonM (g)	Number of annuli	Measured in field	Measured in lab
				Zumbro River						
1984	20 Aug	F	139.5	124.8	12.52	11.34	0.0602	2		√
				Mississippi River						
1991	3 Sep	M	119.2	103.5	8.44	7.66	0.0001	1		√
1993	29 Jul	?	54.1	46.2	0.85	0.70	-.-	0		√
1994	18 Jul	M	67.2	58.4	1.91	1.59	0.0001	0		√
1994	12 Aug	F	84.1	71.3	3.48	3.02	0.0010	0		√
1994	12 Aug	M	76.5	66.5	2.80	2.48	0.0001	0		√
1994	17 Aug	?	90.6	77.1	3.89	-.-	-.-	0	√	
1994	17 Aug	?	80.4	70.2	3.56	-.-	-.-	0	√	
1994	17 Aug	?	88.5	76.2	3.86	-.-	-.-	0	√	
1994	17 Aug	?	90.6	78.5	3.88	-.-	-.-	0	√	
1994	17 Aug	?	88.1	76.8	3.75	-.-	-.-	0	√	
1994	17 Aug	?	87.5	74.9	3.70	-.-	-.-	0	√	
1994	17 Aug	?	87.1	73.8	3.54	-.-	-.-	0	√	
1994	24 Aug	?	84.0	72.8	3.49	-.-	-.-	0	√	
1994	24 Aug	?	89.5	78.0	3.63	-.-	-.-	0	√	
1994	24 Aug	?	97.7	75.9	3.50	-.-	-.-	0	√	
1994	24 Aug	?	94.0	80.9	4.13	-.-	-.-	0	√	
1994	24 Aug	?	79.6	68.7	2.40	-.-	-.-	0	√	
1994	24 Aug	?	86.6	74.4	3.78	-.-	-.-	0	√	
1994	24 Aug	?	86.5	74.8	3.27	-.-	-.-	0	√	
1994	24 Aug	?	87.8	73.8	3.45	-.-	-.-	0	√	
1994	24 Aug	?	86.4	74.0	3.03	-.-	-.-	0	√	
1994	24 Aug	?	84.4	72.9	3.03	-.-	-.-	0	√	
1994	24 Aug	?	85.9	73.8	3.12	-.-	-.-	0	√	
1994	24 Aug	?	90.0	77.2	3.87	-.-	-.-	0	√	
1994	24 Aug	?	83.1	72.9	3.23	-.-	-.-	0	√	
1994	29 Sep	F	88.5	75.4	3.61	3.16	0.0012	0		√
1994	13 Oct	M	99.2	84.5	4.95	4.44	0.0001	0		√
1994	14 Oct	M	90.8	78.4	4.19	3.60	0.0001	0		√
1995	12 Jun	?	26.2	22.1		0.04	-.-	0		√
1995	20 Jun	?	33.2	27.8		0.10	-.-	0		√
1995	23 Jun	M	37.4	31.9	0.28	0.25	<0.0001	0		√
1995	23 Jun	M	33.4	27.7	0.20	0.16	<0.0001	0		√
1995	23 Jun	M	27.6	23.3	0.10	0.08	<0.0001	0		√
1995	30 Jun	M	45.4	38.1	0.47	0.41	<0.0001	0		√
1995	11 Aug	?	78.0	67.0	2.34	2.03	-.-	0		√

Table 3. Velocities measured at three relative depths at Hershey Island and Island #36 in the habitat from which crystal darters were collected.

Site/date	Maximum water column depth (m)	Relative depth of measure	Velocity (cm/sec) range	mean	2SE
Hershey Island	1.0	15 cm below surface	45.8 - 50.2	48.7	2.0
8 July 1995		midwater	35.6 - 39.9	38.7	2.1
		15 cm above bottom	30.9 - 37.6	35.0	2.9
Island #36	2.0	15 cm below surface	29.9 - 32.8	31.1	1.7
24 August 1994		midwater	- -	-.-	-.-
		15 cm above bottom	16.4 - 21.8	18.6	3.3
Island #36	1.5	15 cm below surface	57.9 - 60.8	59.4	1.4
18 August 1995		midwater	52.4 - 56.7	55.1	2.0
		15 cm above bottom	- -	-.-	-.-

Table 4. Food items in the stomachs of 19 crystal darters from Pools 4, 5, and 5a of the Mississippi River, 1991-1995.

Taxon	Hershey Island		Island D6		Island #36			Is.OC	Pool 5	Pool 5a	
	3 Sep 91	18 Jul 94	29 Jul 93	12 Aug 94	24 Aug 94	23 Jun 95	30 Jun 95	29 Sep 94	20 Jun 95	14 Oct 94	12 Jun 95
Acari											
Hydrachnidae	56	2	1	2	2			2		1	
Cladocera											
Daphnidae						16			2		1
Leptadora sp.						1			1		
Diptera											
Antocha sp.										1	
Ceratopogonidae				8							
Chironominae	1	1	4	58	20	6	23	1	1	6	
Simuliidae							1	1		1	
Ephemeroptera											
Baetis sp.	1			3			1			1	
Hexagenia sp.			1								
Tricorythodes sp.		1	1		2						
Hemiptera											
Corixidae										1	
Ondonata											
Stylurus sp.								1			
Trichoptera											
Hydropsyche sp.	5	7	3	6	5	1	1		1	1	
Potomyia sp.	17			18			3			13	
Total food items	80	11	10	95	29*	24	29	5	5	25	1
No. stomachs	1	1	1	2	6	3	1	1	1	1	1

*Items recovered by stomach lavage