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ABSTRACT

The Striated Darter, *Etheostoma (Catonotus) striatulum*, is a rare percid whose known range is restricted to 15 streams in the mid-to-upper Duck River system, Tennessee. The last rangewide assessment of its conservation status occurred in 1992, a survey which yielded only 26 specimens. In June-July 2006 we reevaluated the darter's population status and characterized its habitat by surveying 30 reaches in 22 streams. Striated Darters were detected in 11 of 30 reaches with a total of 102 individuals observed; 78 were young-of-year juveniles and 24 were adults. In late July total lengths ranged 19-31 mm (mean = 24 mm) for juveniles and 39-49 mm (mean = 43 mm) for adults, with only two age classes indicated. Several new occupied reaches were identified in streams where the darter had been collected previously; however, four historically occupied reaches, including the type locality, failed to produce specimens. At one of the better sites, a mark-recapture experiment revealed a population estimate of 136 Striated Darters per 100 m at a density of 0.14 individuals per m^2. The 11 occupied reaches had the following mean characteristics: elevation 215 m above sea level, stream order 4.3, link magnitude 65, riparian zone width 11 m, wetted channel width 11 m, mid-channel depth 25 cm, discharge 0.01 m^3/s, water temperature 26 C, pH 8.0, and conductivity 247 µS. On average, approximately one-fourth of the bottom surface of runs and pools was covered with broken slabrock substrate in the 11 occupied reaches. The number of individuals of other *Catonotus* species (*E. flabellare*, *E. crossopterum* and *E. nigripinne*) observed in occupied reaches was highly variable but averaged 53 individuals per reach. Environmental characteristics of occupied reaches were not significantly different from those of unoccupied reaches, at least for variables measured in this study. Our results highlight a species with limited distribution and abundance, a short lifespan, and whose status parallels that of other imperiled *Catonotus* species.

INTRODUCTION

The Striated Darter, *Etheostoma striatulum* Page & Braasch, is a small *Catonotus* darter of the *E. virgatum* group found within the Nashville Basin physiographic region in Tennessee (Fig. 1). The darter's known range spans parts of the mid-to-upper Duck River drainage in Bedford, Coffee, Lewis, Marshall, and Maury counties, with occurrence records in only 15 streams (Page and Braasch, 1977; Page, 1980; Cook et al., 1996). Other *Catonotus* species found in the drainage include *E. flabellare*, *E. smithi*, *E. crossopterum* and *E. nigripinne* (Etnier and Starnes, 1994).

Etheostoma striatulum is a small-bodied darter that reaches a recorded maximum standard length of 47 mm (Cook et al., 1996). It is considered to be an annual species, with the oldest observed specimen in Page's (1980) life history study aged at 17 months (a female). Page (1980) observed that all April-collected males were one year old and in spawning condition. He also documented rapid growth, with males and females reaching half of their maximum body size in the first three months of life.

Little is known about the Striated Darter's population status and environmental associations due to the paucity of research conducted on the species since its formal description 30+ years ago. Page and Braasch (1977) examined 89 specimens when describing the species, and Page's (1980) life history study utilized 191 individuals harvested over a two-year period, December 1976 to January 1979. Cook et al. (1996) conducted a status survey in 1992 encompassing all known historical collection localities. Only 26 specimens were collected from a total of 10 sites, illustrating Page's (1980) belief that the darter was a "generally uncommon" species. Further, Etnier and Starnes (1994) noted that their collection efforts at several historic sites had produced no additional specimens.

Anthropogenic disturbances in the Duck River system are likely affecting the distribution and abundance of what may be a naturally rare species. Tennessee Department of Environment and Conservation (as of 2001) identified 18 "potentially unsafe" and another 13 "impaired" stream segments in the Duck River drainage. Cook et al. (1996) listed the most prevalent threats as stream alterations, runoff from livestock pastureland, and siltation from agricultural practices. In addition, annual species like the Striated Darter are particularly vulnerable to adverse habitat modifications by sudden events such as extreme flow conditions or chemical spills. Such disturbances could conceivably inhibit or prevent spawning in a given year, thereby undermining the viability of local populations. The darter is considered threatened in Tennessee but receives no federal protection.

The few individuals observed within Striated Darter populations, combined with a small geographic range, make this species a prime candidate for implementation of conservation practices. Such implementation will benefit from current information on population status and environmental conditions in Striated Darter streams. Therefore, the objectives of this study were to (1) determine population status of the darter at historic and potential new sites across its range, (2) conduct a population estimate at one occupied site, and (3) relate the darter's presence or absence to environmental variables measured at all sites.

METHODS

Population Status

Thirty, 100-m reaches were sampled during June and July 2006 (Table 1, Fig. 2) with an emphasis on revisiting sites in the Cook et al. (1996) study and new locations that could support Striated Darter populations. Detailed site descriptions and coordinates are provided by Abernathy (2007). Each reach was divided into five, 20-m sections. Most sampling was conducted using seining methods with the exception of four deeper sites where seining was relatively ineffective; these sites (8, 27, 28, and 29) were sampled by snorkeling. The Duck River proper was sampled at Henry Horton State Park (7) although not under the standard seining or snorkeling protocol used at the other 29 sites because of the different stream conditions found in the Duck River mainstem (see Abernathy, 2007).

At the beginning of the survey we compared the relative effectiveness of collecting *Catonotus* darters with seining versus backpack electrofishing at Site 11 in Butler Creek. Seining produced more individuals representing a wider range of body sizes than did electrofishing. We also wanted to avoid potential injuries to darters that might be induced by electrofishing. For these reasons our primary sampling technique was seining.

The standard seining protocol consisted of two persons using short seine hauls while vigorously kicking and disturbing the substrate. The seine dimensions were 1.2 m x 3.0 m and the mesh size was 3.2 mm. All *Catonotus* darters, including the Striated Darter, were removed from the stream, counted, identified to the lowest possible taxonomic level, and placed in separate aerated buckets until sampling in that 20-m section was completed. Our protocol did not include the Cook et al. (1996) "set-kick" seining technique of encircling single slab rocks.

We devised a system to determine how many seine hauls would be conducted in a given reach section. First, the mean width of each 20-m section was obtained by averaging two random wetted channel width measurements taken within the section. Sections that averaged ≤5 m in width were given five seine hauls. The number of seine hauls increased as mean section width increased: a section 6-10 m wide was sampled with 10 seine hauls; 11-15 m wide, 15 seine hauls; 16-20 m wide, 20 seine hauls; and a section 21-25 m wide, 25 seine hauls.

The snorkeling protocol was to thoroughly examine the substrate within the given stream reach. This process consisted of two persons slowly and deliberately moving upstream through the reach in a zigzag fashion. Snorkeling effort ranged from 90—110 min per reach.

Population Estimate

A population estimate was conducted at one site, Flat Creek at Hwy. 64 (Site 2, Table 1, Fig. 2), using the Petersen mark-recapture method on 25-26 July 2006. A pilot study of mark-recapture procedures was conducted at two other sites (13, 15). Population estimate procedures followed Martin et al. (1999) except that block nets were placed at the upstream and downstream boundaries of each site. Striated Darters collected on the first day were anesthetized with 20 mg/L clove oil, marked by cutting a small amount of tissue from the lower portion of their caudal fin, revived in freshwater until normal fin and opercular movement was observed, and then placed back in the stream randomly throughout the 100-m reach. The reach was then resampled 24 h later to count numbers of marked and unmarked Striated Darters. Furthermore, Striated Darters at sites 2, 13, and 15 were measured to the nearest mm total length (TL) on 24-26 July 2006 to enable construction of length-frequency histograms and delineate population age-class structure.

Population estimates were established for both age-0 (<32 mm TL) and age-1+ (>32 mm TL) classes using the formula $N = (MC)/R$, where N = the population estimate, M = number of individuals marked on the first day, C = number of individuals collected on the second day that were not marked on the first day, and R = number of individuals marked on the first day subsequently recaptured on the second day. Striated Darter density was calculated by dividing the population estimate by the surface area of the site; surface area was determined by multiplying the mean width of each 20-m section by its length and summing these five areas. An estimate of seining gear efficiency was obtained by dividing initial catch on the first day by the population estimate (N) calculated for the site.

Environmental Variables

Striated Darter presence or absence was related to 12 environmental variables measured at the 30 sites. Elevation, stream order, and link magnitude (Osborne and Wiley, 1992), were determined using contour lines on U.S. Geological Survey topographic maps (1:24,000 scale) and Maptech software (Terrain Navigator, version 6.02); only perennial streams were included when calculating stream order and link magnitude. Riparian zone width (RZW) was evaluated by visually estimating the extent of woody vegetation on both sides of the stream to generate an average one-side-only RZW; tape measurements were taken occasionally to check visual estimates. Mean mid-channel depth was determined by taking three mid-channel readings per 20-m section (no redundant readings) and averaging the 15 values; mean wetted channel width was obtained by averaging two channel widths per 20-m section as described above for "Population Status". Discharge was measured once per reach using a Marsh-McBirney Flo-Mate 2000 and top-setting wading rod (McMahon et al., 1996). Water temperature and conductivity were measured with a YSI Model 85 meter, and pH was measured with an Oakton Instruments pH Testr 3+ meter.

The amount of microhabitat available for Striated Darters was ranked categorically for each 20-m section in a reach; these five ranks were then averaged to generate a single index of available microhabitat for each reach. Microhabitat categories were based on visual estimates of the percent of loose stone microhabitat present in runs and pools within the section (riffle areas were excluded). Category ranks were: 0 = <5% available stone habitat; 1 = 6-25% available habitat; 2 = 26-50% available habitat; 3 = 51-75% available habitat; and 4 = 76-100% available habitat. The accuracy of the visual-estimation method was checked in early August 2006 at two representative sites outside the suite of sites canvassed in this study.

Other *Catonotus* species collected in the study reaches were handled in the same manner as the Striated Darter. Individuals were classified as "unknown spottails" if they were *E. crossopterum* or *E. nigripinne* because distinguishing non-nuptial individuals of these two species can be very difficult (see Page et al., 1992). Abundance of other *Catonotus* was calculated by summing the number of spottails (*E. crossopterum* and/or *E. nigripinne*) plus *E. flabellare* to generate a total per 100-m reach.

Statistical Analysis

Frequency histograms were constructed separately for reaches where Striated Darters were present versus reaches where they were absent by breaking continuous environmental variables into discrete intervals, or by following existing intervals for categorical variables. Each environmental variable was analyzed using Fisher's Exact Test in SAS version 8.2 (SAS Institute, 1995) to determine whether frequency distributions of presence versus absence reaches differed from one another. For all statistical analyses, = 0.1.

RESULTS

Population Status

The Striated Darter was present at 10 of 26 seining reaches and one of four snorkeling reaches (Table 1, Fig. 2). The darter's continued presence was confirmed at six of the 10 occupied sites identified by Cook et al. (1996) in their 1992 survey; however, it was not found in four previously occupied sites including the type locality (1, 6, 7, 8). The darter was found in five reaches (13, 14, 15, 22, 27) in 2006 that were not sampled in 1992. Sites 13, 14 and 15 were new location records in streams known to be inhabited elsewhere by the species in 1992 (Fig. 2). Striated Darters were collected in Alexander Creek in 1937 and Noah Fork in 1962; our sampling at sites 22 and 27 reaffirmed their presence in these streams, albeit at different locations than the historic records.

One hundred and two Striated Darters were collected in the 11 occupied reaches (Table 1); 78 of these individuals were young-of-the-year juveniles <32 mm TL and 24 were considered age-1+ adults, yielding a juvenile-to-adult ratio of 3.3 to 1 (this ratio was heavily influenced by 42 juveniles observed at Site 13). Length-frequency analysis in late July confirmed a distinct separation between the two age classes (Fig. 3). Age-0 juveniles (N = 88) at three sites averaged 23.5 ± 4.9 mm TL and ranged 19—31 mm TL, while age-1+ adults (N = 35) averaged 42.8 ± 1.7 mm TL and ranged 39—49 mm TL. The juvenile-to-adult ratio at these three sites was 2.5 to 1, slightly lower than that calculated for the wider survey.

Population Estimate

In Flat Creek (Site 2), 14 individuals were collected and 13 were marked on the first day, and 21 individuals were collected on the second day with two of these being recaptures (one juvenile and one adult). The population estimate for both age classes combined was 136 Striated Darters per 100 m at a density of 0.14 individuals per m^2. Population estimates for age 0 and age 1+ individuals per 100 m were 32 and 117 individuals, respectively. Seining gear efficiency at Site 2 was 10%, indicating that only one in 10 Striated Darters was vulnerable to the gear at this particular site.

Environmental Variables

The 11 reaches occupied by Striated Darters had the following mean characteristics: elevation 215 m above sea level, stream order 4.3, link magnitude 65, riparian zone width 11 m, wetted channel width 11 m, mid-channel depth 25 cm, discharge 0.01 m^3/s, water temperature 26 C, pH 8.0, and conductivity 247 µS (Table 2). On average, approximately one-fourth of the bottom surface of runs and pools was covered with broken slabrock substrate in occupied reaches (mean index of available microhabitat was 1.5). The number of individuals of other *Catonotus* species observed in occupied reaches was highly variable but averaged 53 individuals per reach.

Environmental characteristics of occupied reaches were not significantly different from those of unoccupied reaches (Table 2; Fisher's Exact Test; all $P \geq 0.20$). Frequency distributions for most variables associated with Striated Darter presence mimicked those associated with darter absence.

DISCUSSION

Population Status

Our study represents the first rangewide assessment of Striated Darter populations using a standardized protocol at sites of fixed length (100 m). As such, our data provide a numerical baseline at 25 seined sites to which future population monitoring data can be compared. The previous survey in 1992 by Cook et al. (1996) differed from our survey in a number of ways. First, Cook et al. surveyed during May, July, and October whereas we sampled in June and July. Second, Cook et al. used an unspecified mixture of set-kicks and standard seine hauls, whereas we used only the latter. A set-kick involved placing the seine around a single slab rock, lifting the slab with two persons kicking the substrate, thereby "chasing" the fish into the net. The set-kick technique specifically targeted a habitat feature presumed likely to yield Striated Darters: slab rocks over bedrock. Third, Cook et al. did not standardize sampling effort at each site. For example, the number of set-kicks and seine hauls (collectively termed "attempts") in their survey varied from 1 to 25 attempts at the ten sites occupied by the darter. Finally, Cook et al. did not estimate the efficiency of their sampling methods. We found our seining efficiency to be 10% (determined from data at a single site) which suggests a fairly high probability that Striated Darters went undetected at one or more sites where they were actually present in low numbers.

Despite the differences between the 1992 and 2006 surveys, some broad patterns in Striated Darter population status are apparent. In both surveys Striated Darter presence was confirmed at only 10-11 stream reaches and only 24-26 adults were observed (assuming the 26 specimens reported by Cook et al. were adults). The species is clearly a rare fish with a limited range and we concur with Etnier and Starnes (1994) and Cook et al. (1996) that Striated Darter populations are quite vulnerable to depletion or extirpation.

Six of the 10 sites where Cook et al. (1996) found Striated Darters produced individuals during our survey (Fig. 2). Only one of these six sites, however, yielded >10 individuals (Site 9). This reach of Flat Creek provided ample habitat conditions for Striated Darters. Most of the 16 individuals were collected around pool margins, often where broken slabrock was found abutting *Justicia* sp. beds. Upstream of Site 9 in Flat Creek, Site 13 produced the three highest Striated Darter counts seen in this study. Three separate sampling events produced 44, 57, and 152 Striated Darters (the latter two counts were obtained during the population estimate pilot study). This site contained very little broken slabrock and only modest amounts of *Justicia* sp. Most individuals were juveniles collected over open bedrock. Much more of what is perceived to be optimal *Catonotus* habitat (i.e., more broken slabrock present) can be found both upstream and downstream of Site 13.

Three new occurrences were identified in streams known to be inhabited by *E. striatulum* (Sites 13, 14, and 15) and new occurrences were noted for two additional streams, Alexander Creek (22) and Noah Fork (27). Striated Darters had been collected in both streams prior to 1992, yet were not collected during the 1992 survey. The easternmost (Site 27) and westernmost (Site 10) sites where *E. striatulum* was encountered are outliers not only in geography but also geology. These two sites show both Nashville Basin and Highland Rim qualities. Both streams contain more cherty gravel than do the remainder of the streams sampled. Most of the streams sampled within the interior Nashville Basin display a prominently bedrock substrate intermingled with patches of gravel and cobble. Gravel and cobble are much more prevalent in both Noah Fork and West Fork of Bigby Creek. Only one individual Striated Darter was collected at each site. It may be that Striated Darters were never common in either drainage due to habitat restrictions, such as less available loose, broken slabrock over bedrock. It would be interesting to see if more intensive sampling in optimal habitat within these two streams produces more *E. striatulum* specimens. As one proceeds downstream through the Noah Fork and Bigby Creek drainages, the nature of these streams tends to shift from Highland Rim origins towards qualities representative of interior Nashville Basin streams. The focus of Striated Darter studies within these two streams may need to be shifted accordingly.

Population Estimate

Our population estimate of 0.14 Striated Darters per m^2 at Site 2 in Flat Creek was intermediate between the Cook et al. (1996) estimate of 0.04 per m^2 at Site 3 in Hurricane Creek and the Page (1980) estimate of 1.34 per m^2 at Site 1 in Wartrace Creek. The density at Site 1 calculated by Page (1980) was only in the slabrock portion of a large pool at the type locality, and thus probably represents a value near the high end of the range of abundances exhibited by the species.

Through our population estimate we were able to generate a rough estimate of our seining efficiency at Site 2. Future research should examine collecting gear efficiency at multiple sites to better place survey results in context. It will remain important to understand detection probabilities, especially when monitoring population status in upcoming years.

The pilot study conducted at two sites refined the protocol used in the mark-recapture population estimate for this species. A common dose of clove oil at 40 mg/L (e.g., Detar and Mattingly, 2005) was initially used to anesthetize Striated Darters in the pilot study. This dose proved to be too strong for age-0 individuals to recover and age-1+ individuals required increased recovery time (25 min) before being released back into the stream. All of the individuals that failed to recover from anesthesia were juveniles (<32 mm TL). This could be linked to stress due to handling, anesthesia, fin clipping, or any combination thereof. Regardless, it appears that Striated Darters should be handled with care during any subsequent sampling events. The initial clove oil (anesthesia) concentration of 40 mg/L was reduced to 20 mg/L for the actual mark-recapture experiment. The 20 mg/L dose was sufficient for anesthetizing fish while still allowing recovery in a reasonable amount of time.

Environmental Variables

Cook et al. (1996) reported mean stream widths of 11 m at sites occupied by Striated Darters in their 1992 survey, with a range of 5-20 m. We calculated exactly the same average wetted channel width, 11 m, from our 2006 occupied sites, with a similar range of 5-19 m. In 2006 Striated Darters occupied 1 third-order site, 6 fourth-order sites, and 4 fifth-order sites which reflects this range of stream widths. However, the frequency distribution of wetted channel widths at occupied sites did not differ from that of unoccupied sites (Table 2). In fact, none of the reach-scale environmental variables showed a statistically significant difference, suggesting that (1) other reach-scale variables and (2) variables at different spatial scales should be examined in future studies. Increasing sample size to increase statistical power at the reach scale could help determine whether the trend noted for water temperature is a real phenomenon. However, the apparent limited distribution of the species will ultimately limit sample size at the reach scale.

Darters belonging to the subgenus *Catonotus* are believed to require broken slabrock for spawning and/or habitat. Cook et al. (1996) reported that slab rocks occupied by Striated Darters typically averaged 25 by 22 by 5 cm. However, we were unable to identify a link between amount of microhabitat available and the presence or absence of Striated Darters. Striated Darters were collected at sites with an abundance (>50%) of available microhabitat, as well as at sites with apparently insufficient microhabitat. Many sites also contained beds of *Justicia* sp. Although these stands of *Justicia* sp. were not included in scoring for microhabitat categories, a number of Striated Darters were collected in and around these stands.

A larger temporal scale (other months, seasons, years) should be used when examining habitat preferences of the Striated Darter at different stages during its lifetime. Older individuals are believed to be obligated to loose stones for breeding purposes and appear to use them, as well as *Justicia* sp. beds, for non-breeding habitat. Young-of-the-year individuals may not begin to compete with larger adults for habitat until they reach the point where they are competitive or until their diet has shifted to larger prey that are not found over open slabrock. Page (1980) showed that a decrease in the amount of crustaceans consumed by Striated Darters occurred as individuals became larger, and these were subsequently replaced by larger insects, primarily chironomid larvae.

Werner and Gilliam (1984) proposed that such ontogenetic shifts are common in animals where resource use and predation risk are related to body size. Therefore, reaches with characteristics such as Site 13, where 42 of 44 individuals were juveniles collected over open bedrock, may be utilized by Striated Darters prior to adulthood. These smaller individuals are presumably less competitive than adults at acquiring habitat space, use different prey resources, and therefore may occupy different habitat until they reach a point where they can secure their own stones for habitat and/or nesting. It is also possible that these younger individuals may have been dislocated from upstream through a high-water event and subsequently settled in this area. The Striated Darter is believed to be an annual species with the oldest observed individual being 17 months (Page, 1980). Should adults perish during summer or autumn, it is conceivable that younger individuals may move in and occupy the niche space vacated by senescing individuals. In short, no definitive statements can be made regarding microhabitat due to the number of individuals observed away from what is believed to be optimal adult *Catonotus* habitat. Enough individuals were collected near emergent stands of *Justicia* sp. and over open bedrock to create some uncertainty regarding the nature (obligatory or facultative) of the relationship between Striated Darters and broken slabrock outside of the spawning season.

Etheostoma crossopterum and *E. nigripinne* often appear to be the most dominant benthic species in streams where they occur (Table 1). In many middle and upper Duck River tributaries, one can hardly pull a seine through a slabrock pool or riffle without collecting several specimens of either *E. crossopterum* or *E. nigripinne*. Barcheek darters in the *E. virgatum* group, like the Striated Darter, show very unique distribution patterns and causation behind these distributions has yet to be fully determined. Barcheeks often have large geographic gaps in their distribution and these gaps are often filled in by other barcheeks (Page and Schemske, 1978). Barcheek species are rarely, if ever, collected sympatrically. Barcheek darters are found primarily in the Cumberland River system, yet certain members of this group can be found in the lower Ohio and lower Tennessee systems. *Etheostoma striatulum*, however, is an outlier when compared to other barcheek distributions. *Etheostoma striatulum* occurs in the upper Duck River drainage and apparently has no contact zone with other barcheeks. It is also interesting to note that the middle portion of the Duck River is largely void of barcheeks. There appears to be a substantial amount of suitable habitat within this portion of the drainage, yet something seems to be restricting barcheeks from range expansion into this area. The extreme lower Duck River and its tributaries are often inhabited by *E. smithi*, whereas the upper reaches are occupied by *E. striatulum*.

This biogeographic phenomenon, along with various other aspects of *Catonotus* species' ecology and life histories, may be driven by competitive exclusion (Page and Schemske, 1978). These authors believe that competition among slab-pool species of *Catonotus* appears responsible for their allopatry. Page and Schemske (1978) also speculated that the presence of members of the *E. squamiceps* complex (e.g., *E. crossopterum* or *E. nigripinne*) often appears to drive body-size reductions in other *Catonotus*. These body-size reductions may be in response to the fact that members of the *E. squamiceps* complex are often larger than other *Catonotus* and are more competitive (and thus more successful) in their ability to secure larger and more optimal nesting sites (stones). These competitively inferior *Catonotus* species may be forced to utilize less-than-optimal habitat.

Despite this suggestive evidence in the literature, no link between the number of other *Catonotus* and the presence or absence of the Striated Darter could be established in our study. As mentioned earlier, large numbers of *E. crossopterum* and/or *E. nigripinne* were collected at sites with and without Striated Darters (Table 1). These members of the *E. squamiceps* complex, and more specifically, *E. crossopterum*, may be better at adapting to degraded stream conditions (Strange, 2000). Both *E. crossopterum* and *E. nigripinne* are much larger than *E. striatulum* and should be more competitive at securing habitat space.

Although not quantified in this study, it appeared that at a number of sites either *E. crossopterum* or *E. nigripinne* appeared to be using broken slabrock and other flat objects for habitat, whereas *E. striatulum*, if observed, was often collected around stands of *Justicia* sp. Also, juvenile *E. crossopterum* or *E. nigripinne* appeared to favor filamentous algae mats for habitat instead of open bedrock that juvenile Striated Darters appeared to prefer. Again, more research into the ecological relationships of *E. striatulum* with other members of the subgenus *Catonotus* are necessary to make any definitive statements.

Conservation Implications

This study reaffirmed that *Etheostoma striatulum* is a rare species with a relatively small geographic range. Cook et al. (1996) found only 26 Striated Darters at 10 of 16 historically known collection localities and concluded that the species' range had been diminished as of 1992. Similarly, we only observed 24 adults and 78 juveniles at 11 sites in 2006. A few other *Catonotus* species have similar levels of low abundance, including *E. chienense*, *E. forbesi*, and *E. lemniscatum* (Blanton and Jenkins 2008). Warren et al. (1994) reported collecting 72 *E. chienense* from only five sites in the Obion Creek and Bayou du Chien drainages of western Kentucky. Eisenhour and Burr (2000) observed 71 *E. lemniscatum* at 12 sites in Big South Fork of the Cumberland River, and Hansen et al. (2006) reported 75 adult *E. forbesi* at six sites in the upper Caney Fork River system. Although survey techniques may not be directly comparable among studies, the Striated Darter appears to be as uncommon as these other rare species in its subgenus, two of which (*E. chienense* and *E. lemniscatum*) are federally protected endangered species.

Although no significant differences in environmental associations were elucidated in our study, anecdotal evidence suggests that habitat degradation continues to be problematic in Striated Darter streams. For example, we did not detect the darter at four sites where it was seen in 1992, including the type locality which is in a degraded condition. As noted above, additional research will be required to better understand the threats faced by this species.

The combination of low abundance, small geographic range, non-detection at selected sites, and anecdotal evidence of degraded stream conditions warrants the attention of biologists and policymakers charged with resource conservation duties in the Tennessee region. Regular monitoring of population trends and efforts to protect and restore stream habitat quality would be prudent conservation measures to encourage the persistence of this unique Duck River species.

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TABLE 1. Number of individuals of *Etheostoma striatulum*, *E. flabellare*, and *E. crossopterum* + *E. nigripinne* observed at 30 sites sampled during June–July 2006 in the Duck River system of middle Tennessee. Site locations are illustrated in Fig. 2.

			Number of Individuals Observed			
			E. striatulum			
Site	Stream	County	Age 0	Age 1+	*E. flabellare*	*E. crossopterum* + *E. nigripinne*
1	Wartrace Creek	Bedford	0	0	0	319
2	Flat Creek	Bedford	8	0	0	22
3	Hurricane Creek	Bedford	0	3	1	19
4	Fall Creek	Bedford	7	2	1	6
5	North Fork Creek	Bedford	0	3	0	60
6	Wilson Creek	Marshall	0	0	0	59
7	Duck River	Marshall	0	0	2	1
8	East Rock Creek	Marshall	0	0	0	0
9	Flat Creek	Maury	14	2	0	53
10	West Fork Bigby Creek	Lewis	0	1	8	35
11	Butler Creek	Bedford	0	0	17	303
12	Dog Branch	Maury	0	0	0	28
13	Flat Creek	Maury	42	2	0	297
14	North Fork Creek	Bedford	0	4	0	43
15	Wartrace Creek	Bedford	5	6	0	7
16	Globe Creek	Maury	0	0	0	0
17	Little Bigby Creek	Maury	0	0	0	1
18	West Fork Bigby Creek	Maury	0	0	0	1
19	East Rock Creek	Marshall	0	0	0	81
20	Little Flat Creek	Maury	0	0	0	67
21	Clem Creek	Bedford	0	0	0	13
22	Alexander Creek	Bedford	2	0	0	33
23	Flat Creek	Bedford	0	0	6	10
24	Knob Creek	Maury	0	0	3	1
25	Silver Creek	Maury	0	0	7	74
26	Fountain Creek	Maury	0	0	2	0
27	Noah Fork	Coffee	0	1	0	0
28	Garrison Fork	Bedford	0	0	0	0
29	Big Bigby Creek	Maury	0	0	12	21
30	Noah Fork	Coffee	0	0	7	2
		Totals	78	24	66	1,556

TABLE 2. Descriptive statistics and Fisher's Exact Test results (*P* value in rightmost column) for 12 environmental characteristics measured at 30 sites in the middle-upper Duck River system where *Etheostoma striatulum* was present (N = 11) or absent (N = 9) during a survey in June-July 2006.

Characteristic	Striated Darter Present Sites			Striated Darter Absent Sites			*P*
	N	Mean ± SD	Range	N	Mean ± SD	Range	
Elevation (m above sea level)	11	215 ± 18	186-250	19	212 ± 24	177-256	0.414
Stream Order	11	4.3 ± 0.7	3-5	18	4.0 ± 0.8	2-5	0.906
Link Magnitude	11	65 ± 32	27-129	18	74 ± 72	2-264	0.841
Riparian Zone Width (m)	11	11 ± 7	5-20	19	12 ± 9	0-30	0.319
Wetted Channel Width (m)	11	11 ± 4	5-19	19	14 ± 15	6-75	0.767
Mid-channel Depth (cm)	5	25 ± 20	9-44	11	27 ± 15	7-60	1.000
Discharge (m^3/s)	6	0.01 ± 0.01	0.0-0.01	12	0.42 ± 1.38	0.00-4.79	1.000
Water Temperature (C)	11	26 ± 2	21-28	19	26 ± 3	21-30	0.202
pH	3	8.0 ± 0.0	7.9-8.3	9	7.9 ± 0.4	7.6-8.6	0.763
Conductivity (□S)	7	247 ± 108	152-376	17	238 ± 116	27-391	0.261
Available Microhabitat	11	1.5 ± 0.8	0.2-3.0	19	1.4 ± 0.7	0.0-3.0	0.784
Abundance of other *Catonotus*	11	53 ± 83	0-297	19	51 ± 96	0-319	0.520

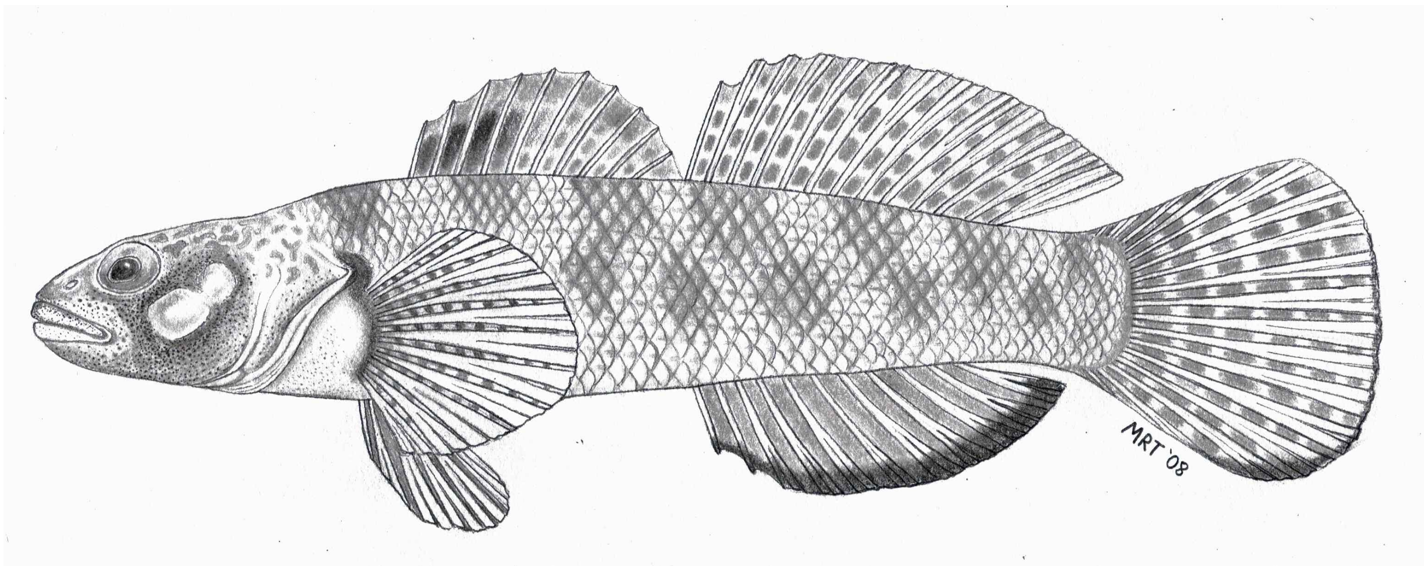

FIGURE 1. The Striated Darter, *Etheostoma striatulum*, as illustrated by Matthew R. Thomas.

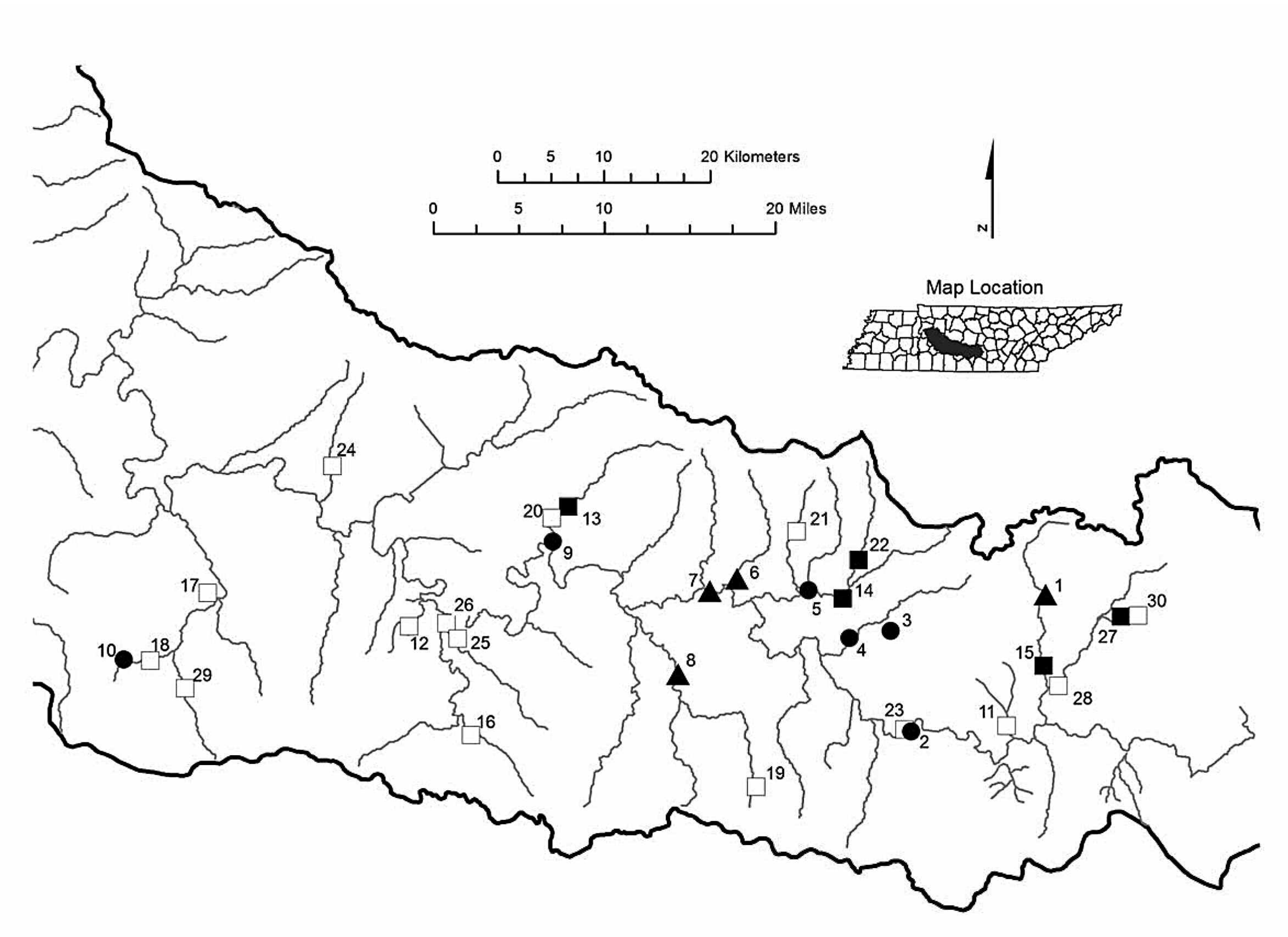

FIGURE 2. Middle-upper portion of the Duck River drainage in Tennessee showing 30 sites sampled during June-July 2006 for the Striated Darter, *Etheostoma striatulum*. Site coordinates can be found in Abernathy (2007). Filled circles indicate Striated Darter presence in both 2006 and a 1992 survey by Cook et al. (1996); filled triangles indicate absence in 2006 and presence in 1992; filled squares indicate presence in 2006 and absence or not sampled in 1992; and empty squares indicate absence in 2006 and not sampled in 1992.

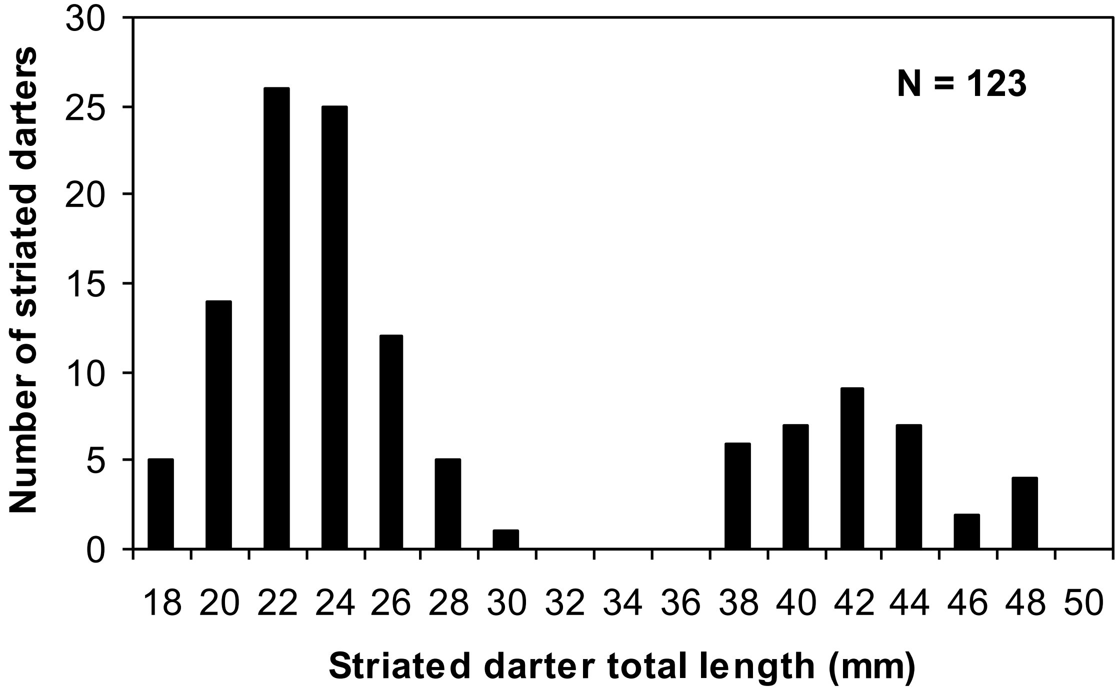

FIGURE 3. Length-frequency histogram depicting Striated Darter age-class structure at population estimate study site (2) and pilot study sites (13, 15) on 24-26 July 2006. Length intervals from left are 18-19 mm TL, 20-21 mm TL, and so forth.