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# Design and evaluation of a translocation strategy for the fringed darter (*Etheostoma crossopterum*) in Illinois

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**Abstract**

The fringed darter (*Etheostoma crossopterum*) was introduced into two streams where neither the fringed darter nor any other species of the same subgenus occur but that otherwise have suitable habitat. Darters were collected from two streams in the Cache River basin, and a combination of darters from each source stream were moved to the receiving streams, which also were in the headwaters of the Cache River basin (20 males and 40 females to each). Darters were moved in late March 2001 at the beginning of their reproductive season, which continues for approximately 2 months. Fringed darter nests were present within 3 days at both introduction sites and nests were found thereafter until late May at which time searching for nests was terminated. Twenty-five nests were found in 2001 compared with 168 nests in 2002. A total of 8714 eggs were counted in 22 nests during 2001 with a mean of 413 eggs per nest ($n = 19$ nests). In September 2001 and 2002, surveys for juveniles and adults indicated successful recruitment in both streams. Mean size of juvenile darters differed significantly between the two introduction sites in 2001. The design of this study allowed for a rapid, initial assessment of the translocations, aspects of which appeared successful. Moving fishes at the beginning of their reproductive season could increase the chance of successful reproduction and eventual establishment. The protocol for translocation of fringed darters might be applicable to other similar and endangered darters such as Barrens (*Etheostoma forbesi*), relict (*E. chienense*), and duskytail darters (*E. percnurum*). Sampling was conducted in other areas of the Cache River basin in search of additional populations of fringed darters. An updated account is given of the distribution of the fringed darter in Illinois.
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*Keywords:* Spawning time; Conservation; Stream fishes; Translocation; Surrogate species

## 1. Introduction

Captive breeding and reintroduction of some fish species has become necessary for rebuilding or maintaining their populations (Minckley, 1995; Shute et al., 1998; Rakes et al., 1999). Often this work is done when a species has become critically endangered. One of the earliest efforts involving translocation for the purpose of conserving a species was for the snail darter (*Percina tanasi*) (Etnier and Starnes, 1993). Several transplants of large numbers of wild-caught snail darters were made; the numbers were large because the source population was in danger of total annihilation from the closure of Tellico Dam; therefore, as many darters as possible were moved (Hickman and Fitz, 1978). Such a large initial seed population conserves genetic diversity, but in some cases, might not be possible. Most translocations have the intention of establishing a new population while not affecting the source population from overharvesting.

Recommendations and guidelines for conducting animal translocations have been published with the intention of increasing the success of future translocation efforts (Williams et al., 1988; Griffith et al., 1989; Dodd and Seigel, 1991; Maitland, 1995). The number of individuals released must be adequate, should consist of several age classes of wild-caught individuals, and should be released in areas with suitable habitat. Other factors to be considered are sex ratio of natural populations, reproductive season and fecundity, and presence of congeneric species or other potential competitors at introductions sites. Griffith et al. (1989:479) recommended that "Those planning translocations should adopt rigorous data recording procedures." Transloca-

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tion and captive breeding programs should be initiated well before a species is critically imperiled, and initial studies could be performed on biologically similar, more abundant (surrogate) species (Meffe, 1987; Griffith et al., 1989). "The greatest potential for establishing satellite populations may occur when a candidate population is expanding and numbers are moderate to high. These conditions are the ones that tend to make endangered species biologists relax; our analysis suggests that these conditions may point out the time for action." Griffith et al. (1989:479). The methodology used in the present study generally follows the recommendations of authors mentioned above.

Intentional movement and release of live organisms for any reason, but especially for conservation purposes, must be done with great care. Unfortunately, there are many examples of both accidental and unauthorized, intentional releases of nonindigenous fishes into new areas; many of these examples relate to species sold as fishing bait; however, some introductions have been for recreational or other purposes (Fuller et al., 1999). At the minimum, the fauna of the proposed introduction sites should be known and careful consideration should be given to potential impacts to the existing fauna. In addition, the appropriate permits should be obtained from regulatory agencies that oversee the area of interest. The State "Department of Natural Resources" is the agency most likely to be consulted in such matters, and a written plan outlining the intent and need for the introduction would be evaluated by the agency prior to issuance of permits for such a project.

The purpose of the study was twofold. First, I sought to establish new stream populations of fringed darters within a drainage basin where the species is native. This was done with the permission and cooperation of the Illinois Department of Natural Resources (hereafter ILDNR). Second, this study provides a test of whether a new population could be established from a relatively small number of founders. If additional populations of Illinois fringed darters can be established now, future listing of the species as threatened or endangered in the State or loss of the species from the Illinois fauna might be avoided. The proposed times of translocation and nest searching should allow for rapid initiation of reproductive efforts as well as provide a method for assessing the initial success of translocation of adults. A detailed proposal was submitted to the ILDNR, which then granted the permit to perform the translocations as outlined in the proposal (i.e. translocations only in the designated streams within the native river drainage of the species).

### *1.1. Study species*

The fringed darter (*Etheostoma crossopterum*) is a small fish that occurs in rocky streams in portions of Alabama, Tennessee, Kentucky, and Illinois (Braasch and Mayden, 1985; Page et al., 1992; Mettee et al., 1996; Poly and Wilson, 1998). Until recently, populations of fringed darter in Illinois had been misidentified as a similar species, the spottail darter (*Etheostoma squamiceps*), which in Illinois occurs only in the southeastern portion of the State (Poly and Wilson, 1998). The fringed darter and other members of the subgenus *Catonotus* are egg-clusterers, depositing a single layer of eggs on the undersides of slab rocks or other objects (Page, 1974, 1980; Bandoli et al., 1991; Poly, 2000). Aspects of the life history of fringed darters in Kentucky and Illinois have been studied, and spawning season extends from March to May or June (Page, 1974; Poly and Wilson, 1998; Poly, 2000).

In 1997 fringed darters were found in six streams in the lower portion of the Cache River basin but were absent at many other sites within the basin (Poly and Wilson, 1998, unpublished data). Modifications to streams in the Cache River basin, including channelization and removal of riparian vegetation, have resulted in degraded aquatic habitats (Lopinot, 1972; Illinois Natural History Survey, 1978). Lopinot (1972) listed the amount of stream and river lengths affected by channelization per county in Illinois. One hundred sixty-eight km of stream have been channelized in Union and Alexander counties in which lies the majority of the historic range of fringed darter in Illinois (Fig. 1). In streams that contain populations of fringed darters, about 26 km have been channelized (Lopinot, 1972). The negative effects of such changes on fish and invertebrate communities are well documented (Etnier, 1972; Illinois Natural History Survey, 1978; Trautman, 1981; Berkman and Rabeni, 1987). Because the fringed darter has a small distribution within the Cache River basin, possibly because of past disturbances to streams in the basin, introduction of fringed darters to other suitable streams in the basin could be advantageous for the continued existence of the species in Illinois, particularly because streams continue to be impacted by anthropogenic activities. Translocation is likely the only means by which fringed darters can gain access to streams in the upper Cache River basin because there is much distance and degraded habitat between extant stream populations and these streams.

During sampling efforts in 1997 to determine where the fringed darter occurred, two streams in the headwaters of the Cache River basin were sampled that did not yield fringed darters. Bradshaw Creek and an unnamed tributary of the Cache River appeared suitable for fringed darters; both streams are moderate sized creeks with clear water and rocky substrates (Fig. 1). Because there are no historical records of fringed darters in the two streams or any nearby streams, this translocation should be considered an introduction, rather than repatriation or augmentation (Reinert, 1991). The only darters captured at both creeks were

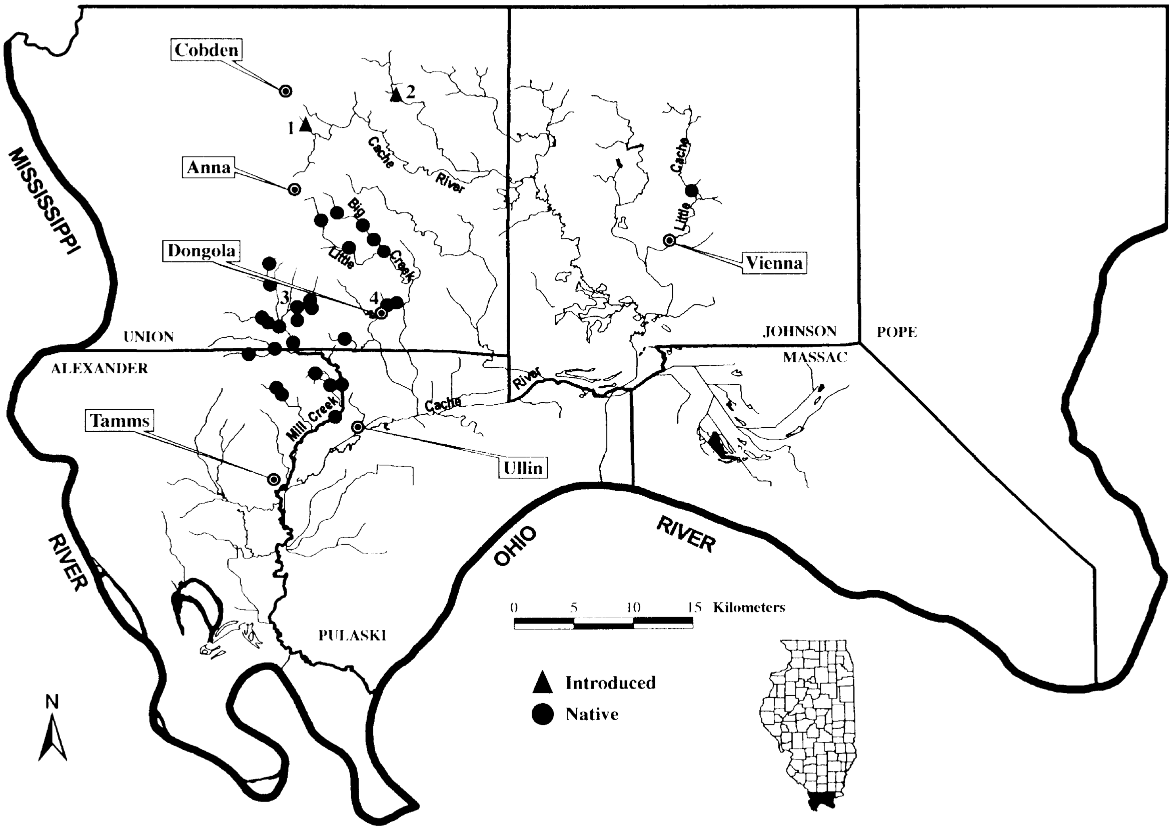


Fig. 1. Distribution of the fringed darter (*Etheostoma crossopterum*) in the Cache River basin of southern Illinois from collection records through the year 2002 (30 site records; some points represent more than one record). Only one darter was collected in 1964 at the location in Little Cache Creek, and the species has not been collected in that stream again. Solid triangles = introduced populations (1 = tributary of Cache River, 2 = Bradshaw Creek), solid circles = native populations (3 = Mill Creek, 4 = tributary of Big Creek). Modified from Poly and Wilson (1998).

blackside darter (*Percina maculata*), bluntnose darter (*Etheostoma chlorosomum*), and slough darter (*Etheostoma gracile*), which are not ecologically similar to the fringed darter in terms of feeding, reproduction, and habitat use (Braasch and Smith, 1967; Kuehne and Barbour, 1983; Page, 1983). Blackside darter is an egg burier, whereas bluntnose and slough darters are egg attachers (Page et al., 1982). Fringed darters co-occur naturally with fantail darter (*Etheostoma flabellare*) in Little Creek and adjacent Big Creek, but in most streams in the Cache River basin are not sympatric with either fantail darter or stripetail darter (*Etheostoma kennicotti*). Due to lack of other ecologically similar darters, presence of suitable habitat, and native status of fringed darters within the river basin, successful introductions of the species from other streams seemed feasible and would expand the overall population.

## 2. Methods

### 2.1. Study area and field methods

On 25 March 2001 adult fringed darters were collected with a seine from two sites where the species is abundant [Mill Creek at Miller Rd. (Co. Rd. 1500E) near quarry, 7 km W Dongola, Union Co., Illinois (T13S, R1W, Sec. 20, 37°22′02″/89°14′55″) and unnamed tributary of Big Creek at old U.S. Rt. 51 bridge (Co. Rd. 1975E/1980E) in Dongola, Union Co., Illinois (T13S, R1W, 37°21′53″/89°09′48″)] (Fig. 1). The time period of collection for adults was near the beginning of the breeding season and allowed males and females to be distinguished easily because of pronounced, seasonal sexual dimorphism. All females were gravid, and all males possessed nuptial pigmentation typical of mature individuals preparing to reproduce. Sex, length, and weight of each fish as well as stream name, location, and water temperature were recorded. Total length (mm) of each darter was measured with a stainless steel ruler, and individual weights were measured to 0.1 g with an Acculab® Pocket Pro® 250-B portable electronic balance. Water temperature was measured to 0.1 °C with a Taylor® digital thermometer. Two days prior to collecting darters for translocation, water temperatures in receiving streams and source streams were compared to insure that temperature acclimation of fishes would not be a problem. At least two age classes of adults (Age-I and Age-II) were represented among the 60 darters based on length frequency data. Darters were held in aerated coolers from period of capture and data collection to time of release. Fishes were allowed to acclimate for 30 min in a mixture of water from the original capture site and release site before being released into the receiving stream. Sixty darters were relocated to a single site on each of two receiving streams (Bradshaw Creek and an unnamed tributary of Cache River; Fig. 1) on the same day of collection (25 March 2001). Each introduction site received 13 males and 27 females from Mill Creek and 7 males and 13 females from tributary of Big Creek. Each site received 40 females and 20 males because more than one female may spawn with a single male (W. Poly, personal observation), and the sex ratio of a population in Ferguson Creek, Kentucky was 1.9 female: 1 male (Page, 1974). Bradshaw Creek is a fourth order stream with an average width of 8.5 m (6.8–10.2, $n=5$) within the study section [upstream of Winghill Rd., 9 km E Cobden, Union Co., Illinois (T11S, R1E, Sec. 30, 37°31′49″/89°08′58″)]. Tributary of Cache River is third order and has an average width of 4.6 m (2.1–6.2, $n=5$) within the study section [at U.S. Rt. 51 bridge, 3.5 km SSE Cobden, Union Co., Illinois (T12S, R1W, Sec. 5, 37°30′12″/89°13′54″)]. Slab rocks are far more abundant at Bradshaw Creek than at tributary of Cache River.

Visual searches for nesting males were conducted on six dates between 28 March and 27 May 2001 over a 100 m reach of stream at each introduction site. In 2002, nest searches took place on fives dates between 14 March and 15 May 2002 at each site. Nest searches outside the study reach were performed each year but were positive only at Bradshaw Creek in 2002 (these nests and number of rocks checked were included in totals for 2002 at both sites). Searches were accomplished by gently tilting rocks and looking for eggs and darters (eggs attached to underside of rocks). When a nest was located, the nest rock depth (0.1 cm; distance from stream bottom to water surface) and number of adult males and females at the nest were recorded. In 2001, egg clusters were photographed quickly for counting number of eggs per nest (Bandoli et al., 1991), and rocks with eggs were replaced (generally, males return to the nest rock and continue guarding the nest after such a disturbance (W. Poly, personal observation). The number of bluntnose minnow (*Pimephales notatus*) nests were recorded because this species also deposits its eggs on the undersides of rocks and other objects, and nest rock depth was measured in 2002. Nests of fringed darters contain larger, golden yellow or orange eggs compared to smaller, purple or gray eggs of bluntnose minnows and can be distinguished easily (Bandoli et al., 1991; W. Poly, personal observation). In addition, identification of nests can be based on presence of either species because males of both species guard the nests.

Sampling was conducted throughout the Cache River basin during 2001 and 2002 in an attempt to locate other streams that contained fringed darters. A 3.0 × 1.8 m seine and dip nets were used as well as visual searching for nest-guarding males. The pre- and post-introduction fish communities at each translocation site were determined by seining a 150 m section of each stream on 14 October 2000, 15–16 September 2001, and 9–10 September 2002; all habitats were sampled thoroughly with a single pass through each 150 m stream segment. All captured fishes were held in coolers until a section of stream had been sampled (to avoid recaptures), then were identified, enumerated, and returned to the stream (except for voucher specimens retained on 14 October 2000 and 9–10 September 2002). During the seining surveys of 15–16 September 2001 and 9–10 September 2002, adult and young-of-the-year fringed darters were measured and weighed by the same method as the parental stock (see earlier) and were distinguished as adults or juveniles by size. All fringed darters were returned to the stream after data were recorded. Voucher specimens of fringed darters from new sites of occurrence and of other fishes from the translocation sites were preserved in 10% formalin and deposited in the fish collections of the University of Michigan Museum of Zoology and California Academy of Sciences.

### 2.2. Statistical analyses

Mean adult and juvenile sizes (weight and length) were compared between source and between introduced populations, respectively (unequal sample sizes). Sizes of adults introduced to streams were not compared (i.e. mixtures of fishes from the source streams). Weight data were not normally distributed and had unequal variances; therefore, all comparisons were made using the Mann–Whitney $U$ test (Zar, 1999). All statistics were performed with StatView v. 5.0 (SAS Institute, Inc., 1999), and results were considered significant at $P<0.05$ (adjusted for number of comparisons: $P<0.0125$ for adults from source populations and $P<0.0125$ for juveniles from introduced populations).

## 3. Results

### 3.1. Parental stock from source streams

Male and female darters from Mill Creek were larger than darters from tributary of Big Creek (Table 1). Male weight ($P=0.005$) and length ($P=0.0006$) and female weight ($P=0.008$) and length ($P=0.0009$) were significantly different between the two source populations. However, size distributions were equalized when darters from both source streams were combined for the receiving streams (Table 1 and Fig. 2a,b). All darters appeared to be in good condition when captured and at time of release.

Table 1
Size distributions for adult and juvenile fringed darters (*Etheostoma crossopterum*) from source (Mill Creek and tributary of Big Creek) and introduced populations (Bradshaw Creek and tributary of Cache River) in Illinois (mean followed by range in parentheses)

| Stream | Total length (mm) | | Weight (g) | |
|---|---|---|---|---|
| | Male | Female | Male | Female |
| *Adult darters* | | | | |
| Mill Creek (source) ($n=26$ males, 54 females) | 81 (64–90)[a] | 62 (49–77)[b] | 5.4 (2.6–7.5)[c] | 2.6 (1.1–4.7)[d] |
| Trib. Big Creek (source) ($n=14$ males, 26 females) | 68 (55–89)[a] | 55 (45–75)[b] | 3.5 (1.5–7.2)[c] | 2.2 (1.0–5.6)[d] |
| Bradshaw Creek (introduction) ($n=20$ males, 40 females) | 77 (55–89) | 60 (46–77) | 4.9 (1.5–7.5) | 2.5 (1.0–5.6) |
| Trib. Cache River (introduction) ($n=20$ males, 40 females) | 75 (57–90) | 59 (45–76) | 4.5 (1.7–7.2) | 2.5 (1.1–5.2) |
| *Juvenile darters* | | | | |
| Bradshaw Creek (2001 offspring; $n=46$) | 46 (36–57)[e] | | 0.9 (0.4–1.6)[f] | |
| Trib. Cache River (2001 offspring; $n=107$) | 38 (29–48)[e] | | 0.5 (0.2–1.1)[f] | |
| Bradshaw Creek (2002 offspring; $n=115$) | 36 (27–50) | | 0.4 (0.1–1.1)[g] | |
| Trib. Cache River (2002 offspring; $n=25$) | 38 (31–46) | | 0.5 (0.3–0.9)[g] | |

Single pairs of means in each column differed significantly ($P<0.05$; adjusted for number of comparisons: $P<0.0125$ for adults from source populations and $P<0.0125$ for juveniles from introduced populations).

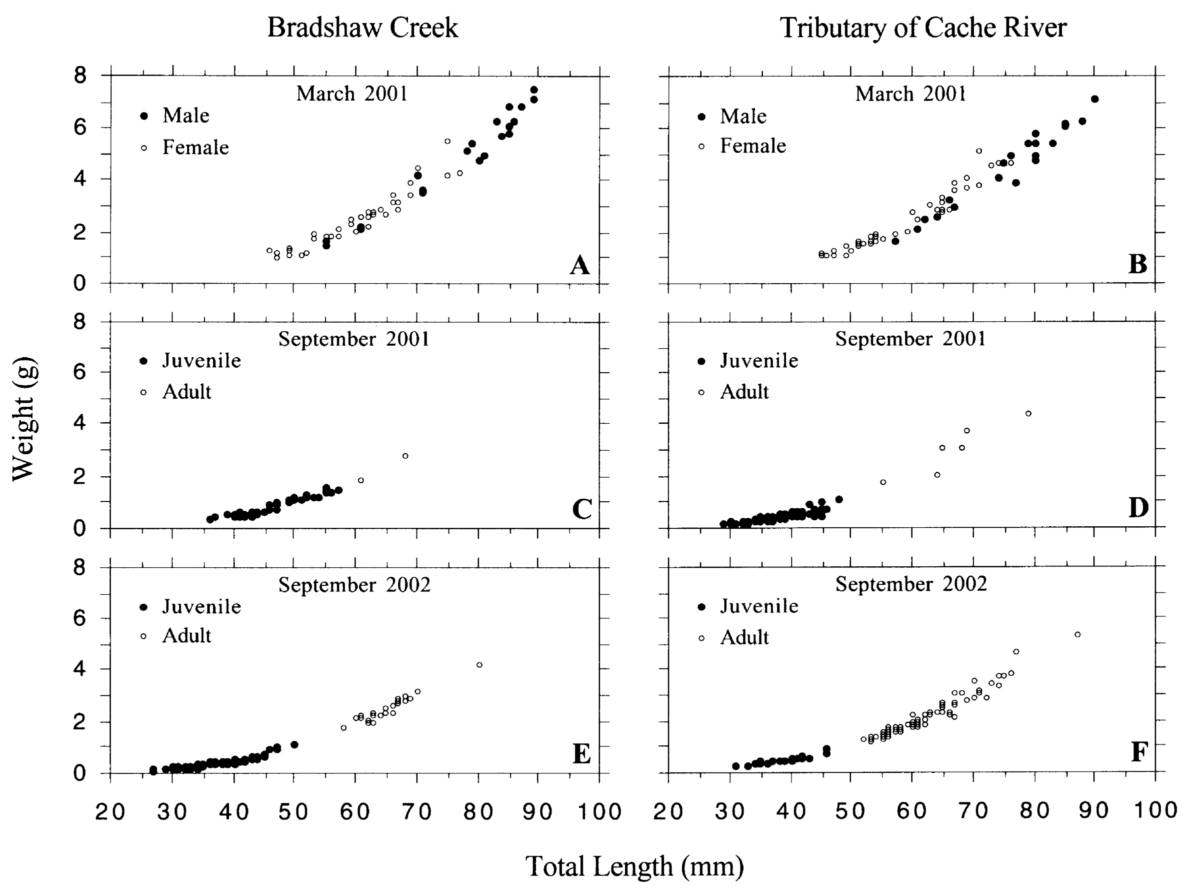


Fig. 2. Weight vs length scatterplots for adult fringed darters released in Bradshaw Creek (A) and tributary of Cache River (B) in March 2001; same for juveniles and adults captured at Bradshaw Creek (C, E) and tributary of Cache River (D, F) in September 2001 and 2002.

### 3.2. Reproductive activities and numbers of nests and eggs

Brief observations were made of several large males released into Bradshaw Creek. After about 10 min of watching the fishes, male–male combat was observed for about 15 min. Agonistic displays indicated that the act of moving the fishes to a new stream did not deter their impetus to procure nesting sites. Three males were under a large rock and were boldly marked with black stripes on the side of the body, black heads, and black fins. Two of the males were displaying to one another laterally and at one point had their mouths locked in combat. Consistent with these observations was the

Table 2
Summary of nest data for fringed darter (*Etheostoma crossopterum*) and bluntnose minnow (*Pimephales notatus*) at Bradshaw Creek and tributary of Cache River from March-May 2001 and 2002

| Date | Number of nests | Number of eggs | Number of rocks examined | Number of *P. notatus* nests |
|---|---|---|---|---|
| *Bradshaw Creek (2001)* | | | | |
| 28 March | 1 | 295 | 210 | 0 |
| 5 April | 4 | 1359 | 211 | 0 |
| 19 April | 4 | 1252[a] | 300 | 3 |
| 29 April | 4 | 1527[b] | 722 | 4 |
| 13 May | 1 | 65 | 591 | 7 |
| 27 May | 0 | 0 | 222 | 2 |
| Subtotal | 14 | 4498 | 2256 | 16 |
| *Tributary of Cache River (2001)* | | | | |
| 28 March | 1 | 173 | 177 | 0 |
| 5 April | 3 | 739 | 226 | 0 |
| 19 April | 2 | 795 | 238 | 3 |
| 29 April | 1 | 2016 | 296 | 3 |
| 13 May | 2 | [c] | 285 | 5 |
| 27 May | 2 | 493 | 202 | 1 |
| Subtotal | 11 | 4216 | 1424 | 12 |
| Total | 25 | 8714 | 3680 | 28 |
| *Bradshaw Creek (2002)* | | | | |
| 14 March | 0 | – | 141 | 0 |
| 30 March | 20 | – | 436 | 0 |
| 16 April | 47 | – | 710 | 0 |
| 30 April | 43 | – | 1137 | 11 |
| 15 May | 14 | – | 626 | 3 |
| Subtotal | 124 | – | 3050 | 14 |
| *Tributary of Cache River (2002)* | | | | |
| 14 March | 0 | – | 126 | 0 |
| 30 March | 10 | – | 179 | 0 |
| 16 April | 16 | – | 274 | 0 |
| 1 May | 7 | – | 353 | 2 |
| 15 May | 11 | – | 517 | 3 |
| Subtotal | 44 | – | 1449 | 5 |
| Total | 168 | – | 4499 | 19 |

[a] Some eggs had fungus and could not be counted.
[b] Total based on three nests; all eggs in fourth nest had fungus.
[c] No egg count obtained.

presence of egg clusters (nests) at both sites only 3 days post-introduction (Table 2). Mean water temperatures during the spawning season (for dates with nests present) were 15.5 °C (range = 6.9–19.6) and 16.3 °C (range = 10.4–22.3) in 2001 and 2002, respectively. In 2001, 3680 rocks were examined for nests, resulting in detection of 25 nests [1–4 (mean = 2) per date], whereas in 2002, 168 nests were discovered [0–47 (mean = 17) per date; 4499 rocks checked], which was > 6× the number found the previous year (Table 2). Nests were distributed over a longer section of both streams in 2002 compared with 2001. Sixty-six nests had males present, but some males escaped detection due to low visibility on some sampling dates. Females were observed at seven nests occupied by males, and females and juveniles were seen in the study areas occasionally. Mean depth of nest rocks was 17.2 cm (range = 6.2–30.8 cm, $n$ = 173 nests). A total egg count of 8714 was obtained from 22 nests, and mean number of eggs per nest was 413 (range = 65–2016; $n$ = 19 nests). All eggs in one nest were covered with fungus, and three other nests had lower egg counts due to fungus covering and destroying some eggs. Bluntnose minnows began spawning several weeks later than fringed darters (Table 2), and mean nest depth was 23.6 cm (range = 16.2–33.7 cm, $n$ = 14 nests). One large rock that contained fringed darter eggs on 30 March and 16 April 2002 (with male present) was occupied by a male bluntnose minnow and its nest of eggs on 30 April.

### 3.3. Recruitment of offspring

In 2001, 46 juveniles and two adults were captured in Bradshaw Creek, whereas 107 juveniles and six adults were collected in tributary of Cache River. In 2002, 115 juveniles and 28 adults were collected in Bradshaw Creek compared with 25 juveniles and 79 adults in tributary of Cache River (Table 3). In 2001, juvenile darters were larger in Bradshaw Creek than in tributary of Cache River, and mean weight ($P$ < 0.0001) and length ($P$ < 0.0001) compared between the two sites were significantly different (Table 1 and Fig. 2c,d). In 2002, only weight ($P$ = 0.0005), not total length ($P$ = 0.0228), of juveniles differed significantly. Two distinct age classes of darters were represented at both sites in 2002 (Fig. 2e,f).

### 3.4. Fish community structure and abundance of fringed darters

The fish communities of both introduction sites were similar in terms of species composition and abundance, and fringed darter comprised 15% and 20% of the fish communities at tributary of Cache River and Bradshaw Creek, respectively, in 2001 compared with 7% and 9% in 2002 (Table 3). Two minnow species, *Lythrurus umbratilis* and *Pimephales notatus*, exhibited large increases in abundance during 2002.

### 3.5. Distribution of fringed darter in Illinois

Sixteen sites were sampled throughout the Cache River basin in search of additional populations of fringed darters. Fringed darters were found at five sites where they had not been collected previously; however, all of these new sites were located within the same general area and stream systems where fringed darters were

Table 3
Species composition and abundance at translocation sites (Bradshaw Creek and tributary of Cache River) on 14 October 2000 (pre-introduction), 15–16 September 2001, and 9–10 September 2002 (post-introduction) (absolute abundance followed by relative abundance in parentheses)

| Species | Bradshaw Creek | | | Tributary of Cache River | | |
|---|---|---|---|---|---|---|
| | Pre (2000) | Post (2001) | Post (2002) | Pre (2000) | Post (2001) | Post (2002) |
| Cyprinidae | | | | | | |
| *Campostoma anomalum pullum* | 17 (6%) | 17 (7%) | 35 (2%) | 23 (9%) | 46 (6%) | 39 (3%) |
| *Cyprinella lutrensis* | – (0%) | – (0%) | – (0%) | – (0%) | 4 (1%) | 15 (1%) |
| *Lythrurus umbratilis* | 1 (<1%) | 35 (14%) | 333 (21%) | 11 (4%) | 20 (3%) | 220 (15%) |
| *Notemigonus crysoleucas* | – (0%) | – (0%) | – (0%) | – (0%) | – (0%) | 2 (<1%) |
| *Pimephales notatus* | 51 (18%) | 21 (9%) | 664 (41%) | 51 (20%) | 51 (7%) | 592 (41%) |
| *Semotilus atromaculatus* | 4 (1%) | 4 (2%) | 7 (<1%) | 4 (2%) | 72 (10%) | 18 (1%) |
| Catostomidae | | | | | | |
| *Catostomus commersoni* | – (0%) | – (0%) | – (0%) | 2 (1%) | 56 (8%) | 9 (<1%) |
| *Erimyzon oblongus* | – (0%) | 4 (2%) | – (0%) | – (0%) | 24 (3%) | – (0%) |
| Ictaluridae | | | | | | |
| *Ameiurus natalis* | 3 (1%) | 7 (3%) | 6 (<1%) | – (0%) | 3 (<1%) | 1 (<1%) |
| *Ameiurus nebulosus* | 1 (<1%) | – (0%) | – (0%) | – (0%) | – (0%) | – (0%) |
| *Noturus gyrinus* | – (0%) | – (0%) | – (0%) | 1 (<1%) | 2 (<1%) | 2 (<1%) |
| Fundulidae | | | | | | |
| *Fundulus olivaceus* | 15 (5%) | 45 (18%) | 62 (4%) | 27 (10%) | 41 (6%) | 43 (3%) |
| Aphredoderidae | | | | | | |
| *Aphredoderus sayanus* | 15 (5%) | 9 (4%) | 2 (<1%) | 15 (6%) | 177 (24%) | 16 (1%) |
| Poeciliidae | | | | | | |
| *Gambusia affinis* | – (0%) | – (0%) | – (0%) | 8 (3%) | 23 (3%) | 9 (<1%) |
| Centrarchidae | | | | | | |
| *Lepomis cyanellus* | 9 (3%) | 9 (4%) | 13 (1%) | – (0%) | – (0%) | 1 (<1%) |
| *Lepomis gulosus* | – (0%) | – (0%) | – (0%) | – (0%) | – (0%) | 1 (<1%) |
| *Lepomis macrochirus* | 39 (14%) | 5 (2%) | 16 (1%) | 92 (35%) | 5 (1%) | 66 (5%) |
| *Lepomis megalotis* | 71 (25%) | 8 (3%) | 61 (4%) | 6 (2%) | 27 (4%) | 49 (3%) |
| *Lepomis microlophus* | – (0%) | – (0%) | – (0%) | – (0%) | – (0%) | 3 (<1%) |
| *Lepomis* spp. (indet. yoy) | – (0%) | – (0%) | 227 (14%) | – (0%) | – (0%) | 191 (13%) |
| *Micropterus salmoides* | 4 (1%) | 2 (1%) | 4 (<1%) | 6 (2%) | – (0%) | 2 (<1%) |
| Percidae | | | | | | |
| *Etheostoma chlorosomum* | 6 (2%) | 3 (1%) | 5 (<1%) | – (0%) | – (0%) | – (0%) |
| *Etheostoma crossopterum* | – (0%) | 48 (20%) | 143 (9%) | – (0%) | 113 (15%) | 104 (7%) |
| *Etheostoma gracile* | 31 (11%) | 26 (11%) | 14 (1%) | 5 (2%) | 13 (2%) | 15 (1%) |
| *Percina maculata* | 19 (7%) | 2 (1%) | 9 (1%) | 10 (4%) | 59 (8%) | 48 (3%) |
| Cottidae | | | | | | |
| *Cottus carolinae* | – (0%) | – (0%) | 3 (<1%) | – (0%) | – (0%) | – (0%) |
| Total individuals | 286 | 245 | 1604 | 261 | 736 | 1446 |
| Total species | 15 | 15+1 | 15+1 | 14 | 16+1 | 20+1 |

known to occur. Including data from previous sampling, there are 30 site records for the fringed darter in Illinois (Fig. 1).

## 4. Discussion

Adult males not discovered during the 2001 nest surveys could have been nesting either inside or outside the study sections or might have been eliminated from the breeding population through predation, disease, or dispersal. Fungal infection was a cause of mortality for developing embryos. Troll (1986) estimated mortality rates of 16 and 33% for eggs of spottail darter (*E. squamiceps*) in two Illinois streams. Drought conditions in 2002 caused complete drying of some pools within the study area in Bradshaw Creek and likely resulted in some mortality of fringed darters. However, juvenile and adult fringed darters persisted in several shallow pools along with other fish species. Accurately estimating the number of survivors in the present study would be difficult, and future abundance data and genetic analyses may provide more informative results.

The difference in growth of juveniles observed between the two streams in 2001 could be due to any number of factors such as resource abundance and competition from other fishes or crayfishes. Perhaps variation in resources among streams could account for the differences noted between adults from the two source populations as well as between juveniles at the two introduction sites. Considering the size difference noted between the two source populations and the apparently low number of males nesting at each introduction site in 2001, it is possible that juveniles from each site were over represented by parents from only one of the source populations and reflect heritable differences (founder effects) between the source populations. This can be addressed by future studies of the size distributions and genetic variation of both source and introduced populations (Minckley, 1995).

Competition for food and habitat would not likely occur between fringed darters and either slough or bluntnose darters, considering differences in ecology of these species (Braasch and Smith, 1967; Kuehne and Barbour, 1983; Page, 1983). Possible direct competition for breeding sites could occur with bluntnose minnows, which also nest on the undersides of rocks, and the reproductive seasons of the two species overlap partially (Page, 1980; Bandoli et al., 1991, this study). Concurrent nesting by fringed darters and bluntnose minnows has been recorded in several streams in Illinois, and in Mill Creek a nest of each species occurred on the same rock on 12 June 2000 (this study and unpublished data). Bandoli et al. (1991) observed simultaneous nesting by both spottail darters and bluntnose minnows in southwestern Indiana during mid to late May, but in the present study bluntnose minnows were breeding by mid to late April. When structures for egg laying are abundant, competition would likely be minimal or nonexistent. Both introduction sites have an abundance of Illinois crayfish (*Orconectes illinoiensis*), which may be another competitor with fringed darters for shelter rocks or which might prey on eggs or juveniles.

Although the long-term success of the translocations remains to be seen, the initial evaluation indicates the protocol used herein was successful based on (1) rapid initiation of breeding by adults, (2) normal period of breeding activity (March–May 2001 and 2002), (3) presence of juveniles (young-of-the-year) and adults during follow-up surveys (2001 and 2002), (4) reproduction by the 2001 year class of darters during the succeeding breeding season (2002), and (5) increase of $>6\times$ in number of nests during the second breeding season (2002). In terms of relative proportion of the fish community, fringed darters were abundant at both sites, ranking first to fourth in abundance over 2 years (Table 3).

Monitoring introductions for longer time periods is necessary but has been lacking in many translocation projects (Dodd and Seigel, 1991; Reinert, 1991). Annual surveys of the introduction sites and other areas in the two streams will reveal whether the species has become established. In addition to numbers of fishes observed or collected, nests can be recorded as a measure of abundance in future years (by seining, snorkeling, and visual inspection of rocks). Seining at the introduction sites during the reproductive season was avoided in 2001 because of the potential for disruption of spawning or destruction of nests, adults, and young-of-the-year darters. In 2002, seining was limited to small areas (checked for nests prior to seining) on one day at each introduction site later in the breeding season (to catch breeding adults for removal of fin tissue). Seining will not be carried out at the introduction sites during the breeding season for the next several years. In this study, detailed records were kept on weight, length, sex, and origin of fishes being introduced, and such records should be a routine part of translocation efforts (Griffith et al., 1989). Review of this information along with data from periodic monitoring might be useful for determining limitations of species in becoming established when successful and failed attempts are compared later, and ideally, such information should be made available in published literature (Minckley, 1995). The same factors involved in successful biological invasions, primarily by nonnative species, should be considered in translocation efforts for conservation (Burke, 1991; Moyle and Light, 1996). Abiotic factors were considered most important concerning invasion success of nonindigenous fishes (Moyle and Light, 1996).

The concept of the present study design was to move fishes at the beginning of their natural breeding season so that the number of introduced fishes can be considered in terms of the adults and their offspring, which substantially raises the number of fishes introduced. Moreover, if the fishes begin breeding soon after release at the new site, the chances of finding mates and reproducing successfully should be higher because they can breed before dispersal and mortality lower encounter rates among conspecifics. If successful reproduction occurs, there will be an additional age class, which should improve the chances of establishing a self-sustaining population. This same strategy can be repeated over successive years to boost the initial stocking while not taxing source population(s) by removing a large number of fishes at one time.

The translocation of fringed darters was intended to establish additional populations of the species within the same river basin as a protective measure to insure the survival of the species in Illinois. Additional goals and potential benefits include preventing the future listing of fringed darter as a State threatened or endangered species, learning if a relatively small number of fishes can successfully found a self-sustaining population, and applying the protocol to other similar species (particularly in the subgenus *Catonotus*) that are currently listed as threatened or endangered. Species such as relict darter (*Etheostoma chienense*), Barrens darter (*E. forbesi*), and duskytail darter (*E. percnurum*) have restricted ranges and have experienced modifications to their habitats, thus, are more susceptible to extirpation or extinction (Layman, 1991; Madison, 1995; Piller and Burr, 1999). Because the biology of darters that belong to the *Etheostoma squamiceps* species group and subgenus *Catonotus* is similar (Page, 1980; Bandoli et al., 1991), a closely-related species can be used as a surrogate to test various management strategies before implementing plans involving protected species. The result is likely to be a reduced failure rate and an ability to avoid unsuccessful restoration attempts. Efforts to reintroduce duskytail darters have been underway and have consisted of releasing captive-raised individuals (Shute et al., 1998). Other recent studies have examined the use of supplemental nest substrates by darters of the *Etheostoma squamiceps* species group, and the benefits of such habitat enhancement for conservation efforts appears promising (Bandoli et al., 1991; Piller and Burr, 1999). Restoration of degraded aquatic habitats might be beneficial in some instances as well.

If the fringed darter becomes established, the genetic composition of the new populations can be compared with the source populations, and several genetic principles believed to affect the survival of animal populations can be tested (Meffe, 1986). Population genetics of fringed darters and similar species was investigated by Strange (2000); however, detailed study of Illinois populations has not been performed. The use of wild-caught individuals for translocations alleviates potential negative effects of artificial selection that can occur in captive-raised populations (Meffe, 1986). In this study the starting population size was 60 fishes (20 male, 40 female), but the true effective population size during the initial colonization is unknown. Nevertheless, genetic evaluations will provide valuable information in regard to the number of individuals necessary for such a stocking program. Additional fringed darters could be moved to the two sites, but greater benefit to future translocation programs involving endangered species will be gained by evaluating the success of the initial translocations and by studying the genetic attributes of the populations. If 60 fish prove to be sufficient to establish the species, and especially, if no loss of genetic diversity is apparent, future translocations of this and other fish species can be attempted with less potential impact to source populations from removal of large numbers of individuals. Three of 13 introductions of four species of fishes in streams in Sri Lanka were successful with starting population sizes of 28, 31, and 91 individuals; unsuccessful translocations involved initial population sizes between 22 and 87 (mean = 48) (Wikramanayake, 1990). Besides the intended conservation goals of translocations in the Sri Lankan streams, a number of ecological questions were able to be addressed as well (Wikramanayake and Moyle, 1989).

Investigations of streams in the upper half of the Cache River basin did not result in captures of fringed darters, thus, the fringed darter has a restricted distribution, primarily in Mill Creek, Big Creek, and their tributaries (Fig. 1). Due to its recent discovery in Illinois, the fringed darter is not on the list of State threatened and endangered fishes (Illinois Endangered Species Protection Board, 1999). As recommended earlier (Poly and Wilson, 1998), the fringed darter should not be listed as a protected species in Illinois at present. Instead, efforts to restore habitats that have been disturbed, to prevent further degradation, and to acquire land for protection of fringed darter habitat as a preserve or conservation area would be most beneficial to this and other aquatic species.

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## References

Bandoli, J.H., Lanigan III., J.T., Sheckles, T.A., 1991. Reproduction in the spottail darter in Indiana: use of artificial nest sites. Proceedings of the Indiana Academy of Science 100, 65–75.

Berkman, H.E., Rabeni, C.F., 1987. Effect of siltation on stream fish communities. Environmental Biology of Fishes 18, 285–294.

Braasch, M.E., Mayden, R.L., 1985. Review of the subgenus *Catonotus* (Percidae) with descriptions of two new darters of the *Etheostoma squamiceps* species group. Occasional Papers, Museum of Natural History, University of Kansas 119, 1–83.

Braasch, M.E., Smith, P.W., 1967. The life history of the slough darter, *Etheostoma gracile* (Pisces, Percidae). Illinois Natural History Survey Biological Notes 58, 1–12.

Burke, R.L., 1991. Relocations, repatriations, and translocations of amphibians and reptiles: taking a broader view. Herpetologica 47, 350–357.

Dodd Jr., C.K., Seigel, R.A., 1991. Relocation, repatriation, and translocation of amphibians and reptiles: are they conservation strategies that work? Herpetologica 47, 336–350.

Etnier, D.A., 1972. The effect of annual rechanneling on a stream fish population. Transactions of the American Fisheries Society 101, 372–375.

Etnier, D.A., Starnes, W.C., 1993. The Fishes of Tennessee. The University of Tennessee Press, Knoxville, Tennessee.

Fuller, P.L., Nico, L.G., Williams, J.D. 1999., Nonindigenous Fishes Introduced into Inland Waters of the United States. American Fisheries Society, Bethesda, Maryland, Special Publication 27.

Griffith, B., Scott, J.M., Carpenter, J.W., Reed, C., 1989. Translocation as a species conservation tool: status and strategy. Science 245, 477–480.

Hickman, G.D., Fitz, R.B., 1978. A Report on the Ecology and Conservation of the Snail Darter (*Percina tanasi* Etnier) 1975–1977. Division of Forestry, Fisheries, and Wildlife Development, Tennessee Valley Authority, Norris, Tennessee, Technical Note B28.

Illinois Endangered Species Protection Board., 1999. Checklist of Endangered and Threatened Animals and Plants of Illinois. Springfield, Illinois.

Illinois Natural History Survey, 1978. An Assessment of the Water Quality of the Cache River Basin Derived from a biological Investigation. Prepared for the Illinois Environmental Protection Agency (project coordinator: A.R. Brigham). Illinois Natural History Survey, Urbana, Illinois.

Kuehne, R.A., Barbour, R.W., 1983. The American Darters. The University Press of Kentucky, Lexington, Kentucky.

Layman, S.R., 1991. Life history of the relict, duskytail darter, *Etheostoma* (*Catonotus*) sp., in Little River, Tennessee. Copeia 1991, 471–485.

Lopinot, A.C., 1972. Channelized Streams and Ditches of Illinois. Illinois Department of Conservation, Division of Fisheries, Special Fisheries Report No. 35.

Madison, L.M., 1995. Present distribution of a rare Tennessee fish. Journal of the Tennessee Academy of Science 70, 77–81.

Maitland, P.S., 1995. The conservation of freshwater fish: past and present experience. Biological Conservation 72, 259–270.

Meffe, G.K., 1986. Conservation genetics and the management of endangered fishes. Fisheries 11, 14–23.

Meffe, G.K., 1987. Conserving fish genomes: philosophies and practices. Environmental Biology of Fishes 18, 3–9.

Mettee, M.F., O'Neil, P.E., Pierson, J.M., 1996. Fishes of Alabama and the Mobile Basin. Oxmoor House, Birmingham, Alabama.

Minckley, W.L., 1995. Translocation as a tool for conserving imperiled fishes: experiences in western United States. Biological Conservation 72, 297–309.

Moyle, P.B., Light, T., 1996. Biological invasions of fresh water: empirical rules and assembly theory. Biological Conservation 78, 149–161.

Page, L.M., 1974. The life history of the spottail darter, *Etheostoma squamiceps*, in Big Creek, Illinois, and Ferguson Creek, Kentucky. Illinois Natural History Survey Biological Notes 89, 1–20.

Page, L.M., 1980. The life histories of *Etheostoma olivaceum* and *Etheostoma striatulum*, two species of darters in central Tennessee. Illinois Natural History Survey Biological Notes 113, 1–14.

Page, L.M., 1983. Handbook of Darters. TFH Publications, Neptune City, New Jersey.

Page, L.M., Ceas, P.A., Swofford, D.L., Buth, D.G., 1992. Evolutionary relationships within the *Etheostoma squamiceps* complex (Percidae; subgenus *Catonotus*) with descriptions of five new species. Copeia 1992, 615–646.

Page, L.M., Retzer, M.E., Stiles, R.A., 1982. Spawning behavior in seven species of darters (Pisces: Percidae). Brimleyana 8, 135–143.

Piller, K.R., Burr, B.M., 1999. Reproductive biology and spawning habitat supplementation of the relict darter, *Etheostoma chienense*, a federally endangered species. Environmental Biology of Fishes 55, 145–155.

Poly, W.J., 2000. Nest substrates and spawning time of *Etheostoma crossopterum* in southern Illinois. Transactions of the Illinois State Academy of Science 93, 301–305.

Poly, W.J., Wilson, A.K., 1998. The fringed darter, *Etheostoma crossopterum*, in the Cache River basin of southern Illinois (Percidae: subgenus *Catonotus*). Ohio Journal of Science 98, 6–9.

Rakes, P.L., Shute, J.R., Shute, P.W., 1999. Reproductive behavior, captive breeding, and restoration ecology of endangered fishes. Environmental Biology of Fishes 55, 31–42.

Reinert, H.K., 1991. Translocation as a conservation strategy for amphibians and reptiles: some comments, concerns, and observations. Herpetologica 47, 357–363.

SAS Institute, Inc., 1999. StatView, v. 5.0.1. SAS, Cary, North Carolina.

Shute, P., Shute, J.R., Rakes, P.L., Biggins, R.G., 1998. Recovery success for four listed fish. Endangered Species Bulletin 23, 30–31.

Strange, R.M., 2000. Evolution of Sexual Dimorphisms in Spottail Darters (Teleostei: Percidae). Unpublished PhD dissertation, University of Alabama, Tuscaloosa, Alabama.

Trautman, M.B., 1981. The Fishes of Ohio, revised ed. Ohio State University Press, Columbus, Ohio.

Troll, M.B., 1986. Non-random Mating in the Spottail Darter (*Etheostoma squamiceps*). Unpublised MS thesis, Illinois State University, Normal, Illinois.

Wikramanayake, E.D., 1990. Conservation of endemic rain forest fishes of Sri Lanka: results of a translocation experiment. Conservation Biology 4, 32–37.

Wikramanayake, E.D., Moyle, P.B., 1990. Ecological structure of tropical fish assemblages in wet-zone streams of Sri Lanka. Journal of Zoology (London) 218, 503–526.

Williams, J.E., Sada, D.W., Deacon Williams, C., et al., 1988. American Fisheries Society guidelines for introductions of threatened and endangered fishes. Fisheries 13, 5–11.

Zar, J.H., 1999. Biostatistical Analysis, fourth ed. Prentice-Hall, Upper Saddle River, New Jersey.