Reintroduction of Four Imperiled Fishes in Abrams Creek, Tennessee

Article *in* Southeastern Naturalist · January 2009

DOI: 10.1656/1528-7092(2005)004[0093:ROFIFI]2.0.CO;2

3 authors, including:

Peggy Shute
U.S. Fish and Wildlife Service
14 PUBLICATIONS **228** CITATIONS

SEE PROFILE

2005 *SOUTHEASTERN NATURALIST* 4(1):93–110

Reintroduction of Four Imperiled Fishes in Abrams Creek, Tennessee

J.R. SHUTE[1], PATRICK L. RAKES[1], AND PEGGY W. SHUTE[2,*]

Abstract - This project's goal was to restore populations of four rare fishes into Abrams Creek, Blount County, TN. These species, all on the US Endangered and Threatened Wildlife List, include two catfishes, the smoky madtom (*Noturus bailey*) and the yellowfin madtom (*N. flavipinnis*), the duskytail darter (*Etheostoma percnurum*) and the spotfin chub (*Erimonax monachus*). Captive propagation, reintroduction, and non-invasive monitoring techniques were used for this restoration effort, which began in 1986. By 2000, there was evidence of reproduction for all four species. As of 2003, the number of these species stocked in Abrams Creek was 3167 smoky madtoms, 1574 yellowfin madtoms, 3430 duskytail darters, and 11,367 spotfin chubs. Increasing population sizes were indicated for three of the four fishes, and smoky madtom and duskytail darter abundances were nearly comparable to native populations in Citico Creek, Monroe County, TN.

Introduction

Most recovery plans of federally listed fishes call for restoring extirpated populations, with the goal of downgrading status, or removing the species from the Endangered and Threatened Wildlife list. In many situations, because of the rarity of the target species, captive propagation may be the most appropriate method to obtain individuals for stocking. However, as Meffe (1987) noted, captive propagation for non-game fishes, especially rare or sensitive species has not been a focus of hatcheries. This is especially true in the southeastern United States, although recently several federal and state fish hatcheries have become more involved in projects to propagate rare fishes and mussels (Andreasen and Springer 2000).

Since the 1960s, endangered and threatened species in the western United States have been propagated for reintroduction projects (Andreasen and Springer 2000, Hendrickson and Brooks 1991, Johnson and Jensen 1991). Many of these rare western fishes are large minnows (Cyprinidae), suckers (Catostomidae) and pupfishes (Cyprinodontidae), groups of fishes for which the culture techniques have been developed. Fisheries biologists have cultured related minnows as forage or bait for game fishes, and husbandry for pupfish and other killifish has been developed by specialized hobbyist groups and is generally well known.

[1]Conservation Fisheries, Inc., 3424 Division Street, Knoxville, TN 37919. [2]Regional Natural Heritage Project, Tennessee Valley Authority, 400 West Summit Hill Drive, WT 11C-416, Knoxville, TN 37920. [*]Corresponding author - pwshute@tva.gov.

In the southeastern United States, most of the rare fishes are madtom catfishes (Ictaluridae), darters (Percidae), and reproductively specialized minnows (Etnier and Starnes 1991). Many species of southeastern fishes are being extirpated from parts of their historical ranges. There have been a few attempts to transplant or reintroduce rare southeastern fishes. For example, snail darters (*Percina tanasi* Etnier, threatened) have been translocated (Etnier and Starnes 1993), as have watercress darters, (*Etheostoma nuchale* Howell and Caldwell, endangered; Howell and Black 1976, US Fish and Wildlife Service 1993a). Spring pygmy sunfish (*Elassoma alabamae* Mayden, Elassomatidae), robust redhorse (*Moxostoma robustum* (Cope), Catostomidae), and lake sturgeon (*Acipenser fulvescens* Rafinesque, Acipenseridae), have been reintroduced into formerly occupied areas (Bryant et al. 1996, Freeman 1999, Mayden 1993, Shute and Etnier 2001). Despite an increasing proportion of jeopardized fauna (Etnier 1994, Warren and Burr 1994, Warren et al. 2000, Williams et al. 1989), few southeastern fishes have been maintained in aquaria or cultured in hatcheries in association with recovery programs. For many, life history requirements are poorly known, including physical factors necessary to stimulate reproduction and allow for larval and juvenile growth in captivity.

Of the reintroduction or translocation projects listed above, only robust redhorse and lake sturgeon involved captive propagation to produce transplant animals and multiple stockings in a single stream. The spring pygmy sunfish reintroduction and the snail darter and watercress darter translocations have been successful, based on sustained reproduction and recruitment (Etnier and Starnes 1993, Howell and Black 1976, Mayden 1993, US Fish and Wildlife Service 1993a). Robust redhorse and lake sturgeon individuals have been observed since stocking, but these efforts have been too recent to determine success.

Background

Historically, four fishes that are currently federally threatened or endangered were known from Abrams Creek in the Little Tennessee River system, Blount County, TN (Fig. 1). These are smoky madtom, *Noturus baileyi* Taylor (Ictaluridae, endangered); yellowfin madtom, *N. flavipinnis* Taylor (threatened); duskytail darter, *Etheostoma percnurum* Jenkins (Percidae, endangered); and spotfin chub, *Erimonax* (= *Cyprinella*) *monachus*(Cope) (Cyprinidae, threatened). A 1957 stream reclamation project to enhance the trout fishery resulted in the extirpation of all four species (Lennon and Parker 1959, Simbeck 1990).

The smoky madtom was originally only known from Abrams Creek, and because of the 1957 project, was presumed extinct when it was formally described by Taylor (1969). It was subsequently listed as

endangered when an extant population was discovered in Citico Creek (also a Little Tennessee River tributary, Fig. 1) in the nearby Cherokee National Forest, Monroe County, TN (Bauer et al. 1983, Dinkins 1984, Dinkins and Shute 1996, US Fish and Wildlife Service 1984a).

The yellowfin madtom was historically more widespread throughout the upper Tennessee River drainage, but was also presumed extinct at the time of its formal scientific description (Taylor 1969). The discovery of three extant, but geographically isolated, populations in the late 1970s and early 1980s resulted in its listing as a threatened species. At the time of listing, the existence of the Citico Creek population was unknown (Dinkins and Shute 1996, Shute 1984, US Fish and Wildlife Service 1977).

The duskytail darter was presumably relatively widespread throughout the upper Tennessee and parts of the Cumberland drainages (US Fish and Wildlife Service 1994). It is presently known only from four geographically isolated localities: one in the Cumberland River drainage and three extant populations in the Tennessee River drainage, including the one in Citico Creek (Jenkins 1993; Layman 1984a, 1984b, 1991). It was listed as endangered in 1993 (US Fish and Wildlife Service 1993b, 1994).

Historically, the spotfin chub was relatively widespread, being found in larger streams throughout most of the Tennessee drainage in Georgia, North Carolina, Tennessee, and Virginia, including Citico Creek (specimens from 1936 in the University of Michigan Museum of Zoology: UMMZ 113292) , and Abrams Creek (specimens from 1941: UMMZ 163294, 129466, and 1632805). Presently, the species is only known from four tributary stream systems in the Tennessee drainage in North Carolina, Tennessee, and Virginia (Jenkins and Burkhead 1984). In the Little Tennessee River system, it is presently found in the mainstem of the river upstream of Fontana Reservoir, and in the lower ends of a few tributaries, Swain and Macon Counties, NC. It was listed as a threatened species in 1977 (Jenkins and Burkhead 1984, US Fish and Wildlife Service 1977).

The objective of this long-term study, which began in 1986, was to determine the feasibility of re-establishing viable populations of fishes within their former range. Over this period we have been able to collect data on fishes with very different life history requirements. Three species are benthic: the duskytail darter, the riffle-dwelling smoky madtom, and the pool-dwelling yellowfin madtom; and the fourth species, the spotfin chub, is a mid-water schooling minnow.

History of the reintroduction project

Abrams Creek is a moderate sized (10–25 m width) fourth order stream, with a drainage area of about 23,000 hectares (Fig. 1). A 7.6 m

waterfall (Abrams Falls) at creek km 22.4 isolates the aquatic community into two distinct segments (Simbeck 1990). Below the waterfall, the stream flows 19.4 km through the Valley and Ridge physiographic province to its inundation by Chilhowee Reservoir.

As mentioned above, in 1957, in conjunction with the closing of Chilhowee Dam on the Little Tennessee River, nearly all of the fishes from the section of the stream downstream of Abrams Falls were eliminated by ichthyocides intended to enhance the trout fishery (Lennon and Parker 1959, Simbeck 1990). Although some fishes have reinvaded the stream, nearly half of the 64 species historically reported from this reach of Abrams Creek were extirpated (Simbeck 1990), including the four imperiled species. The historic fish diversity of the lower portion of Abrams Creek was comparable to the current Citico Creek assemblage, where extant populations of three of these four species are known (see Dinkins and Shute 1996).

In 1986, a multi-agency project to restore the native fish fauna in Abrams Creek was initiated. Rare fishes were the first targets for restoration. Cooperators included the North Carolina Wildlife Resources

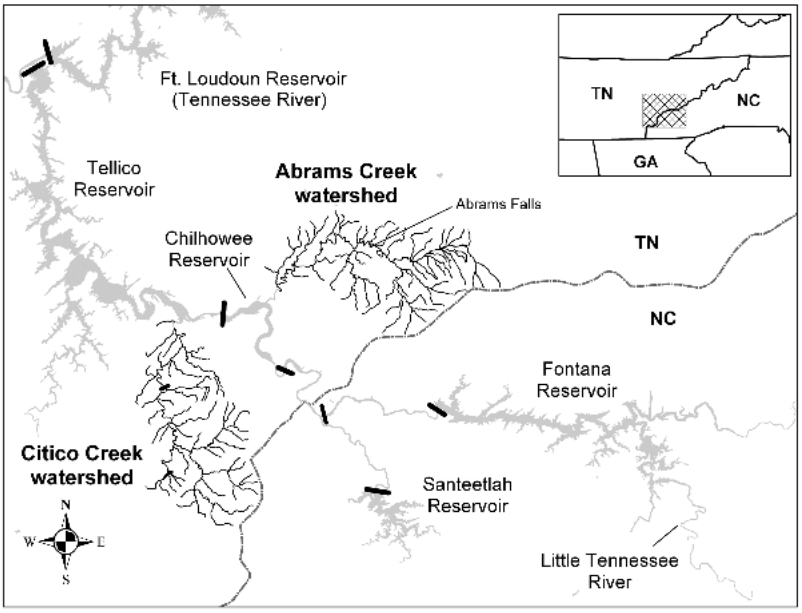

Figure 1. Map of portions of the Little Tennessee River system of the Tennessee River drainage in Tennessee and North Carolina, showing Abrams Creek (location of reintroduction efforts) and Citico Creek (location of source populations for smoky and yellowfin madtoms and duskytail darters). The mainstem of the Little Tennessee River upstream of Fontana Reservoir is the source for spotfin chubs. Dams are indicated by black bars.

Commission (NCWRC), Tennessee Wildlife Resources Agency (TWRA), US Fish and Wildlife Service (FWS), US Forest Service (USFS), National Park Service (NPS), and University of Tennessee (UT). A Recovery Team consisting of representatives from these agencies met annually to discuss and prioritize management activities, based on the most recent survey information. Establishing viable populations of federally listed fishes within their historical ranges has been a high priority goal outlined in the FWS' recovery plans for these four listed species (US Fish and Wildlife Service 1983, 1984b, 1985, 1994).

One of the first efforts in this project was the collection and immediate transportation of spotfin chubs from the Little Tennessee River upstream of Fontana Reservoir (Swain County, NC) to Abrams Creek. Dr. David Etnier (UT) led the collecting efforts, assisted by FWS, NPS, NCWRC, and TWRA personnel. Since the spotfin chub population in this section of the Little Tennessee River was relatively robust, removing these individuals was considered not to be detrimental to the long-term persistence of the population. Approximately 630 individuals were collected and stocked in Abrams Creek between 1988 and 1990 (Table 1). However, because no spotfin chubs were

Table 1. Number of individuals of four imperiled fishes stocked into Abrams Creek, Great Smoky Mountains National Park, Blount County, TN from 1986–2003. In some cases (noted by asterisks), stocked fish included adults spawned in previous years. Details of annual efforts were included in annual, unpublished reports to FWS, TWRA, FWS, and NPS[A].

Year	Smoky madtom (*Noturus baileyi*)	Yellowfin madtom (*Noturus flavipinnis*)	Duskytail darter (*Etheostoma percnurum*)	Spotfin chub (*Erimonax monachus*)
1986	0	18	0	0
1987	92	115	0	0
1988	118	155	0	250[B]
1989	174	90	0	38[B]
1990	151	0	0	340[B]
1991	134	0	0	0
1992	0	0	0	0
1993	52*	0	85	0
1994	38*	26*	51	709*
1995	166*	94*	118*	1200
1996	116*	0	667*	0
1997	438*	0	396*	0
1998	116*	61*	216*	3500
1999	369*	247*	203*	3350
2000	604*	365*	0	500
2001	264*	85*	1694*	1480
2002	315*	286*	0	0
2003	20*	32*	0	0
Total	3167	1574	3430	11,367

[A]The most recent report is Rakes and Shute (2004).

[B]These individuals were collected from the Little Tennessee River upstream of Fontana Reservoir and transported directly to Abrams Creek. Most were adults.

seen in Abrams Creek following the 1988 and 1989 stockings, the Recovery Team recommended that captively produced individuals be used for any future stocking. Conservation Fisheries, Inc. (CFI), a nonprofit organization managed by two of the authors of this paper (JRS and PLR), began propagating spotfin chubs for the reintroduction project in 1994 (see Rakes et al. 1999).

Nearby Citico Creek is the only source for smoky madtoms, and Citico's yellowfin madtom population was determined to be the most appropriate source for the restoration in Abrams Creek. However, smoky and yellowfin madtom populations in Citico Creek were not thought to be robust enough to remove individuals for stocking. Therefore, efforts to captively produce these madtoms were begun at UT in 1986. This effort was eventually moved to a facility operated by CFI.

CFI also developed techniques for propagating duskytail darters from Citico Creek before this species was listed as endangered. The successful completion of this task, and the species' listing as endangered resulted in the addition of this darter to the Abrams Creek restoration project.

Methods

Captive propagation

Smoky and yellowfin madtoms used for the reintroduction efforts were obtained by collecting egg or larval clutches from nests in Citico Creek and rearing them in laboratory aquaria. As reported by Dinkins and Shute (1996), male smoky and yellowfin madtoms defend slabrocks and guard egg clutches located beneath them. Yellowfin and smoky madtom nests contain about 100 and 30 eggs, respectively (Dinkins and Shute 1996). These egg clutches were collected by snorkeling during the spawning season, looking beneath large, flat rocks, and gently collecting the egg masses. Egg masses were transferred into plastic bags by hand or with a hand-held dip net such that they were never exposed to air. Occasionally newly hatched larvae were discovered. These were collected with a turkey baster and also transferred to plastic bags held open under the surface of the water. Eggs or larvae were collected from many different areas throughout each species' range within Citico Creek. In addition to rearing wild-collected madtom nests, CFI also maintained a captive adult population and attempted to stimulate reproduction in aquaria.

Duskytail darters stocked in Abrams Creek were reared from eggs produced by captive adults or eggs collected from Citico Creek. Duskytail darters also use flat rocks for nesting cover; eggs are attached to the undersides of the rock. Although single males attend nests, their nests may contain eggs produced by several females (Layman 1984a,

1984b, 1991). These wild-spawned nests were collected by snorkeling during the spawning season and looking beneath appropriate rocks. When nests were found, the rocks with eggs attached were transported in coolers of creek water to the CFI facility for rearing.

Since 1994, all spotfin chubs used for stocking Abrams Creek were spawned and reared in captivity as described by Rakes et al. (1999). Spotfin chubs deposit eggs in crevices in rocks on the stream bottom (Jenkins and Burkhead 1984). The captive spotfin chubs that produced aquarium-spawned eggs were collected from the Little Tennessee River just upstream of Fontana Reservoir. Approximately 20 individuals were collected every other year and added to the captive population. Because spotfin chubs are believed to live three or four years, some adults probably spawned for two consecutive years. An average of 12–18 adults each year comprised spawning groups.

This paper does not present details of the collection or transportation of adults, nests, eggs or larvae, or the captive propagation portion of this project. The hatchery aquarium systems and husbandry techniques used to maintain and propagate all of the fishes used for this project have evolved since 1986, and have been detailed in annual, unpublished reports to TWRA, FWS, USFS, and NPS from 1986 through 2004.

Genetic makeup of founding populations

Meffe (1986, 1987) discussed captive propagation and reintroduction of endangered fishes. He noted that reintroduction projects should strive to document the genetic variation present in wild, natural populations of the target species, and to account for this genetic variation in captive populations and in the founders of restored populations. When this project began, genetic techniques necessary to answer these questions would have required the sacrifice of many individuals. The rarity of the subject fishes and their federal protection status precluded this. We have attempted to introduce the maximum amount of genetic variation present in the source populations in the reintroduced populations by varying collections spatially and temporally: 1) nests collected for captive propagation were taken from throughout the range of the fishes in Citico Creek; 2) the reintroduced populations were supplemented by multiple, mostly annual, stockings; and 3) wild-collected individuals were added to the captive spawning groups, more or less annually.

Stocking logistics

Originally, we stocked Abrams Creek in late summer or early fall with four or five month-old fishes. However, we theorized that more individuals would survive if they were released at a larger size, and if they were not required to survive winter in the stream so soon after stocking. Therefore, after 1992, most fishes released into Abrams Creek

were approaching one year of age, and had been held in the CFI hatchery through winter. Many stocked smoky madtoms and duskytail darters would have been reproductively mature and able to spawn soon after being introduced to the creek.

Many individuals were released at night so that they could be acclimated to their natural surroundings with minimal likelihood of being preyed upon. The specific stream reaches stocked have gradually increased from a single pool and glide in 1986 up to 22 pools or glides in 2003, over approximately 6.5 stream km. Groups of fishes to be stocked were certified as disease or pathogen-free, according to FWS protocols (pers. comm., Norman Heil, Warm Springs National Fish Hatchery).

Population monitoring

For the long-term, global persistence of all four rare fishes, we determined that it was imperative to monitor both the establishment of reintroduced populations in Abrams Creek and the source population in Citico Creek. We used a direct observation, visual census described by Dinkins and Shute (1996) because continued harassment of these rare fishes using traditional survey methods (seining and/or electroshocking) would be counterproductive. In an effort to standardize annual effort, and to afford comparison between the natural and reintroduced populations, abundance indices (number of fish observed per person hour of observation) were developed from these snorkel surveys. Methods and personnel were as consistent as possible between years.

Beginning in 2001, some stocked fishes were tagged (injected with Northwest Marine Technologies' VIE© tags—Visible Implant Elastomer,) as a method to follow dispersal and survival in the reintroduced populations. CFI aquarium trials with several species of darters, madtoms, minnows, and topminnows (unpubl. data, J.R. Shute) indicated that Elastomer tags can be retained and still observed at least as long as three years. In addition, Coombs (2003) tagged 90 redline darters (*Etheostoma rufilineatum* (Cope)) with various colors of paint and observed them in CFI aquaria for 125 days. Although she noted that some colors were more easily seen than others, all fish retained their tags, and there was no mortality during this trial. In the field, she observed tagged redline darters more than a year after they had been tagged and released. Bailey et al. (1998) found tag retention of coho salmon (*Oncorhynchus kisutch* (Walbaum)) smolts to range between 90 and 98%. Since 2001, CFI ahs released a total of 599 tagged smoky madtoms, 403 tagged yellowfin madtoms, and approximately 200 tagged spotfin chubs.

Results

Status of captive propagation and stocking

Ten to twenty smoky madtom clutches and two or three yellowfin madtom clutches have been removed from Citico Creek for captive propagation each year between 1986 and through the end of 2003. Between 1993 and 2003, five to ten duskytail darter nest rocks (with eggs attached, as described above) also have been removed from Citico Creek for captive reproduction. Survivorship has varied considerably between egg clutches and years, but overall has averaged 53% for yellowfin madtoms, 55% for smoky madtoms, and 49% for duskytail darters. The duskytail darter figure includes survivorship of wild-collected eggs and eggs spawned in laboratory aquaria. Survivorship of wild-spawned eggs is much higher than those spawned in the aquaria (unpubl. data, P.L. Rakes). Spotfin chubs produce large numbers of offspring that are difficult to count; therefore survivorship estimates are not reported here.

From 1986 through the end of 2003, there were 3167 smoky madtoms, 1574 yellowfin madtoms, 3430 duskytail darters, and 11,367 spotfin chubs stocked in Abrams Creek (Table 1). A management activity designed to augment the Citico Creek population resulted in stocking some captively reared yellowfin madtoms in Citico Creek instead of Abrams Creek in 1990, 1993, and 1996 (see Table 1), and in 1999 captively produced individuals were stocked in both streams. In 1991 and 1997, no yellowfin madtom nests were collected, so none were stocked in either Abrams or Citico creeks. Young reared from nests collected in spring and summer 1992 were kept in aquaria through the winter and released in the spring of 1993.

Status of Abrams Creek reintroduction

Since the initial stocking in the fall of 1986 and through 2003, there have been 123 separate observations of smoky madtoms, 74 observations of yellowfin madtoms, 433 observations of duskytail darters, and 147 observations of spotfin chubs documented in Abrams Creek (Table 2).

Smoky madtom. Reintroduced smoky madtoms were first observed in Abrams Creek in 1990. Since then, observations have been relatively consistent, and individuals have been increasingly abundant. Abundance indices for smoky madtom surveys in Abrams Creek have varied between 0.03 and 1.5 from 1986 to 2003 (Fig. 2), which are nearly comparable to Citico Creek indices (unpubl. data, P.L. Rakes). However, the index for Abrams Creek in 2002 surveys actually exceeded the highest ever for observations in Citico Creek (1.3). In addition, since 1996 we have consistently observed evidence that smoky madtoms are reproducing in Abrams Creek (Table 2). In 2002, 43 of the total 56 smoky madtoms observed were young-of-year. Because none of the

individuals released in 2002 were young from 2002 spawns, these individuals all resulted from successful spawning in Abrams Creek. In 2003, only 17 smoky madtoms were observed, but 13 of these were young-of-year, and none of the fish were tagged—all were wild-spawned.

Yellowfin madtom. In some years, no yellowfin madtoms were stocked in Abrams Creek (see Table 1) because the Recovery Team recommended stocking captively reared individuals in Citico Creek to augment its tenuous population. However, in spite of stocking irregularity, reintroduced yellowfin madtoms have been found in Abrams Creek almost every year since 1994 (Fig. 2). Abundance indices for Abrams Creek surveys through 2003 were not as high as those from our Citico Creek observations, but they have gradually increased. Since 1995 we have periodically observed evidence of yellowfin madtom spawning in Abrams Creek; in 2002 young yellowfin madtoms were found in many locations throughout Abrams Creek (Table 2). As with smoky madtom observations, a majority of the yellowfin madtoms observed in 2002 (16 of 29) were young-of-year, all the result of Abrams Creek spawning. Although only nine yellowfin madtoms were observed in 2003, these

Table 2. Number of individuals of four fishes reintroduced into Abrams Creek, Great Smoky Mountains National Park, Blount County, TN, observed in snorkel surveys from 1986–2003. NA indicates not applicable. Asterisks indicate that evidence of reproduction was observed during snorkel surveys. Details of annual efforts were included in annual, unpublished reports to FWS, TWRA, FWS, and NPS[A].

Year	Smoky madtom (*Noturus baileyi*)	Yellowfin madtom (*Noturus flavipinnis*)	Duskytail darter (*Etheostoma percnurum*)	Spotfin chub (*Erimonax monachus*)
1986	NA	0	NA	NA
1987	0	0	NA	NA
1988	0	0	NA	0
1989	0	0	NA	0
1990	1	0	NA	0
1991	2	0	NA	0
1992	0	0	NA	0
1993	1	0	2	0
1994	4	1	0	0
1995	8	3*	18*	2
1996	2*	2	16*	0
1997	5*	0	22*	0
1998	8*	1	14*	91
1999	5*	11	19*	46[B]
2000	11*	10*	54*	8*
2001	3*	8*	47*	0
2002	56*	29*	119*	0
2003	17*	9*	122	0
Totals	123	74	433	147

[A] The most recent report is Rakes and Shute (2004).

[B] In addition to the snorkel surveys reported here, eleven spotfin chubs were collected by NPS personnel using electroshockers (D.A. Etnier, University of Tennessee, pers. comm).

were all believed to be wild-spawned, since no untagged yellowfin madtoms had been released since 2001.

Duskytail darter. Duskytail darters have been observed in Abrams Creek since 1993, and although abundance indices for our observations of the reintroduced population are not as high as Citico Creek (2.1 to 7.9 between 1994 and 2001, unpubl. data P.L. Rakes) they have steadily increased (Fig. 2). Since 1995, males guarding nests and wild-spawned young-of-year duskytail darters have been consistently observed (Table 2).

Spotfin chub. We observed spotfin chubs in Abrams Creek beginning in 1995, and individuals were observed in relatively high densities for two consecutive years (1998 and 1999, Fig. 2). Although the abundance index for 2000 observations was lower than the previous few years, the first evidence of reproduction was noted in the reintroduced population in October 2000, when three young-of-year spotfin chubs were observed by several snorkelers. No spotfin chubs were observed during surveys in 2001, 2002, or 2003, but because of their relative mobility, we assume that spotfin chubs may disperse more quickly throughout Abrams Creek than the other three reintroduced fishes. Also, recent collection of spotfin chubs in small streams in the Little Tennessee and Holston watersheds (unpubl. data, TVA Regional Natural Heritage Project) sug-

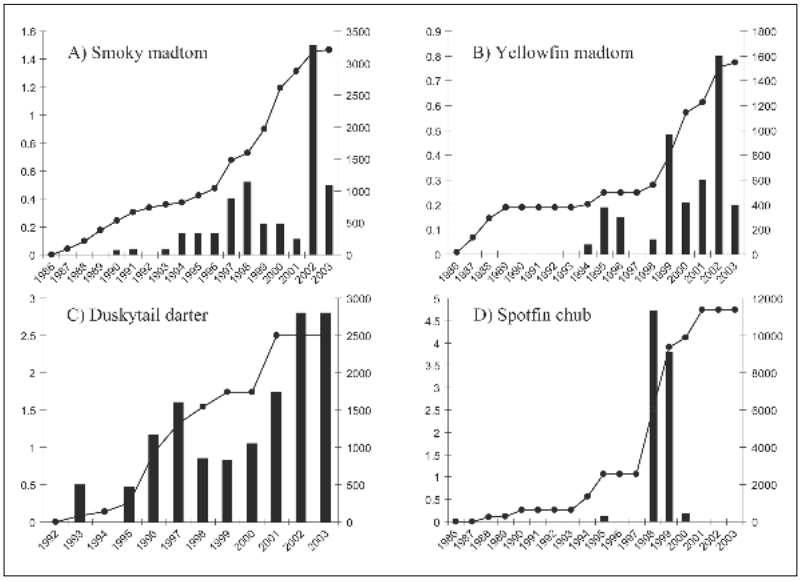

Figure 2. Average annual abundance indices (bars, left scale) calculated from snorkel observations of four imperiled fishes reintroduced into Abrams Creek, Great Smoky Mountains National Park, Blount County, TN from 1986–2002. Lines on each graph indicate the cumulative number of individuals (right scale) that were stocked.

gest that spotfin chubs may use smaller streams seasonally. Citico and Abrams Creeks are considerably smaller sized streams than those where spotfin chubs are considered to have resident populations. Therefore, the historic records may represent seasonal use, and the main resident population would have been found in the Little Tennessee River proper. Jenkins and Burkhead (1984) also indicate that spotfin chub populations in lower Abrams and Citico creeks may have been somewhat reliant on a hypothetical lower Little Tennessee River population. Additionally, regular surveys of the Little Tennessee River source population (upstream of Fontana Reservoir) have not occurred. Therefore, abundance indices for natural spotfin chub populations were not available for comparison to Abrams Creek.

Discussion

Qualifications for reintroduction projects

Tear et al. (1993) noted that 64% of 314 recovery plans for US federally listed species call for reintroduction as a recovery task. Conant (1988) noted that reintroduction might not be practical because areas where a species has been extirpated may still not be suitable for the reasons that the species was extirpated in the first place, and that translocation into suitable habitats not known to have been inhabited by the species might be preferable. There are few reports of fish reintroduction attempts, especially for the small, nongame species that dominate the Endangered and Threatened Wildlife List from the southeastern United States.

Abrams Creek is a good candidate for species reintroduction for several reasons. A short-term event in Abrams Creek resulted in the extirpation of the four listed fishes, and the coincidental creation of the impoundment prevented these fishes from re-establishing populations. Abrams Creek, with its watershed located mostly within the Great Smoky Mountains National Park, is more likely to maintain suitable water and habitat quality than a stream draining privately owned lands. This locality is also within the core of the historic range for all four fishes. Griffith et al. (1989) and Sarrazin and Legendre (2000) have suggested a reintroduction is most likely to be successful in the core of a species' historic range.

Deterrents to success

Few streams are truly pristine and Abrams Creek has been degraded by livestock and tourists in Cades Cove (Matthews 1978). Until recently, the NPS sought to maintain the historical integrity of the park by allowing cattle farming in Abrams Creek headwaters in Cades Cove. As a result, Abrams Creek has been affected by sediment loading and elevated nutrient concentrations (Matthews 1978). Since 1993, a cooperative project between NPS, USFS, UT, Tennessee Valley Authority,

Trout Unlimited, and a local wildlife artist has apparently improved the water and habitat quality in Abrams Creek (Fraley 1998) by restoring riparian vegetation and fencing and removing cattle from Abrams Creek and its tributaries in Cades Cove.

Reading et al. (1991) pointed out the importance of involving the local public, whose support and cooperation are necessary for any reintroduction project to be successful. At Abrams Creek, part of the stocking area is adjacent to a well-used NPS campground, and although the "local public" includes many frequent park users, there are also many visitors from across the country. Educational information is needed to lessen the impacts of unintentional habitat destruction or fish harassment by these visitors. Campers building small rock dams in the creek are reducing the spawning cover available for nesting madtoms and duskytail darters, and could also unknowingly be reducing reproductive success by dislodging eggs. The dams alter flow patterns, sediment deposition, and microhabitats. Some of these dams have been constructed from almost every moveable rock in the immediate area. Our 2002 smoky madtom observations indicated that this innocent activity could affect the survival and expansion of the smoky madtom population in these high use areas. Declines in abundance index were noted in these high use areas in 2002, and the only smoky madtoms observed in 2003 were in remote sections of Abrams Creek. Ostermann et al. (2001) summarized factors affecting reintroduction success in projects like this one, and noted human-related mortality of released animals as an important concern.

Deterrents to documenting success

Our experiences prompt us to caution others looking for success in similar projects not to abandon efforts prematurely. It takes time to document success when stocking limited numbers of non-game fishes because they are small, short lived, and cryptic. The smoky madtom and duskytail darter are small, cryptic, benthic fishes that live only one or two years and probably do not quickly move far from stocking sites (Dinkins and Shute 1996). The yellowfin madtom, though slightly longer-lived (three or four years), is completely nocturnal, and in addition to the characteristics listed above must be surveyed for after dark. While the spotfin chub is less cryptic than the other three fishes, it can be difficult to identify while snorkeling, especially when mixed with other schooling minnows, and may disperse a considerable distance beyond the initial stocking sites.

Determination of success

Etnier (1994) discussed rarity of fishes and our ability to detect them. He suggested that increasing sampling efforts, especially for species that normally exist in low population densities, would increase

our ability to determine whether a fish population has become extirpated or whether it simply exists at very low levels. As Figure 2 indicates, there appear to be threshold population levels above which we were ultimately able to detect the presence of the rare fishes being stocked in Abrams Creek. These thresholds were different for each species. Observations of three of the four target species in Abrams Creek have been relatively common in recent years, and abundances of smoky madtoms and duskytail darters approach those in Citico Creek. In addition, we have now documented reproduction of all four reintroduced species in Abrams Creek. In fact, the unusually high proportion of young-of-year smoky and yellowfin madtoms observed in 2002 surveys suggest explosive population increases may be occurring.

We report here that our efforts to reintroduce smoky and yellowfin madtoms and duskytail darters into Abrams Creek have been successful. Whether spotfin chubs are present in low, dispersed densities (see Etnier 1994), or whether spotfin chubs have failed to become established in Abrams Creek is yet to be determined. Until all four fishes are much more widespread throughout the entire 19.4 km of lower Abrams Creek, and populations of all four are self-sustaining and relatively stable over 10 years (as suggested in recovery plans for all four species; US Fish and Wildlife Service 1983, 1984b, 1985, 1994) the project will not be complete.

In the southeastern US, we know of only a few attempts to reintroduce fishes, and even less documentation of success or failure (see Introduction). Although criteria suggested by Ostermann et al. (2001) based on mammal reintroductions (including survival and recruitment) may be appropriate for assessing success of fish reintroductions, we suggest that the necessary data are lacking, and may be difficult or impractical to obtain for the small, nongame fishes that comprise a large proportion of federally listed fishes in the southeastern United States. Direct observation, abundance indices, and consistent evidence of spawning in the newly established population may be, by necessity, sufficient evidence to evaluate success.

Anders (1998) commented on what is often a crisis situation in conservation biology—managing endangered and threatened species, and the reluctance that may accompany recommendations for captive propagation and reintroduction. The potential outcome of our project was also uncertain when we began these efforts in 1986. However, we report that with relatively small amounts of funding and effort, additional populations of three endangered or threatened fishes are well on their way to becoming re-established in a formerly occupied stream. The status of the spotfin chub efforts is presently inconclusive.

Acknowledgments

We would like to thank: US Fish and Wildlife Service, especially Dick Biggins, for funding and for granting permits allowing us to handle these rare fishes; TWRA, especially Bob Hatcher and Richard Kirk, for granting permits and soliciting project funds; USFS, especially Jim Herrig, for allowing founding animals to be removed (via nests) from their population in the Cherokee National Forest and for providing funds to monitor the source populations of smoky and yellowfin madtoms and duskytail darters; the NPS for permission to stock these rare fishes; and the World Wildlife Fund for providing journal publication costs. The Tennessee Aquarium, especially Matt Hamilton, helped to rear fish. The Fish Health Center at Warm Springs National Fish Hatchery conducted disease and pathogen assays for fishes to be stocked. Northwest Marine Technologies, Inc. supplied tagging equipment and materials for the Visible Implant Elastomer tags (VIE ©) for tagging stocked fishes. Many UT students and other volunteers helped to snorkel Citico Creek searching for nests, and also Abrams Creek surveying for stocked fishes. These include Bo (John T.) Baxter, Dick Biggins, Stephanie Brough, Chris Cameron, Bill Chipley, Chris Coco, Joyce Coombs, Gerald Dinkins, Mike Doosey, David Etnier, Michael Etnier, Brian Evans, Steve Fraley, Kelly Harpster, Barry Hart, Jim Herrig, Nanci Jackson, Ben Keck, Jason Khym, Frank Kriegler, Matt Kulp, Steve Layman, Rick LeDuc, Lee Eichols, Jim Negus, Chris Paxton, Melissa Petty, Chris Skelton, Amanda Smith, John Taylor, Kelly Taylor, David Teague, Craig Walker, Darlene Walther, Sherry Wehner, and Bill Yambert. Gary Pyle and Bo Baxter assisted with figures, and Carol Johnston, Jim Williams, Mary Freeman, and two anonymous reviewers provided constructive comments on the manuscript.

Literature Cited

Anders, P.J. 1998. Conservation aquaculture and endangered species: Can objective science prevail over risk anxiety? Fisheries 23(11):28–31.

Andreasen, L., and C. Springer. 2000. Hatcheries promote fish recovery. Endangered Species Bulletin 25:32–33.

Bailey, R.E., J.R. Irvine, F.C. Dalziel, and T.C. Nelwon. 1998. Evaluation of visible implant fluorescent tags for marking coho salmon smolts. North American Journal of Fisheries Management 18:191–196.

Bauer, B.H., G.R. Dinkins, and D.A. Etnier. 1983. Discovery of *Noturus baileyi* and *N. flavipinnis* in Citico Creek, Little Tennessee River system. Copeia 1983:558–560.

Bryant, R.T., J.W. Evans, R.E. Jenkins, and B.J. Freeman. 1996. The mystery fish. Southern Wildlife 1:26–35.

Conant, S. 1988. Saving endangered species by translocation: Are we tinkering with evolution? BioScience 38:254–258.

Coombs, J.A. 2003. Tag retention in re-introduced species of selected darters in the Pigeon River, TN. M.S. Thesis, University of Tennessee, Knoxville, TN. 165 pp.

Dinkins, G.R. 1984. Aspects of the life history of the smoky madtom, *Noturus baileyi* Taylor, in Citico Creek. M.S. Thesis, University of Tennessee, Knoxville, TN. 50 pp.

Dinkins, G.R., and P.W. Shute. 1996. Life histories of *Noturus baileyi* and *N. flavipinnis* (Pisces: Ictaluridae), two rare madtom catfishes in Citico Creek, Monroe County, Tennessee. Bulletin Alabama Museum of Natural History 18:43–69.

Etnier, D.A. 1994. Our southeastern fishes: What have we lost and what are we likely to lose? Southeastern Fishes Council Proceedings 29:5–9.

Etnier, D.A., and W.C. Starnes. 1991. An analysis of Tennessee's jeopardized fish taxa. Journal of the Tennessee Academy of Science 66:129–133.

Etnier, D.A., and W.C. Starnes. 1993. The Fishes of Tennessee. The University of Tennessee Press, Knoxville, TN. 681 pp.

Fraley, S.J. 1998. A baseline survey of aquatic macroinvertebrate communities at seven sites in the Abrams Creek system, Great Smoky Mountains National Park, Blount County, Tennessee. M.S. Thesis, University of Tennessee, Knoxville, TN. 114 pp.

Freeman, B.J. 1999. Robust redhorse. Pp. 161–162, *In* T.W. Johnson, J.C. Ozier, J.L. Bohannon, J.B. Jensen, and C. Skelton (Eds.). Protected Animals of Georgia. Georgia Department of Natural Resources, Social Circle, GA. 247 pp.

Griffith, B., J.M. Scott, J.W. Carpenter, and C. Reed. 1989. Translocation as a species conservation tool: Status and strategy. Science 345:447–480.

Henrickson, D.A., and J.E. Brooks. 1991. Transplanting short-lived fishes in North American deserts: Review, assessment, and recommendations. Pp. 283–298, *In* W.L. Minckley and J.E. Deacon (Eds.). Battle Against Extinction: Native Fish Management in the American West. University of Arizona Press, Tuscon, AZ. 517 p.

Howell W.M., and A. Black. 1976. Status of the watercress darter. Southeastern Fishes Council Proceedings 1:1–3.

Jenkins, R.E. 1993. Duskytail darter *Etheostoma percnurum* Jenkins (new species). Pp. 877–881, *In* R.E. Jenkins and N.M. Burkhead 1993. Freshwater Fishes of Virginia. American Fisheries Society, Bethesda, MD.1079 pp.

Jenkins, R.E., and N.M. Burkhead. 1984. Description, biology, and distribution of the spotfin chub, *Hybopsis monacha*, a threatened cyprinid fish of the Tennessee River drainage. Bulletin of the Alabama Museum of Natural History 8:1–30.

Johnson, J.E., and B.L. Jensen. 1991. Hatcheries for endangered freshwater fishes. Pp. 199–218, *In* W.L. Minckley and J.E. Deacon (Eds.). Battle Against Extinction: Native Fish Management in the American West. University of Arizona Press. Tuscon, AZ. 517 pp.

Layman, S.R. 1984a. The life history and ecology of the duskytail darter, *Etheostoma* (*Catonotus*) sp., in Tennessee's Little River. M.S. Thesis, University of Tennessee, Knoxville, TN. 57 pp.

Layman, S.R. 1984b. The duskytail darter, *Etheostoma* (*Catonotus*) sp., confirmed as an egg-clusterer. Copeia 1984:992–994.

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

Lennon, R.S., and P.S. Parker. 1959. The reclamation of Indian and Abrams Creeks, Great Smoky Mountains National Park. US Fish and Wildlife Service Special Scientific Report 306. 22 pp.

Matthews, R.C., Jr. 1978. Ecological survey of Abrams Creek in the Great Smoky Mountains National Park. Management Report No. 28, National Park Service, Southeast Region, Uplands Field Research Laboratory. 195 pp.

Mayden, R.L. 1993. *Elassoma alabamae*, a new species of pygmy sunfish endemic to the Tennessee River Drainage of Alabama (Teleostei: Elassomatidae). Bulletin of the Alabama Museum of Natural History. 16:1–14.

Meffe, G.K. 1986. Conservation genetics and the management of endangered fishes. Fisheries 11(1):14–23.

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

Ostermann, S.D., J.R. Deforge, and W.D. Edge. 2001. Captive breeding and reintroduction evaluation criteria: A case study of peninsular bighorn sheep. Conservation Biology 15:749–760.

Rakes, P.L., and J.R. Shute 2004. Captive propagation and population monitoring of rare southeastern fishes: 2003 by Conservation Fisheries, Inc. Unpublished Final Report for 2003 field season second quarter report for fiscal year 2004 prepared for Tennessee Wildlife Resources Agency, Contract no. GR-04-15966-00, Nashville, TN.

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

Reading, R.P., T.W. Clark, and S.R. Kellert. 1991. Towards an endangered species reintroduction paradigm. Endangered Species Update 8:1–4.

Sarrazin, F., and S. Legendre. 2000. Demographic approach to releasing adults versus young in reintroductions. Conservation Biology 14:488–500.

Shute, P.W. 1984. Ecology of the rare yellowfin madtom, *Noturus flavipinnis* Taylor, in Citico Creek, Tennessee. M.S. Thesis. University of Tennessee, Knoxville, TN. 100 pp.

Shute, P.W., and D.A. Etnier. 2001. Southeastern Fishes Council Regional Reports, Region III — North-Central. Southeastern Fishes Council Proceedings 42:19–20.

Simbeck, D.J. 1990. Distribution of fishes of the Great Smoky Mountains National Park. M.S. Thesis, University of Tennessee, Knoxville, TN. 128 pp.

Taylor, W.R. 1969. A revision of the catfish genus *Noturus* Rafinesque with an analysis of higher groups in the Ictaluridae. Bulletin of the US National Museum 282. 315 pp.

Tear, T.H., J.M. Scott, P.H. Haywood, and B. Griffith. 1993. Status and prospects for success of the Endangered Species Act: A look at recovery plans. Science 262:976–977.

US Fish and Wildlife Service. 1977. Endangered and threatened wildlife and plants: Final threatened status and critical habitat for five species of southeastern fishes. Federal Register 42:45526–45530.

US Fish and Wildlife Service. 1983. Recovery plan for spotfin chub *Hybopsis monacha*. US Fish and Wildlife Service, Atlanta, GA. 46 pp.

US Fish and Wildlife Service. 1984a. Endangered and Threatened wildlife and plants. Determination of Endangered status and designation of Critical Habitat for the smoky madtom (*Noturus baileyi*). Federal Register 49:43065–43068.

US Fish and Wildlife Service. 1984b. Recovery plan, yellowfin madtom (*Noturus flavipinnis)*. US Fish and Wildlife Service, Atlanta, GA. 25 pp.

US Fish and Wildlife Service. 1985. Recovery plan for smoky madtom (*Noturus baileyi*) Taylor. Asheville Endangered Species Field Station, Region 4, Atlanta, GA. 26 pp.

US Fish and Wildlife Service. 1993a. Watercress darter (*Etheostoma nuchale*) recovery plan. US Fish and Wildlife Service, Jackson, MS. 18 pp.

US Fish and Wildlife Service. 1993b. Endangered and Threatened wildlife and plants: Determination of endangered status for duskytail darter, palezone shiner, and pygmy madtom. Federal Register 58:25758–25763.

US Fish and Wildlife Service. 1994. Duskytail darter recovery plan. US Fish and Wildlife Service, Atlanta, GA. 25 pp.

Warren, M.L., Jr., and B.M. Burr. 1994. Status of freshwater fishes of the United States: Overview of an imperiled fauna. Fisheries 19(1):6–18.

Warren, M.L., Jr., B.M. Burr, S.J. Walsh, H.L. Bart, Jr., R.C. Cashner, D.A. Etnier, B.J. Freeman, B.R. Kuhajda, R.L. Mayden, H.W. Robison, S.T. Ross, and W.C. Starnes. 2000. Diversity, distribution, and conservation status of the native freshwater fishes of the southern United States. Fisheries 25(10):7–31.

Williams, J.E., J.E. Johnson, D.A. Hendrickson, S. Contreras-Balderas, J.D. Williams, M. Navarro-Mendoza, D.E. Mcallister, and J.E. Deacon. 1989. Fishes of North America endangered, threatened, or of special concern: 1989. Fisheries 14(6):2–20.