

STATUS REVIEW AND DISTRIBUTION OF THE STRIATED DARTER, *ETHEOSTOMA STRIATULUM*, AND COPPERCHEEK DARTER, *ETHEOSTOMA AQUALI*, IN THE DUCK RIVER SYSTEM, TENNESSEE

KENNETH M. COOK, CHRISTOPHER A. TAYLOR, AND BROOKS M. BURR

Department of Zoology, Southern Illinois University at Carbondale, Carbondale, IL 62901-6501 (KMC, BMB)
Center for Biodiversity, Illinois Natural History Survey, Champaign, IL 61820 (CAT)

ABSTRACT—Over 50 sites were sampled or reconnoitered in the Duck River system, Tennessee, during May, July, and October 1992, to determine the present range and general abundance of *Etheostoma striatulum* and *Etheostoma aquali*. Ten of 16 historically known sites yielded *E. striatulum* in our survey. *Etheostoma aquali* was collected from eight of 25 identifiable historic localities and seven new localities in the Duck and Buffalo rivers. Twenty additional sites within the known range of both species were sampled but did not yield either species. *Etheostoma striatulum* was reproducing at 10 sites as judged from males guarding nest rocks or nest rocks with eggs. No nest of *E. aquali* was found. *Etheostoma striatulum* generally occupied small, slow-flowing headwaters underlain by slab rock over bedrock; it was rarely found in mainstem habitats. Habitat occupied by *E. aquali* included moderate to swift riffles in mainstem habitats with loose boulder and cobble substrates. Potential threats to the continued existence of these species include habitat degradation in the watershed and in-stream modifications. We recommend that *E. striatulum* be granted threatened status in Tennessee and *E. aquali* remain listed as threatened in Tennessee.

The United States is home to, perhaps, the richest temperate freshwater fish fauna in the world. Of the 790 species native to its waters (Page and Burr, 1991), nearly 90% are nonsport fishes which occupy a variety of lotic and lentic habitats (Warren and Burr, 1994). Presently, 15-20% of these species are recognized as imperiled (endangered, threatened, or of special concern; Williams et al., 1989; Master, 1990). This is especially true in southeastern states where fish diversity and endemism are at their highest. The state of Tennessee supports over one-third (between 302 and 319 species) of the fishes found in the United States. In Tennessee, the family Percidae is represented by 93 species, 90 of which are darters (Etnier and Starnes, 1993). Among these are two species endemic to the Duck River system in the Highland Rim and Nashville Basin physiographic provinces (Starnes and Etnier, 1986; Etnier and Starnes, 1993) and considered jeopardized in Tennessee. The striated darter (*Etheostoma striatulum*) is "deemed in need of management," and the coppercheek darter (*Etheostoma aquali*) is listed as "threatened" (Etnier and Starnes, 1991; Tennessee Wildlife Resources Agency, 1994). Both species were C2 candidates for federal listing by the United States Fish and Wildlife Service (1994).

Etheostoma striatulum is a member of the *Etheostoma virgatum* or barcheck darter complex of the subgenus *Catonotus*. The barcheck darters generally are characterized by the presence of an iridescent red and white diagonal bar on their cheek (Page and Braasch, 1977; Braasch and Mayden, 1985). Prior to its description (Page and Braasch, 1977), *E. striatulum* was known as the "Duck River relative of *E. virgatum*" or "Duck River barcheck darter." The common name "striated darter" references the faint dark parallel marks along the straw colored sides. Color photographs and recent descriptions of the species are provided by Etnier and Starnes (1993) and Page (1983).

Etheostoma striatulum is limited in distribution primarily to upper tributaries of the Duck River in Bedford and Marshall counties,

Tennessee (Fig. 1). Individuals have been collected in the Duck River mainstem in Bedford, Marshall, and Maury counties; however, it is uncertain whether these represent waifs or permanent populations.

Etheostoma aquali is a member of the *Etheostoma maculatum* complex of the subgenus *Nothonotus*. Members of the complex are characterized by the presence of scales associated with the postorbital spot on the upper cheek and egg-clumping behavior (Etnier and Williams, 1989). The common name "coppercheek darter" references the copper-colored lines or reticulations on the cheek of live specimens. The species was described by Williams and Etnier (1978). Color photographs and descriptions of the species are in Etnier and Starnes (1993) and Page (1983).

Etheostoma aquali ranges from the Duck River system near Manchester (Coffee Co.) west to the confluence of the Duck and Buffalo rivers in Humphreys Co. In the Buffalo River subsystem, the species has been collected only from the mainstem in Lewis, Wayne, and Perry counties (Williams and Etnier, 1978; Fig. 2).

This survey and status review was undertaken to determine if *E. striatulum* and *E. aquali* still occur at historical sites, to sample additional localities within their known ranges, and to identify present and potential threats to the species. *Etheostoma striatulum* and *E. aquali* receive some protection from the state of Tennessee (Johnson, 1987; Etnier and Starnes, 1991; Tennessee Wildlife Resource Agency, 1994), and the information reported here is intended to provide baseline data necessary for future evaluations of the conservation status of each species.

METHODS

During May, July, and October 1992, >50 sites within the known ranges of *E. striatulum* and *E. aquali* were sampled or reconnoitered to

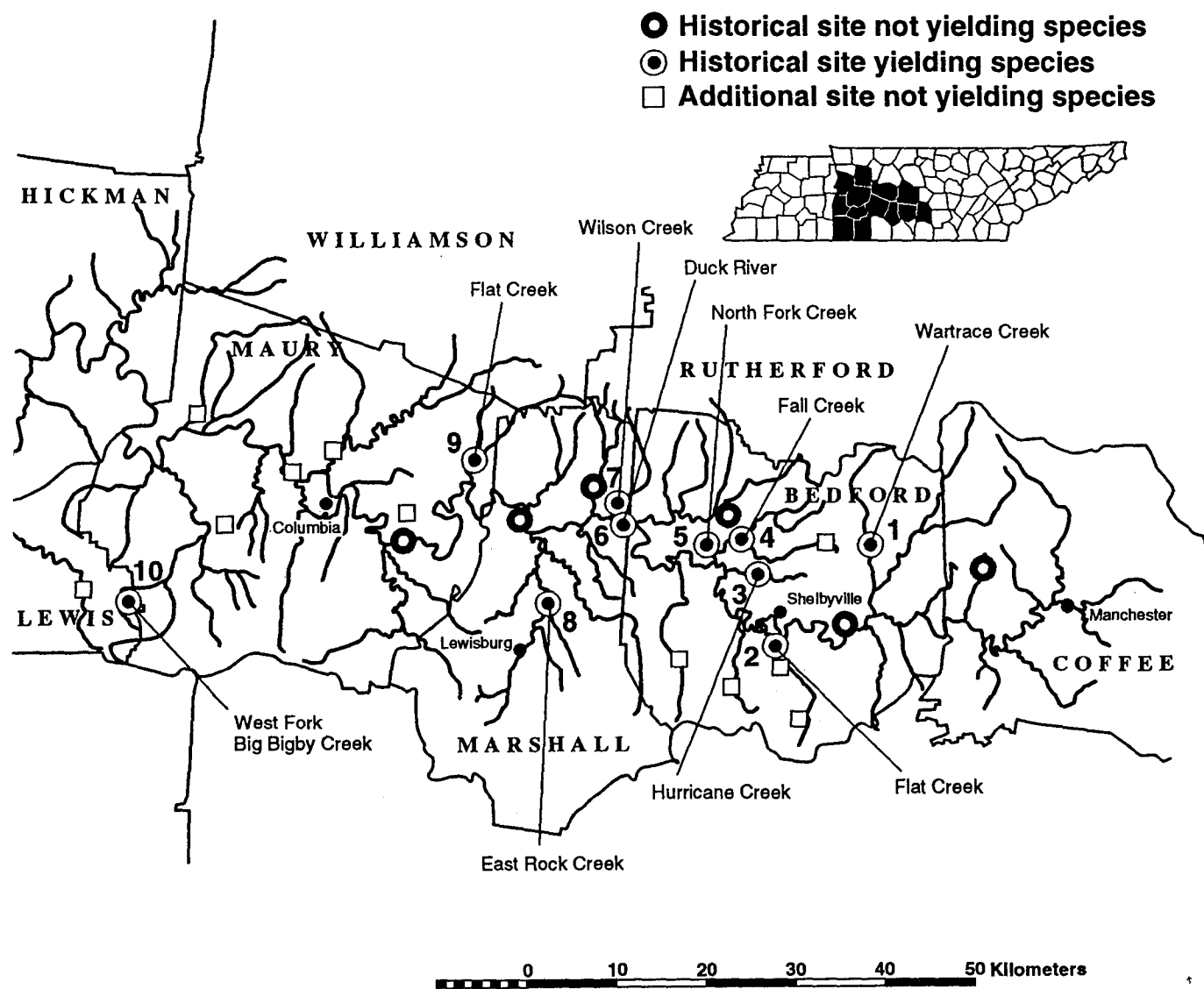


FIG. 1. Historical and additional localities sampled for the striated darter (*Etheostoma striatulum*) in the Duck River system, Tennessee. Complete locality information is provided in Appendices I and II. Site numbers correspond to those referenced in Appendix II and Table 1.

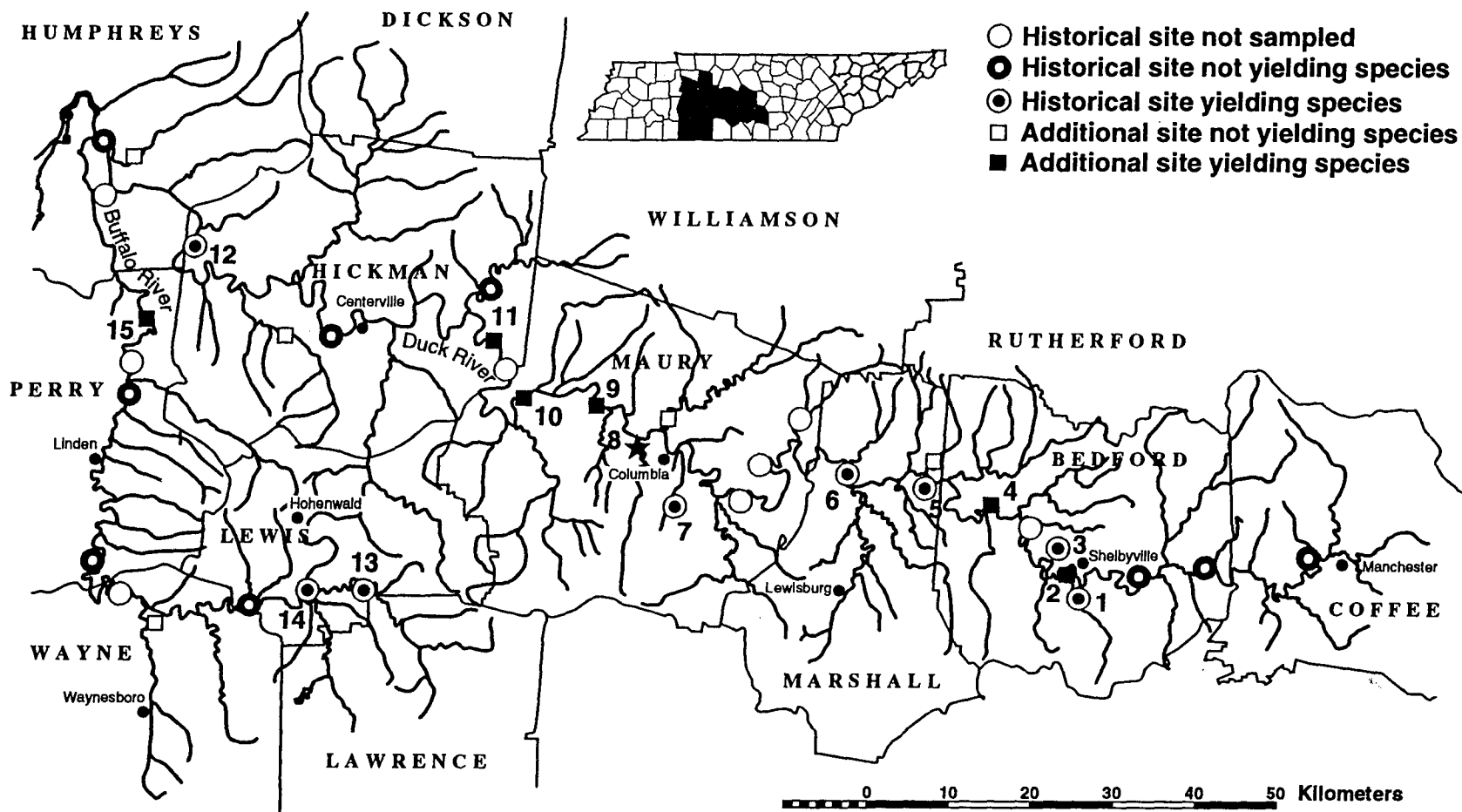


FIG. 2. Historical and additional localities sampled for the coppercheek darter (*Etheostoma aquali*) in the Duck River system, Tennessee. Complete locality information is provided in Appendices III and IV. Site numbers correspond to those referenced in Appendix IV and Table 2. The star symbol near Columbia, Maury Co., indicates the locality of the specimen collected in October 1993.

record changes in historical distributions or to identify new sites of occurrence. Ten museum collections (Appendix I) were canvassed to compile a list of historical collection sites. Institutional abbreviations follow Leviton et al. (1985) and Leviton and Gibbs (1988). The terms "drainage, system, and subsystem" follow Jenkins and Burkhead (1994).

Historic locality information often was vague (i.e., inaccurate distances, erroneous directions from a landmark, ambiguous road number or name), and field sites were selected after reviewing maps and making judgements based on site descriptions. For example, six historic collections for *E. striatulum* on Hurricane Creek (Bedford Co.) were likely from the same sampling site, as were five for North Fork Creek (Bedford Co.). Several historic records for *E. aquali* with discrepancies in locality information also were judged to be from the same site. Tennessee county maps compiled and designed by C. J. Puetz were used to identify potential new localities for either species.

Survey localities were sampled using a 3-m by 2-m minnow seine with 3.2-mm mesh and standard seining techniques (sensu Etnier and Starnes, 1993; Jenkins and Burkhead, 1994). Most *E. striatulum* and *E. aquali* were collected using a set-kick method. The most successful method of collecting *E. striatulum* was by setting the seine around a single slab rock over bedrock in a quiet, shallow pool and, as the slab rock was raised, having two individuals kick in the general area concomitantly scooping and "chasing" the fish into the net. Most *E. aquali* were collected by setting the seine in riffles with gravel to cobble-boulder substrate and kicking to the net while moving the substrate. Size (diameter) classification of substrate follows Cowardin et al. (1979) as modified by Burr and Warren (1986). Voucher specimens were preserved in 10% formalin, transferred to 70% ethanol, and deposited in the Southern Illinois University at Carbondale Ichthyology Collection.

A population estimate was conducted for *E. striatulum* by repeatedly seining a 160-m² bedrock pool in Hurricane Creek, Bedford Co., until no additional individual was captured. General habitat associated with each species at capture sites was characterized by measuring stream width, depth, and temperature and by noting substrate type. At three capture sites for *E. aquali*, surface velocity was estimated over a distance of 10 m. Water-column velocity was estimated as surface velocity X 0.8 (for rough bottom streams; sensu Orth, 1983).

RESULTS

Etheostoma striatulum—All known historical localities of *E. striatulum* were sampled during our survey (see Appendix I for historical localities and Appendix II for sites visited). Ten of 16 historical sites sampled for *E. striatulum*, yielded the species (Appendix II; Fig. 1). No new site of occurrence was identified within the known range for the species, although some areas had habitat which appeared suitable.

Our survey confirmed the existence of *E. striatulum* in small tributaries of the Duck River in Bedford, Marshall, Maury, and Lewis counties and in one location in the mainstem Duck River, Marshall Co., in May 1992 (SIUC 19909). The farthest upstream historical locality for *E. striatulum* is Noah Fork, Coffee Co., in April 1962 (CU 42144). Our sampling at this site did not yield the species. Our farthest upstream locality for *E. striatulum* was Wartrace Creek, Bedford Co., in May 1992 (SIUC 19568). Historically, the farthest downstream locality is Big Bigby Creek, Lewis Co. (INHS 68265), and we collected the species at this locality in July 1992 (SIUC 20004). The species is unknown from the Buffalo River subsystem.

Most *E. striatulum* were captured in quiet, shallow pools, beneath slab rocks averaging 25 by 22 by 5 cm over bedrock (Table 1). Two site-specific exceptions to this habitat type were collection of an individual in the mainstem Duck River beneath a slab rock over a bedrock shelf (not pool conditions) and collection of an individual in Big Bigby Creek, Lewis Co., in July 1992 (SIUC 20004) in a small pool beneath a slab rock over a gravel substrate. The average number of individuals yielded per site was 3.0, and the range was one to six. Stream width at capture locations averaged 11 m and ranged from 5 m at Big Bigby Creek, Lewis Co., to 20 m at the Duck River mainstem in Marshall Co. Depth at capture averaged 0.17 m and ranged from 0.10 to 0.30 m. Flow was minimal to moderate, and the water was clear to slightly turbid.

In May 1992, a population estimate was made for *E. striatulum* at Hurricane Creek, Bedford Co., in a partially isolated bedrock pool located at the head of a short riffle. The pool was seined until no additional *E. striatulum* was captured. Six individuals were taken from this 160-m² pool (0.04 *E. striatulum*/m²) after eight seine hauls. This site is well known historically with collection records of *E. striatulum* dating to 1937 (UMMZ 121283).

TABLE 1. Summary of field observations at sites that yielded the striated darter (*Etheostoma striatulum*) in the Duck River system, Tennessee (Fig. 1; Appendix II). Attempts refer to the number of set-kicks (see Methods) or seine hauls.

Site	Stream width (m)	Temperature (°C)	Depth at capture (m)	Mean slab rock size (cm)	Substrate over bedrock	Number caught	Attempts
1	7-10	24	0.2	30 by 40 by 6	Gravel/slab rock	5	25
2	12	21	0.1	34 by 32 by 5	Slab rock	2	6
3	10	26	0.2	35 by 30 by 6	Slab rock	6	8
4	12	24	0.3	36 by 18 by 8	Slab rock	5	8
5	10	24	0.2	30 by 32 by 5	Slab rock	4	10
6	12	17	0.2	20 by 22 by 4	Slab rock	1	12
7	20	24	0.1	20 by 20 by 5	Slab rock	1	1
8	10	21	0.2	32 by 20 by 5	Gravel/slab rock	4	8
9	15	21	0.1	22 by 15 by 5	Slab rock	1	4
10	5	24	0.2	15 by 10 by 4	Gravel/slab rock	1	6

During sampling in spring 1992, we observed male *E. striatulum* guarding nests made on the undersides of slab rock over bedrock at Flat Creek, Bedford Co., on 20 May (13 eggs, slab rock 29 by 20 by 5 cm, 10-cm depth, 21°C; 13 eggs, slab rock 40 by 45 by 5 cm, 14-cm depth, 21°C); Fall Creek, Bedford Co., on 19 May (180 eggs, slab rock 41 by 18 by 6 cm, 10-cm depth, 24°C); and Duck River, Marshall Co., on 20 May (7 eggs, slab rock 20 by 20 by 5 cm, 20-cm depth, 24°C). Emaciated males which appeared to be associated with empty (eggless) or recently hatched nests were found at seven other sites sampled during May.

Etheostoma aquali—Seventeen historical localities for *E. aquali* were sampled during our survey (see Appendix III for historical localities and Appendix IV for sites visited). Eight historical sites were not sampled because of uncertainties in the locality information or, when reconnoitered, were judged to lack habitat suitable for the species. *Etheostoma aquali* was collected at eight historical sites and at six new localities (Appendix IV; Fig. 2). In addition, while sampling in October 1993 (not part of our survey), a single specimen was caught from Little Bigby Creek, Maury Co. (no voucher taken), another new locality for the species.

Etheostoma aquali typically occurs in the mainstems of the Duck and Buffalo rivers. The farthest upstream historical locality in the Duck River system is near the mouth of Bashaw Creek, Coffee Co., in November 1978 (UT 91.1704); however, we did not find the species at this site. The farthest upstream we found the species was in the Duck River, Bedford Co., in May 1992 (SIUC 19610), ca. 75 river km downstream from Bashaw Creek (ca. 30 km of which are the reservoir Normandy Lake). The farthest downstream localities in the Duck River system are the Duck River, Humphreys Co., near the mouth of Hurricane Creek, to just above the mouth of the Buffalo River, Humphreys Co. (seven historical records between 1973 and 1983). Our sampling in this reach did not produce the species. The farthest

downstream we collected *E. aquali* was the Duck River mainstem, Hickman Co., in May 1992 (SIUC 19631), ca. 15 km upstream. In the Duck River mainstem, specimens were collected from nine sites between Duck River near Shelbyville, Bedford Co., and Duck River northwest of Only, Hickman Co. In addition, specimens were taken from the lower reaches of two tributaries of the Duck River: 1) Flat Creek, Bedford Co.; 2) Fountain Creek, Maury Co. (Fig. 2).

Prior to our survey, the farthest upstream site known for *E. aquali* in the Buffalo River subsystem was the Buffalo River north of Napier, Lewis Co., in July 1976 (USNM 218002). We collected *E. aquali* at only three sites in the Buffalo River (Fig. 2): just upstream (roughly 2.0 km) from the locality for USNM 218002 in the Buffalo River, Lewis Co., in July 1992 (SIUC 20052); at the mouth of Grinders Creek, Lewis Co., in July 1992 (SIUC 20274); in the Buffalo River north of Lobelville, Perry Co., in July 1992 (SIUC 20200). *Etheostoma aquali* has been collected from the Buffalo River at the mouth of Grinders Creek more than at any other locality in the entire Duck River system (20 positive collections between 1970 and 1990).

Except for one site, all specimens of *E. aquali* were collected under or around loose slab rock or boulders averaging 40 by 30 by 20 cm with a bottom substrate of gravel or bedrock (Table 2). The average number yielded at a site was 5.0, and the range was one to 19. At 11 of 14 sites, five or fewer individuals were collected. All were collected in riffle habitats averaging 0.38 m in depth and ranging from 0.2 to 0.5 m. Stream width averaged 26 m and ranged from 12 to 45 m. Estimated water-column velocities at three collection sites (Flat Creek, Bedford Co.; Duck River, Marshall Co.; and Duck River, Hickman Co.) were 0.40 m/sec, 0.56 m/sec, and 0.56 m/sec, respectively. The water was clear to slightly turbid. At some sites, habitat appeared to be present but could not be sampled effectively because of deep water or swift current. Collections in fall indicated that young-of-the-year and juveniles occupy gravel-cobble habitats in areas devoid of large slab rock or boulders.

TABLE 2. Summary of field observations at sites (Fig. 2; Appendix IV) that yielded the coppercheek darter (*Etheostoma aquali*) in the Duck River, Tennessee. Attempts refer to the number of set-kicks (see Methods) or seine hauls.

Site	Stream width (m)	Temperature (°C)	Depth at capture (m)	Current (m/sec)	Substrate type	Number caught	Attempts
1	12	21	0.20	0.5	Sand-cobble	4	9
2	12	21	0.30		Gravel-cobble	3	7
3							
19 May 1992	15	23	0.30		Gravel-boulder	6	10
9 October 1992	17		0.20-0.50		Gravel-boulder	8	10
4	25	25	0.45		Gravel-boulder	5	10
5							
20 May 1992	25	24	0.30-0.45	0.7	Gravel-cobble	8	12
10 October 1992	25		0.20		Gravel-cobble	19	25
6	30	24	0.40		Gravel-cobble	6	8
7	15	22	0.40		Gravel-boulder	3	12
8	12		0.30		Gravel-cobble	1	5
9	45	24	0.30		Gravel-boulder	3	6
10	25	16	0.80		Mud-cobble	1	11
11	25	23	0.30	0.7	Gravel-cobble	5	10
12	45	22	0.40		Gravel-pebble	4	7
13	25	25	0.30		Gravel-cobble	1	6
14	25	25	0.35		Gravel-cobble	2	8
15	35	25	0.40		Gravel-boulder	1	10

DISCUSSION

As a caveat, we emphasize that in surveys of this nature historical localities usually are visited only once and, generally, during a single season (late spring, early summer, or fall). We realize that movements and abundances of temperate North American fishes may vary considerably by day, season, and year. In many cases, aquatic habitats are being altered so rapidly that regular monitoring of sites is necessary to accurately determine the status of a given species at a historical site. Regular or seasonal monitoring, especially during recruitment or after presumed high winter mortality, would be ideal. Our discovery of six new sites of occurrence for *E. aquali* in a single year illustrates the hit-and-miss character of sampling streams.

The results of our fieldwork and historical collection records demonstrate that *E. striatulum* has a restricted range, naturally occurs in low density, and may be susceptible to local extirpations. After conducting a life-history study on the species, Page (1980) advocated conservation of *E. striatulum* through preservation of the natural characteristics of streams within its range. Etnier and Starnes (1993:538) noted that the occurrence of *E. striatulum* "in fewer than a dozen creeks in a four-county area makes it extremely vulnerable to significant depletion." The specialized nature of fundamental life-history characteristics, such as slab-rock nest sites (Page, 1983, 1985), also suggests that specific habitat preservation is essential to the survival of this species. Quantitative samples of our survey and those of Page (1980), 0.04 and 0.01 individuals/m², respectively, indicate that *E. striatulum* exists in relatively low densities. By comparison, the closely related slabrock darter, *Etheostoma smithi*, has mean adult densities of 0.81 individuals/m² in slab pools (Page and Burr, 1976).

It is clear that *E. striatulum* is successfully reproducing at several sites within the Duck River system, including the mainstem. However, it exploits resources also used by several other species. For example, the syntopic fantail darter (*Etheostoma flabellare*), blackfin darter (*Etheostoma nigrifinne*), bluntnose minnow (*Pimephales notatus*), and several species of crayfish (*Orconectes* spp. and *Cambarus* spp.) often were found guarding nests or occupying spaces beneath slab rocks suitable for cover and nesting of *E. striatulum* (Page, 1980). Interspecific competition for this limited resource appeared to be high and may be related to low population sizes observed for *E. striatulum*. At most sites, the number of *E. striatulum* captured seemed to be correlated with the number of appropriate-sized slab rocks over bedrock.

We found *E. aquali* to be widespread in the Duck River system but suspect low overall population density as judged from the relatively small numbers of individuals obtained at each site. Our low numbers may be attributed to limited habitat in tributaries or ineffective sampling at mainstem sites. In contrast to our observations and collections, we are aware that sampling methods using sodium cyanide often produce large numbers of *Nothonotus* species in appropriate habitat.

Stream fishes with limited ranges and low densities may be vulnerable to minor habitat alterations that cause range fragmentation and result in the loss of genetic diversity by bottleneck or founder effects (Meffe, 1986). The small headwater habitats that *E. striatulum* typically occupies are vulnerable to extreme fluctuations in flow particularly during years of low rainfall or harsh summer conditions. Several years of low flows compounded with instream modifications could be devastating to extant populations of *E. striatulum*. During our survey, the most obvious threats to *E. striatulum* appeared to be stream alterations such as dredging or channelization, which include removal of slab rock critical for spawning; runoff from pasture lands causing excessive algal growth, eutrophication, and low oxygen levels; and sedimentation from land-use practices which creates turbid water and covers potential nesting and feeding sites.

Threats to *E. aquali* were more difficult to identify. The occurrence of *E. aquali* in the mainstems of the Duck and Buffalo rivers suggest that the species is less susceptible to direct threats (e.g., minor stream-riparian alterations, eutrophication). However, generally speaking, potential threats include: the cumulative effects of chemical runoff and residential pollution which could cause increased levels of toxic substances in the watershed, hence lowering the overall health and fitness of *E. aquali*; stream siltation from land-use practices which may affect reproductive success, especially in upper Duck River tributaries; and large-scale stream modifications such as dredging or channelization. Normandy Lake, a reservoir built in the mid to late 1970s on the Duck River in Bedford and Coffee counties, inundated ca. 30 km of the historical range of *E. aquali* (Fig. 2); our sampling at the historical site (Duck River near the mouth of Bashaw Creek) upstream of the lake did not yield the species. Also, two historical sites sampled downstream (the farthest being 45 river km) of the dam failed to produce the species, suggesting that dam discharges are a factor affecting some populations of *E. aquali*. Williams and Etnier (1978) noted that populations of *E. aquali* in the vicinity of the dam could be expected to be reduced or eliminated and that members of the subgenus *Nothonotus* are not tolerant of reservoirs and appear to have only limited tolerance of tailwater habitats.

Given the restricted range and few known spawning areas of *E. striatulum* and *E. aquali*, common sense should be employed when collecting these species for scientific or educational purposes. Several collection records indicated that a relatively large number of individuals (e.g., >200 *E. aquali*) were taken from some sites. Although excessive collecting is rare, it illustrates the type of activity often used to criticize the work of stream biologists. Indeed, the impact of excessive collecting is difficult to assess, but the removal of large numbers of adults from spawning areas prior to and during the breeding season undoubtedly impacts recruitment at a particular site.

As of 1995, the Columbia Dam component of the Duck River project (United States Fish and Wildlife Service, 1995) has been halted. We agree with Williams and Etnier (1978) that the impoundment of the Duck River at the Columbia Dam site would eliminate populations of *E. aquali* occurring in the Duck River mainstem between river mile 137 and 191 and could produce deleterious effects from discharges for many kilometers downstream.

Furthermore, we suggest that the occurrence of *E. striatulum* in the Duck River mainstem reflects the presence of a resident population, indicates seasonal use to avoid unfavorable summer conditions in tributaries, or signals use of the mainstem as an emigration corridor to new headwater habitats. If areas of Maury and Marshall counties are inundated by the Columbia Dam project, increased predation in the new lake conditions could prevent the species from safely avoiding unfavorable situations or limit dispersal.

Future research needs for *E. striatulum* include studies on dispersal and habitats of different life stages, identification of additional headwater streams or mainstem Duck River sites where spawning and recruitment occurs, long-term studies of population dynamics and nesting activity in the mainstem Duck River, and long-term monitoring of population trends and watershed conditions. Research needs for *E. aquali* include an autecological study of the species focusing on such aspects as quantification of seasonal microhabitat preferences and dispersal and habitats of different life stages, quantification of various reproductive parameters (e.g., spawning sites, temperatures, and number of young produced per nest), and long-term monitoring of population trends and catchment conditions.

Because of their endemism to the Duck River system and relatively low population numbers, we recommend that *E. striatulum* be granted threatened status in Tennessee and that *E. aquali* remain listed as threatened in Tennessee. Our survey indicates that the range of *E.*

striatulum has diminished and that the species may be susceptible to local extirpations. *Etheostoma aquali* was found throughout most of its historical range including several new sites of occurrence and appears to show persistence in the Duck River system.

ACKNOWLEDGMENTS

We wish to thank R. G. Biggins and R. M. Hatcher for their correspondence and administrative efforts which led to the funding of this project through the United States Fish and Wildlife Service and the Tennessee Wildlife Resources Agency. We thank the following curators or staff for providing us with historical collection records of the two target species: J. M. Humphries, Cornell University; B. R. Kuhajda and R. L. Mayden, University of Alabama Ichthyological Collection; K. S. Cummings and L. M. Page, Illinois Natural History Survey; G. H. Burgess and C. R. Gilbert, University of Florida Museum of Natural History; T. M. Cavender, Ohio State University Museum of Biological Diversity; J. T. Collins, University of Kansas; N. H. Douglas, Northeast Louisiana University; H. L. Bart, Tulane University; D. W. Nelson, University of Michigan Museum of Zoology; D. A. Etnier, The University of Tennessee, Knoxville; S. L. Jewett, National Museum of Natural History. D. J. Eisenhour and M. L. Warren, Jr., critically reviewed an earlier draft of the manuscript. We gratefully acknowledge the field assistance of R. G. Biggins and R. Hylton (United States Fish and Wildlife Service). P. W. Shute (Tennessee Valley Authority) provided locality records and other courtesies.

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APPENDIX I

Summary of all known collections, prior to this survey, of *Etheostoma striatulum* from Tennessee. Catalog numbers are followed in parentheses by the number of voucher specimens retained. Institutional abbreviations are: CU = Cornell University; INHS = Illinois Natural History Survey; KU = University of Kansas; NLU = Northeast Louisiana University; OSUM = Ohio State University Museum of Biological Diversity; SIUC = Southern Illinois University at Carbondale; UAIC = University of Alabama Ichthyological Collection; UMMZ =

University of Michigan, Museum of Zoology; USNM = National Museum of Natural History; and UT = The University of Tennessee. *Coffee Co.*: Noah Fork Duck River at Noah Community on US Hwy. 41, CU 42144 (1) 22 April 1962. *Bedford Co.*: Wartrace Creek at TN Hwy. 82 bridge, 1 mile E Bell Buckle, INHS 84059 (10) 30 January 1979, INHS 83883 (18) 29 September 1978, INHS 82570 (17) 26 July 1978, INHS 79365 (12) 14 April 1978, INHS 78146 (6) 10 February 1978, INHS 77500 (12) 19 October 1977, INHS 77017 (29) 10 August 1977, INHS 76952 (42) 18 June 1977, INHS 76138 (10) 20 April 1977, INHS 75720 (19) 2 March 1977, INHS 75606 (17) 12 December 1976, INHS 75035 (17) 14 March 1976, INHS 75037 (10), USNM 213789 (10), and NLU 33947 (10) 7 November 1975, UT 91.1174 (10) 7 November 1975; Pannel Branch, tributary of Wartrace Creek, UMMZ 121226 (1) 10 April 1937; Duck River at unnumbered road crossing, 4.0 air miles NW Normandy, UT 91.1548 (1) 22 March 1978; Flat Creek on TN Hwy. 64, 0.2 mile S Shelbyville, UAIC 2534.08 (3) 13 April 1967; Fall Creek NW of Shelbyville, UMMZ 121295 (5) 12 April 1937; Hurricane Creek N of Elbethel, KU 16211 (2) 5 April 1969; Hurricane Creek at unnumbered county road crossing, 5.5 air miles NW Shelbyville, UAIC 5738.01 (3) 13 December 1977; Hurricane Creek NW of Shelbyville, UMMZ 121283 (1) 12 April 1937; Hurricane Creek 4.5 miles NW Shelbyville, UT 91.4246 (8) 14 April 1991 and 13 June 1992; Hurricane Creek 2.5 miles E Halls Mill, KU 20950 (4) date unknown; Hurricane Creek at unnumbered county road, 2.8 miles N of Elbethel, 5.5 miles NNE of Shelbyville, UAIC 10022.01 (4) 21 March 1979; North Fork Creek 2 miles NNW Fall Creek, TN Hwy. 16 bridge, INHS 77518 (3) 19 October 1977; North Fork Creek, UT 91.755 (2) 28 September 1972; North Fork Creek at North Fork Church, KU 16209 (1) 5 April 1969, UT 91.400 (14) 28 August 1969; North Fork Creek Mile 5.1 and to next bridge upstream, UT (uncatalogued) 6 June 1977; North Fork Creek N of Shelbyville, UMMZ 121269 (9) 12 April 1937; Alexander Creek Maps 71 NE and SE Duck River drainage-plotted at unnumbered county road crossing ca. 0.5 mile E of intersection with Long View Road-Versailles Pike on quad map, UMMZ 121361 (2) 16 April 1937. *Marshall Co.*: Wilson Creek at county road, ca. 0.6 mile upstream from the creek mouth, ca. 2 miles SE Chapel Hill, UT (uncatalogued) 9 June 1977; Spring Creek 0.1 mile E of US 31A, 10 miles N Farmington, UAIC 2858.08 (3) 29 March 1968; Duck River at end of unnumbered county road, 2.5 air miles SE Chapel Hill, UT 91.1547 (1) 23 March 1978; Duck River below Lillards Mill Dam along islands, River Mile 179.1, NLU 50237 (1) 25 April 1982, UT (uncatalogued) 25 April 1980; East Rock Creek 1.5 miles NW Farmington, INHS 86776 (1) 11 November 1978. *Maury Co.*: Flat Creek 2 miles W Pottsville, INHS 27588 (15) 8 October 1978; Flat Creek at TN Hwy. 99 bridge (upstream and under bridge), OSUM 58742 (11) 11 November 1984; Duck River at River Mile 149.8, ca. 7 miles SE Columbia, OSUM 55997 (1) 21 September 1972; Duck River left side of islands at River Mile 153.1, UT (uncatalogued) 23 September 1980; Duck River at River Mile 147.3 near mouth of Negro Creek, OSUM 56029 (1) 26 September 1972. *Lewis Co.*: West Fork Big Bigby Creek 3 miles WSW Mt. Joy, INHS 68265 (9) 12 April 1985.

APPENDIX II

Sites in Tennessee sampled for *Etheostoma striatulum* in 1992. Catalog numbers (followed in parentheses by number of voucher specimens taken) and complete locality information for sites yielding *E. striatulum* (in upstream to downstream order by county). Site numbers correspond to those referenced in Table 1 and Fig. 1. SIUC = Southern Illinois University at Carbondale. *Site 1*: Wartrace Creek at TN Hwy. 82 bridge, 0.5 mile E Bell Buckle, Bedford Co., SIUC 19568 (1) 18 May

1992, no SIUC collection number (specimens frozen) 9 October 1992. *Site 2*: Flat Creek at TN Hwy. 64 bridge, 1 mile SW Shelbyville, Bedford Co., SIUC 19536 (2) 19 May 1992. *Site 3*: Hurricane Creek at Dirt Road bridge, 5 miles NNW Shelbyville, Bedford Co., SIUC 19899 (6) 19 May 1992. *Site 4*: Fall Creek at Old Unionville Road, 5 miles NW Shelbyville, Bedford Co., SIUC 19882 (5) 19 May 1992. *Site 5*: North Fork Creek at North Fork Church on Unionville-Deason Road, Bedford Co., SIUC 19860 (4) 19 May 1992. *Site 6*: Wilson Creek at TN Hwy. 270 bridge, 2.5 miles SE Chapel Hill, Marshall Co., SIUC 20778 (1) 31 October 1992. *Site 7*: Duck River at bend in Harris Road, 1 mile E Henry Horton State Park, Marshall Co., SIUC 19909 (1) 20 May 1992. *Site 8*: East Rock Creek at Wade Brown Road, 1 mile NNW Farmington, Marshall Co., SIUC 19649 (4) 20 May 1992. *Site 9*: Flat Creek at TN Hwy. 99 bridge, 2 miles W Pottsville, Maury Co., SIUC 19590 (1) 21 May 1992. *Site 10*: Big Bigby Creek (west fork) at West Fork Road and Bigby Creek Road at Macedonia Church (Church of Christ), 3 miles WSW Mt. Joy, Lewis Co., SIUC 20004 (1) 23 July 1992.

Sites sampled that did not yield *E. striatulum* (in upstream to downstream order by county). *Coffee Co.*: Noah Fork at TN Hwy. 41 crossing at town of Noah, 31 October 1992. *Bedford Co.*: Duck River at TN Hwy. 41A bridge, ca. 5 miles E Shelbyville, 19 May 1992; Goose Creek at New Center Church Road, 6 miles SE Shelbyville, 9 October 1992; Flat Creek at US Hwy. 231 bridge, just S Shelbyville, 19 May 1992; Ashland Branch of Sugar Creek on Sandusky Road, 6.5 miles SW Shelbyville, 9 October 1992; Sinking Creek at TN Hwy. 64 bridge, 7 miles W Shelbyville, 9 October 1992; Pannell Branch at Higgins Road, 1.5 miles W Wartrace, 19 May 1992; Alexander Creek off Unionville-Deason Road, 3 miles SE Unionville, 31 October 1992. *Marshall Co.*: Spring Creek at Unionville Road, just E Chapel Hill, 20 May 1992; Duck River at Milltown, off Leonard Road, below Lillards Mill dam, 21 May 1992. *Maury Co.*: Negro Creek at Negro Creek Road, ca. 6 miles E Columbia, 23 July 1992; Duck River at Roberts Bend Road bridge, 4 miles E Sawdust, 31 October 1992; Big Bigby Creek at Canaan across from the church, 21 May 1992; Fountain Creek at TN Hwy. 50 bridge, 1.5 miles E Glendale, 21 May 1992; Rutherford Creek at US Hwy. 31 bridge, ca. 2.5 miles N Columbia, 31 October 1992; Leipers Creek at TN Hwy. 247 bridge, 1 mile NE of Williamsport, 31 October 1992. *Lewis Co.*: Big Swan Creek at TN Hwy. 99, second bridge E Gordonsburg, 23 July 1992.

APPENDIX III

Summary of all known collection localities, prior to this survey, of *Etheostoma aquali* from Tennessee. Catalog numbers are followed in parentheses by the number of voucher specimens retained. Institutional abbreviations are defined in Appendix I. *Coffee Co.*: Duck River at pools 100 m below mouth of Bashaw Creek, ca. 2.0 air miles W center of Manchester, UT 91.1704 (2) 4 November 1978. *Bedford Co.*: Flat Creek at TN Hwy. 64, 1.5 miles SW Shelbyville, UAIC 10039.13 (22) 25 May 1990; Flat Creek on TN Hwy. 64, 0.6 mile SW of junction TN Hwy. 64 and US 231 at Shelbyville, UAIC 2826.01 (6) 3 February 1968, UAIC 2856.01 (1) 29 March 1968, USNM 218001 (6) 1 October 1967; Duck River at Shelbyville, UAIC 2700.30 (18) 1 October 1967; Duck River at Cortner's Mill, UT 91.749 (1) 4 October 1972; Duck River at US 231, 3 miles S Shelbyville, NLU 54935 (4) 16 April 1984, UT 91.228 (7) 20 October 1968; Duck River 13.4 miles NW Tullahoma on US Hwy. 41A, TU 32989 (6) 17 July 1964; Duck River at unnumbered county road, 5.7 air miles NW of Shelbyville, 2.0 air miles NW Elbethel, UT 91.1600 (1) 20 May 1978; Duck River at Mullins Mill Bridge on US Hwy. 41A, ca. 5 miles E Shelbyville, NLU 56468 (7) 2 April 1985. *Hickman Co.*: Duck River off I-40, first bridge above I-

40, 1 river mile above I-40, UT 91.719 (9) 10 October 1972; Duck River at I-40, UMMZ 201716 (1) 10 March 1968; Duck River at TN Hwy. 50 crossing, ca. 0.25 air mile SW Centerville, UT 91.1673 (4) 22 October 1978; Barren Fork (Duck River) 0.5 mile W Primm Springs, INHS 61728 (1) 23 April 1986. *Humphreys Co.*: Duck River at end of unnumbered county road, ca. 3.4 miles N of Buffalo, UAIC 8877.02 (3) 21 October 1978; Duck River at mouth of Hurricane Creek, UT 91.829 (3) 29 August 1973; Duck River shoals, 1 mile upstream from mouth of Hurricane Creek, UAIC 8835.01 (2) 19 May 1978; Duck River ca. 0.25 mile above mouth of Hurricane Creek, UT 91.1567 (1) 2 April 1978, SIUC 3391 (2) 27 April 1981, INHS 77826 (3) 29 August 1973; Duck River island complex below Cold Branch Landing, UT 91.2662 (2) 21 October 1983; Duck River below bridge just above mouth of Buffalo River, TU 95729 (1) 10 September 1975. *Lewis Co.*: Buffalo River 0.3 mile N of junction of TN Hwy. 99 and Oakgrove Road, NLU 58579 (6) 9 February 1986; Buffalo River on road to North Riverside, ca. 8 miles SE of Hohenwald, NLU 28711 (27) 16 September 1973; Buffalo River at Metal Ford, River Mile 100, ca. 2 miles above mouth of Grinders Creek, USNM 218002 (2) 22 July 1976; Buffalo River at mouth of Grinders' Creek, at TN Hwy. 99, 6 miles S of Hohenwald, INHS 79391 (8) 14 April 1978, INHS 87359 (3) 5 May 1981, UAIC 7966.24 (5) 9 October 1987, KU 20862 (2) and KU 21357 (6) no date given, UMMZ 201717 (2) 10 July 1970, UT 91.1282 (5) 27 April 1974, NLU 52807 (16) 31 March 1983, NLU 33731 (79) 24-25 March 1976, NLU 57465 (1) 15 April 1984, NLU 56517 (14) 1 April 1985, NLU 35592 (235) 11-12 April 1977, NLU 47588 (37) 11 April 1981, NLU 39454 (70) 8-9 April 1978, NLU 45087 (21) 11 April 1980, NLU 30288 (1) 24 May 1974, NLU 64330 (3) 3 April 1990, SIUC 3632 (16) 6 September 1981, SIUC 6467 (16) 22 May 1978. *Marshall Co.*: Duck River at old mill dam ca. 2.0 river miles E from US Hwy. 31A crossing at Henry Horton State Park, UAIC 6395.05 (5) 7 March 1981, NLU 50186 (3) 1 May 1980, UAIC 6432.02 (5) 17 October 1981; Duck River at shoal ca. 2.3 river miles upstream from US Hwy. 31A crossing, ca. 2.25 air miles SE Chapel Mill, UT 91.1696 (7) 5 November 1978; Duck River below Lillard's Mill Dam at islands, River Mile 179.1, NLU 50771 (1) 4 March 1980, NLU 56637 (5) 3 April 1985; Duck River at Condiff Ford Island, 3.7 river miles above US Hwy. 31 bridge, NLU 50174 (4) 28 April 1980. *Maury Co.*: Fountain Creek at and below TN Hwy. 50 at Shady Grove, UT 91.2354 (1) 25 September 1981; Duck River at Brench Island, River Mile 150, UT 91.2440 (3) 7 June 1982; Duck River 0.3 air mile E of I-65, at mouth of Derryberry Branch, NLU 50664 (3) 27 April 1980; Flat Creek (Duck River) 2 miles W Pottsville, INHS 27585 (1) 8 October 1978. *Perry Co.*: Buffalo River at County Road 6242, SE of Lobelville, UT 91.622 (1) 28 September 1971; Buffalo River at junction TN Hwy. 50 and TN Hwy. 13 at Beardstown, NLU 28640 (1) 29 September 1973; Buffalo River and tributaries, 1 mile N Flatwood off TN Hwy. 13, INHS 61795 (1) 22 April 1986. *Wayne Co.*: Buffalo River 2.2 air miles below TN Hwy. 13 bridge, UT 91.3966 (1) 25 September 1990.

October 1992. *Site 4*: Duck River at Halls Mill bridge, 7 miles NW Shelbyville, Bedford Co., SIUC 19534 (5) 19 May 1992. *Site 5*: Duck River at Henry Horton State Park (at TN Hwy. 31A bridge and 3 river miles upstream), Marshall Co., SIUC 19657 (8) 20 May 1992, SIUC unvouchered (19) 10 October 1992. *Site 6*: Duck River at Lillard's Mill Dam at Milltown, off Leonard Road, Marshall Co., SIUC 19600 (6) 21 May 1992. *Site 7*: Fountain Creek at TN Hwy. 50 bridge, 1.5 miles E Glendale, Maury Co., SIUC 19574 (3) 21 May 1992. *Site 8*: Little Bigby Creek at Old Williamsport Road, on W edge of Columbia, Maury Co., (no voucher taken) 10 October 1993. *Site 9*: Duck River at Roberts Bend Road bridge, 4 miles NE Sawdust, Maury Co., SIUC 20767 (1) 31 October 1992. *Site 10*: Duck River at TN Hwy. 50 bridge, 5.5 miles N Cross Bridges, Maury Co., SIUC 19524 (3) 21 May 1992. *Site 11*: Duck River at Bratton Road bridge, 2 miles W Jones Valley, Hickman Co., SIUC 19545 (5) 22 May 1992. *Site 12*: Duck River at TN Hwy. 229 bridge, just E I-40 exit and 1 mile NW Only, Hickman Co., SIUC 19631 (4) 23 May 1992. *Site 13*: Buffalo River at Napier Road, 2 miles N Napier, Lewis Co., SIUC 20052 (1) 23 July 1992. *Site 14*: Buffalo River at mouth of Grinders' Creek, 6 miles S Hohenwald, Lewis Co., SIUC 20274 (2) 24 July 1992. *Site 15*: Buffalo River at Gilmer Bridge Road, at N edge of Lobelville, Perry Co., SIUC 20200 (1) 26 July 1992.

Sites sampled that did not yield *E. aquali* (in upstream to downstream order by county). *Coffee Co.*: Duck River at mouth of Bashaw Creek, 1 mile W Manchester, 18 May 1992. *Bedford Co.*: Duck River at US 41A bridge, about 5 miles E Shelbyville, 19 May 1992; Duck River at Cortner Mill Road, 2 miles WNW Normandy, 19 May 1992. *Marshall Co.*: Duck River at bend in Harris Road, 1 mile E Henry Horton State Park at mouth of North Fork Creek, 20 May 1992. *Maury Co.*: Rutherford Creek at US 31 bridge, 1 mile N Columbia, 31 October 1992. *Hickman Co.*: Duck River at Hwy. 50 bridge Centerville, 22 May 1992; Beaverdam Creek at W Beaverdam Road 5.0 miles SSW Centerville, 22 May 1992; Lick Creek at Primm Springs Road ca. 1 mile W Primm Springs, 22 May 1992. *Humphreys Co.*: Hurricane Creek on Hurricane Creek Road 6 miles S of Waverly, 2 November 1992; Duck River at Forks River Road, 6 miles SSW Waverly, 2 November 1992. *Lewis Co.*: Buffalo River at Ridge Road bridge, North Riverside, 24 July 1992. *Wayne Co.*: Moccasin Creek off Moccasin Creek Road 2.5 miles SE Little Hope, 25 July 1992. *Perry Co.*: Buffalo River at TN Hwy. 13 bridge, 1 mile N Flatwood, 25 July 1992; Buffalo River 0.5 mile downstream of junction of TN Hwy. 50 and TN Hwy. 13, at edge of Billy Carlton Road, 26 July 1992.

APPENDIX IV

Sites in Tennessee sampled for *Etheostoma aquali* in 1992. Catalog numbers (followed in parentheses by the number of voucher specimens taken) and complete locality information for sites yielding *E. aquali* (in upstream to downstream order by county). Site numbers correspond to those referenced in Table 2 and illustrated in Fig. 2. SIUC = Southern Illinois University at Carbondale. *Site 1*: Flat Creek at TN Hwy. 64 bridge, 1 mile SW Shelbyville, Bedford Co., SIUC 19825 (4) 19 May 1992. *Site 2*: Flat Creek at US Hwy. 231 bridge just S of Shelbyville, Bedford Co., SIUC 19681 (3) 19 May 1992. *Site 3*: Duck River at junction TN Hwy. 64 and US 231 in Shelbyville, just below dam, Bedford Co., SIUC 19610 (6) 19 May 1992, SIUC unvouchered (8) 9