Technical / Agency Draft Recovery Plan
for the Laurel Dace (*Chrosomus saylori*)

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EXECUTIVE SUMMARY

Current Species Status: The laurel dace is a small fish endemic to the Tennessee River Basin in Tennessee. The U.S. Fish and Wildlife Service listed laurel dace as an endangered species under the Endangered Species Act of 1973 as amended (Act) on August 9, 2011 (76 FR 48722) and designated critical habitat for the species on October 16, 2012 (77 FR 63604). The Tennessee Wildlife Resources Agency (TWRA) lists the laurel dace as endangered, under the Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act of 1974 (Tennessee Code Annotated §§ 70-8-101-112). Laurel dace persist in three creek systems on the Walden Ridge of the Cumberland Plateau in Tennessee. Only a few individuals have been collected from the two creek systems in the southern part of their range, Soddy and Sale creeks, while laurel dace are more abundant in headwater streams of the Piney River system to the north. Historically, this species is known from seven streams, and currently it occupies six of those. The fish is believed extirpated from Laurel Branch. The laurel dace has a recovery priority number of 5, which indicates a species facing a high degree of threat and a low recovery potential.

Habitat Requirements and Limiting Factors**:** Laurel dace are known from headwater tributaries on Walden Ridge. This is a small fish from the family Cyprinidae that is normally found or collected from pools or slow runs from undercut banks or under slab boulders. The riparian vegetation surrounding the first or second order streams where laurel dace occur includes mountain laurel (*Kalmia latifolia*), rhododendron (*Rhododendron* sp.), and hemlocks (*Tsuga canadensis*). Laurel dace are thought to be sensitive to both water temperature and siltation. Threats to the laurel dace include: (1) land use activities which affect silt levels, temperature, or hydrologic processes of these small tributaries, (2) invasive species including sunfishes, basses, or hemlock woolly adelgid, (3) naturally small population size and geographic range, and (4) climate change.

Recovery Strategy: The recovery strategy for laurel dace is to ensure that viable populations exist in all streams where the species is known to have historically been present, by conserving existing populations and restoring or augmenting populations as needed. To ensure the long-term viability of laurel dace, it will be necessary to protect, and in some cases restore, habitat in the headwater streams of the three drainages where the species currently is found: Piney River (Bumbee, Moccasin, and Youngs creeks), Soddy Creek, and Sale Creek (Cupp Creek and Horn Branch). Existing laws, regulations, and policies must be enforced or used to protect water quality by minimizing erosion and sedimentation in catchments of laurel dace streams. Protecting and restoring habitat would also be necessary in any additional drainages where populations are found or established in the future. In order to implement this strategy, the Service will work with partners to inform the public about laurel dace and measures that can be taken to sustain adequate flows, protect water quality, and reduce fragmentation of suitable habitats within streams where the species occurs. Whenever possible, the Service and other partners will assist citizens and local governments in their efforts to reduce threats resulting from land use practices. In addition to informing the public and promoting compatible land uses and habitat protection in the drainages where laurel dace occurs, it will be necessary to conduct research about the species' life history, interactions with other species, and tolerances to factors that degrade habitat quality. Captive propagation will be necessary to support research and potentially for reintroducing and/or augmenting populations to recover this species.

***Recovery Goal*:** The goal for this recovery plan is to conserve and recover populations of laurel dace to the point that listing under the Act is no longer necessary, which will require the following objectives to be accomplished. In order to recover laurel dace to the point that listing under the Act is no longer necessary, it will be necessary to conserve all existing populations by maintaining, and in some cases, restoring suitable habitat conditions in all streams where the species currently occurs. It will also be necessary to discover or establish one additional population. Because recovery and delisting will be a long, and potentially unachievable goal, an intermediate goal for this recovery plan is to recover the species to the point that it could be reclassified from endangered to threatened. Reclassification to threatened status will be possible when habitat conditions in occupied streams are suitable for the conservation of the species, and viable populations are present throughout suitable habitat in five of the six currently occupied streams.

The following criteria will be used to determine whether the objectives above for reclassification and delisting have been met. The criteria will be achieved by reducing or removing threats to the species' habitat and conserving or establishing viable populations throughout the species' range, as determined by monitoring of demographic and genetic parameters.

Criteria for Reclassification from Endangered to Threatened:

Criterion 1: Suitable instream habitat, flows, and water quality for laurel dace, as defined by recovery tasks 5.1 and 5.2, exist in occupied streams.

Criterion 2: Viable populations[*] are present throughout suitable habitat in Bumbee, Moccasin, and Youngs creeks, and at least two of the following streams: Soddy or Cupp creek or Horn Branch.

Criteria for Delisting:

Criterion 1: Suitable instream habitat, flows, and water quality for laurel dace exist in all occupied streams, and mechanisms exist to ensure that land use activities (including road maintenance) in catchments of streams inhabited by laurel dace will be compatible with the species' conservation for the foreseeable future. Such mechanisms could include, but are not necessarily limited to, conservation agreements, conservation easements, land acquisition, and habitat conservation plans.

Criterion 2: Viable populations[*] are present throughout suitable habitat in Bumbee, Moccasin, Youngs, Soddy, and Cupp creeks and Horn Branch, and one additional viable population exists, either through reintroduction into Laurel Branch or discovery of an additional wild population.

[*]Populations will be considered viable when the following demographic and genetic conditions exist:

- Demographics – monitoring data demonstrate that (a) populations are stable or increasing, (b) two or more age-classes are consistently present over a period of time encompassing five generations (i.e., 15 years), and (c) evidence of recruitment is not absent in more than three years or during consecutive years at any point within that period of time.

- Genetics – populations will be considered to have sufficient genetic variation to be viable if measurements of observed number of alleles and estimates of heterozygosity and effective population size have remained stable or increased during the five generations used to establish demographic viability.

Actions needed:

1. Protect laurel dace habitat via land acquisition, conservation easements, or other mechanisms to reduce threats to instream and riparian habitat.
2. Map suitable habitat in streams where laurel dace are extant or occurred historically, identify streams on Walden Ridge with suitable habitat but no known records of occurrence, and periodically conduct surveys for previously undetected populations and to determine whether populations are still extant in occupied streams.
3. Develop a program to monitor trends in distribution and demographic structure of laurel dace populations, habitat conditions, and land use in catchments of laurel dace streams.
4. Conduct baseline genetic analysis and establish protocol for periodic monitoring to detect trends in genetic variation and structure among populations.
5. Determine life history, interspecies interactions, and tolerance to environmental stressors of the laurel dace, and conduct population viability analysis.
6. Evaluate stream crossings as fish passage barriers or nonpoint pollutant sources and reduce impact if necessary.
7. Establish protocols and plan for captive propagation to support research and reintroduction or augmentation.
8. Develop informational materials and conduct outreach to encourage public participation in laurel dace recovery effort.

Estimated Cost to Downlist to Threatened: The estimated cost to downlist laurel dace to threatened status is not determinable at this time, but we have estimated that the initial five years of implementing this recovery plan would cost $1,225,000 (Table 1).

Table 1. Estimated Cost (in 1000's) for five years.

Year	Action 1	Action 2	Action 3	Action 4	Action 5	Action 6	Action 7	Action 8	Total
1	100	10	19	20	50	12	30	3	244
2	100	5	10	0	20	202	30	3	370
3	100	0	10	0	40	52	30	3	235
4	100	0	6	0	40	22	30	3	201
5	100	5	15	20	10	22	30	3	205
Total	500	20	60	40	160	310	150	15	1255

Estimated Date to Downlist to Threatened: Since many recovery tasks will require voluntary participation by landowners to protect and restore habitat, and we cannot estimate how quickly viable populations will become established in response to efforts to protect and restore habitat conditions, the estimated date for downlisting laurel dace to threatened status is not determinable at this time.

CONTENTS

I. BACKGROUND

A. BIOLOGICAL ASSESSMENT

Taxonomy

The laurel dace (*Chrosomus saylori*), family Cyprinidae and subfamily Leuciscinae, was first collected on Walden Ridge in 1976, but not described as a distinct species until 2001 (Skelton 2001). It is a member of the redbelly dace group (genus *Chrosomus*), comprising seven recognized and one undescribed species in North America. Originally described in the genus *Phoxinus*, a revision by Strange and Mayden (2009) elevated the subgenus *Chrosomus* and reassigned all seven North American *Phoxinus* species to this genus.

Laurel dace were recovered as sister to the undescribed Clinch dace (*Chrosomus* sp. cf. *saylori*) in analysis of the mitochondrial cytochrome *b* gene (Strange and Skelton 2005). Clinch dace are currently known from the upper Clinch River system in Virginia, two sites from the Emory River in Tennessee, and two sites from the Big South Fork Cumberland River drainage in Tennessee (A. George pers. comm. 2012). The group formed by laurel dace and Clinch dace is sister to the federally listed, threatened blackside dace, which occurs in the Upper Cumberland River drainage in Tennessee and Kentucky, and the Powell River drainage in Virginia (Strange and Mayden 2009).

Morphology

Laurel dace have two continuous black lateral stripes and black pigment covering the breast and underside of the head of nuptial (breeding) males (Skelton 2001). The maximum standard length (SL) observed is 6.2 centimeters (cm) (2.4 inches (in)) (Skelton 2001). While the belly, breast, and lower half of the head are typically a whitish-silvery color, at any time of the year laurel dace may develop red coloration below the lateral stripe that extends from the base of the pectoral fins to the base of the caudal fin (Skelton 2001).

Nuptial males often acquire brilliant coloration during the breeding season, as the two lateral stripes, breast, and underside of head turn intensely black and the entire ventral (lower/abdominal) portion of the body becomes an intense scarlet color. All of the fins acquire a yellow color, which is most intense in the paired fins and less intense in the dorsal, anal, and caudal fins. Females also develop most of these colors, though of lesser intensity (Skelton 2001). Broadly rounded pectoral fins of males are easily discerned from the broadly pointed fins of females at any time during the year.

Life History

A detailed examination of life history of laurel dace has not been completed. Skelton (2001) observed nuptial males from late March until mid-June. Studies of other redbelly daces suggest they are nest associates where they occur with nest-building minnow species such as largescale stoneroller (*Campostoma oligolepis*; Raney 1947; Starnes and Starnes 1981). Skelton (2001) did observe a group of 20 laurel dace moving over a stoneroller nest in May 1994. Three year-classes have been noted in some collections of laurel dace, indicating laurel dace live as long as three years, though young-of-year fish are uncommon in collections (Skelton 2001). Analysis of gut contents of 12 laurel dace indicated a preference for a benthic invertebrate diet including fly, stonefly, and caddisfly larvae (Skelton 2001). Skelton (2001) observed that the morphological feeding traits of laurel dace, including a large mouth, short digestive tract, reduced number of pharyngeal (located within the throat) teeth, and primitively shaped basioccipital bone (part of the rear of the skull which bears a pad that opposes the pharyngeal teeth during throat mastication or chewing), are consistent with a diet consisting largely of animal material.

A partial examination of life history has been completed for the closely related and undescribed Clinch dace (*Chrosomus* sp. cf. *saylori*), which may provide some insight into laurel dace life history (White 2012). The gut of Clinch dace (n=63) was short (0.63 of standard length, SE=0.019), s-shaped, and lacked the coiling seen in other *Chrosomus* exclusive of laurel dace. Macroinvertebrates dominated the diet, including dobsonfly (any insect in the subfamily Corydalinae), beetle, fly, and wasp larvae, and ticks. Smaller amounts of algae, other plant materials, and sand grains were observed in the diet. Gut contents corroborated field observations; Clinch dace were seen mostly drift feeding, but would occasionally feed on attached algae and periphyton. These results are largely congruent with other species in the genus (White 2012).

Habitat

Laurel dace have been most often collected from pools or slow runs from undercut banks or beneath slab boulders, typically in first or second order, clear, cool (maximum temperature 26 °C or 78.8 °F) streams. Substrates in streams where laurel dace are found typically consist of a mixture of cobble, rubble, and boulders, and the streams tend to have a dense riparian zone consisting largely of mountain laurel (*Kalmia latifolia*), but also including eastern hemlock (*Tsuga canadensis*), mixed hardwoods, and pines (*Pinus* spp) (Skelton 2001). Water temperature may be a limiting factor in the distribution of this species (Skelton 1997).

Distribution

Despite the fact that surveys for laurel dace have been conducted at over 150 sampling sites, the species is known historically from only seven streams on the Walden Ridge portion of the Cumberland Plateau (Figure 1, Appendix A). Headwater streams on Walden Ridge generally meander eastward before dropping abruptly down the plateau escarpment and draining into the Tennessee River. The seven streams where laurel dace have been found are tributary to three independent systems: Soddy Creek system; three streams that are part of the Sale Creek system (the Horn and Laurel branch tributaries to Rock Creek, and the Cupp Creek tributary to Roaring Creek); and three streams that are part of the Piney River system (Youngs, Moccasin, and Bumbee creeks).

Skelton (2001) considered collections by the Tennessee Valley Authority (TVA) during a rotenone survey of Laurel and Horn Branch in 1976 to represent laurel dace that were misidentified as southern redbelly dace (*Chrosomus erythrogaster*). However, no Laurel Branch specimens are available for confirmation. In five surveys from 1991 to 2004, laurel dace were not collected in Laurel Branch, leading Skelton to the conclusion that they have been extirpated from this stream (Skelton 1997, Skelton 2001, Skelton pers. comm. 2009). Skelton (pers. comm. 2009) also noted that Laurel Branch was impacted by silt, which is present through most of this stream down to the junction with Horn Branch (Kuhajda and Neely 2013).

The current distribution of laurel dace comprises six of the seven streams that were historically occupied; the species is considered extirpated from Laurel Branch (see above). In these six streams, they are known to occupy reaches of approximately 0.3 to 8 kilometers (km) (0.2 to 5 miles (mi)) in length. In 2004, surveys in Soddy Creek produced only a single juvenile laurel dace (Strange and Skelton 2005). In Horn Branch, laurel dace were known from approximately 900 meters (m) (2,953 feet (ft)), and were becoming increasingly difficult to collect (Skelton 1997). Skelton (1997) reported that minnow traps have been the most successful method for collecting laurel dace from Horn Branch, as it is difficult to electroshock the fish due to in-stream rock formations and fallen trees. Only a single juvenile was caught in Horn Branch in 2004 (Strange and Skelton 2005), and a single juvenile was caught in this same reach during 2013 (Kuhajda field notes 2013). A total of 19 laurel dace was collected from Cupp Creek during 1995 and 1996 using an electroshocker (Skelton 1996). However, Skelton found no laurel dace in this stream in 2004, despite attempts to collect throughout an approximately 700-m (2,297-ft) reach (Strange and Skelton 2005) extending from the mouth of Cunningham Branch upstream to an old stream crossing on private property. In 2013, no laurel dace were observed during surveys conducted by TNACI in this reach of Cupp Creek (Kuhajda field notes 2013).

Laurel dace were initially found in Youngs, Moccasin, and Bumbee Creeks in the Piney River system in 1996 (Skelton 1997). Sampling in 2004 led to the discovery of additional laurel dace localities in Youngs and Moccasin Creeks, but the locality where laurel dace were found in Youngs Creek in 1996 was inaccessible due to the presence of a locked gate (Strange and Skelton 2005). The new localities were in the headwaters of these two streams. Four laurel dace were observed at an upstream site on Youngs Creek in 2013, though deep silt deposits were present and habitat conditions for laurel dace were generally poor (Kuhajda field notes 2013). Laurel dace were observed to be abundant at a site on Moccasin Creek in 2013 (Kuhajda field notes 2013) and sparse at a different tributary to Moccasin Creek (entering downstream of the 2013 collection site) in 2010 (Neely field notes 2010).

Persistence of laurel dace at the Bumbee Creek locality was confirmed in 2004 by surveying from a nearby road using binoculars. Direct surveys were not possible because the land had been leased to a hunt club for which contact information was not available, and survey permission could not be obtained (Strange and Skelton 2005). Nuptial male laurel dace are easily discerned from other species present in Bumbee Creek due to their brilliant coloration during the breeding season, as the two lateral stripes, breast, and underside of head turn intensely black and the entire ventral (lower/abdominal) portion of the body becomes an intense scarlet color. This brilliant coloration is easily seen through binoculars at short distances by trained individuals. Laurel dace were observed from the road at the Bumbee Creek site (Walden Mountain Road) in 2010, but no assessment of population size or viability for this subpopulation was possible due to restricted access (Neely field notes 2010). The Tennessee Aquarium Conservation Institute (TNACI) and Tennessee Wildlife Resources Agency (TWRA) sampled the transition zone where Bumbee Creek enters Piney River in 2013 and observed no dace (Kuhajda field notes 2013). However, substrate conditions were such that seining was not a particularly effective sampling technique. The downstream extent of laurel dace in Bumbee Creek is still unknown.

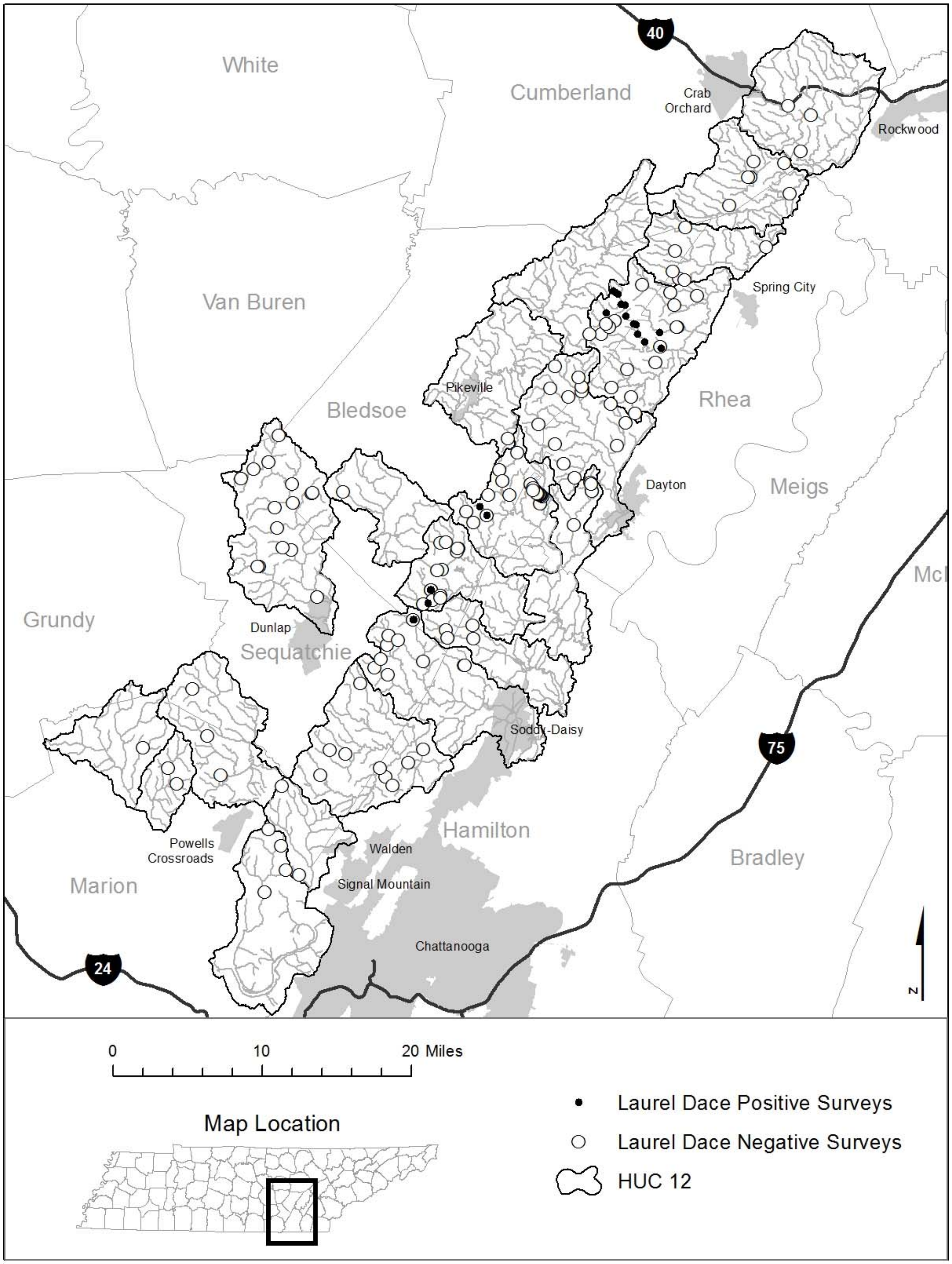

Figure 1. Laurel dace distribution map. Filled circles indicate laurel dace presence during at least one sampling event at that location. Empty circles denote absence. See Appendix A for a table of sampling locations and results (Skelton 1996 and 1997, Strange and Skelton 2005, USFWS unpublished data, A. George field notes 2013, B. Kuhajda field notes 2013, Kuhajda and Neely 2013, Neely field notes 2010 and 2013, USFWS unpublished data).

While reviewing museum records of southern redbelly dace from Tennessee, several geographically interesting records were noted, and the specimens requested for review. In August 1954, Reeve and Marion Bailey collected one adult and three juvenile specimens of dace from Grassy Cove Creek at TN Hwy 68, Cumberland County. These specimens were catalogued at the University of Michigan Museum of Zoology as *Phoxinus erythrogaster*, and were reidentified as *Chrosomus saylori* by D.A. Neely, on the basis of the low lateral line scale counts, short snout, short and deep caudal peduncle, and pigmentation (Neely pers. comm. 2014). The adult male still retains the diagnostic lateral stripe pattern of laurel dace. Grassy Cove is an endorheic basin (a closed drainage basin that does not allow surface outflow to other bodies of water) that drains into a sink and via groundwater to the Sequatchie River. It had not previously been surveyed for laurel dace, and represents a substantial range expansion. Neely (field notes 2013) visited this locality and several others in the basin in April 2013 and did not collect any *Chrosomus*. Additional survey work is warranted in this small basin.

Two other museum records were reassigned to Tennessee dace (*Chrosomus tennesseensis*). These records are from McWilliams Creek in Bledsoe County (a tributary to the Sequatchie River, with headwaters on Walden Ridge very close to the head of Soddy Creek) and Bear Branch in Cumberland County (a Tennessee River tributary that runs off of Walden Ridge just north of known laurel dace sites). These records suggest that the enigmatic distribution of Tennessee dace (completely encircling laurel dace) dates back several decades further than previously thought and may suggest native status in these streams. Further work on this question is warranted.

No population estimates are available for laurel dace. However, based on trends observed in surveys and collections since 1991 (Appendix A), Strange and Skelton (2005) concluded that this species is persisting in Youngs, Moccasin, and Bumbee Creeks in the Piney River watershed, but is at risk of extirpation from the southern part of Walden Ridge in Soddy Creek, and in the Horn Branch and Cupp Creek tributaries to Sale Creek. As noted above, the species is considered to be extirpated from Laurel Branch, which is part of the Sale Creek system.

Population Genetics

The confluences of Soddy Creek, Sale Creek, and Piney River with the Tennessee River lie well below the escarpment of Walden Ridge, and movement of laurel dace among these stream systems is unlikely. Strange and Skelton (2005) analyzed mitochondrial DNA variation in laurel dace among these three drainages and identified two distinct groups: the northern populations in tributaries of the Piney River and the southern populations in Soddy Creek and tributaries to Sale Creek (Strange and Skelton 2005). Six haplotypes (combination of alleles at loci that are found on a single chromosome or DNA molecule) were recovered from thirty individuals in the northern populations, with only one haplotype shared across the populations in the three streams. In contrast, only one haplotype, not found in the northern populations, was recovered from the seven individuals collected from the two southern populations. An analysis of molecular variance revealed that the majority of genetic variation (72%) was recovered between the northern and southern populations rather than between populations in either system (10%) or within populations (17%). Based on these results, Strange and Skelton (2005) recommended treating the northern and southern populations as separate management units. While additional analyses of population genetic structure using nuclear DNA are needed to test the relationships found using mitochondrial DNA, we will maintain the discreteness of these two groups of populations for the purposes of captive propagation and population reintroductions or augmentation until such analyses have been conducted.

Critical Habitat

We designated critical habitat for the laurel dace on October 16, 2012 (77 FR 63604). Based on our current knowledge of the physical or biological features and habitat characteristics required to sustain the species' life history processes, the Service determined that the primary constituent elements specific to the laurel dace are:

(1) Pool and run habitats of geomorphically stable, first- to second-order streams with riparian vegetation; cool, clean, flowing water; shallow depths; and connectivity between spawning, foraging, and resting sites to promote gene flow throughout the species' range.

(2) Stable bottom substrates composed of relatively silt-free gravel, cobble, and slab-rock boulder substrates with undercut banks and canopy cover.

(3) Instream flow regime (magnitude, frequency, duration, and seasonality of discharge over time) sufficient to provide permanent surface flows, as measured during years with average rainfall, and to maintain benthic habitats utilized by the species.

(4) Adequate water quality characterized by moderate stream temperatures, acceptable dissolved oxygen concentrations, moderate pH, and low levels of pollutants. Adequate water quality is defined here as the quality necessary for normal behavior, growth, and viability of all life stages of the laurel dace.

(5) Prey base of aquatic macroinvertebrates, including midge larvae, caddisfly larvae, and stonefly larvae.

We designated six, occupied critical habitat units for laurel dace (Figure 2). The designated critical habitat units include the stream channels within the ordinary high water line. Nearly 100 percent of these units are privately owned, except the small amount that is publicly owned by Bledsoe, Rhea, or Sequatchie Counties in the form of bridge crossings and road easements.
In Tennessee, landowners own the land under non-navigable streams (e.g., the stream channel or bottom), but the water is under State jurisdiction. The six critical habitat units for laurel dace are:

Unit 1: Bumbee Creek – This unit includes 7.8 rkm (4.8 rmi) of Bumbee Creek from its headwaters in Bledsoe County, downstream to its confluence with Mapleslush Branch in Rhea County.

Unit 2: Youngs Creek – This unit includes 7.9 rkm (4.9 rmi) of Youngs Creek from its headwaters in Bledsoe County, downstream to its confluence with Moccasin Creek in Rhea County.

Unit 3: Moccasin Creek – This unit includes 9.0 rkm (5.6 rmi) of Moccasin Creek from its headwaters downstream to 0.1 rkm (0.6 rmi) below its confluence with Lick Creek in Bledsoe County.

Unit 4: Cupp Creek – This unit includes 5.0 rkm (3.1 rmi) of Cupp Creek from its headwaters downstream to its confluence with an unnamed tributary in Bledsoe County.

Unit 5: Horn Branch – This unit includes 4.0 rkm (2.5 rmi) of Horn Branch from its headwaters downstream to its confluence with Rock Creek in Bledsoe County.

Unit 6: Soddy Creek – This unit includes 8.4 rkm (5.2 rmi) of Soddy Creek from its headwaters in Sequatchie County, downstream to its confluence with Harvey Creek in Sequatchie County, Tennessee.

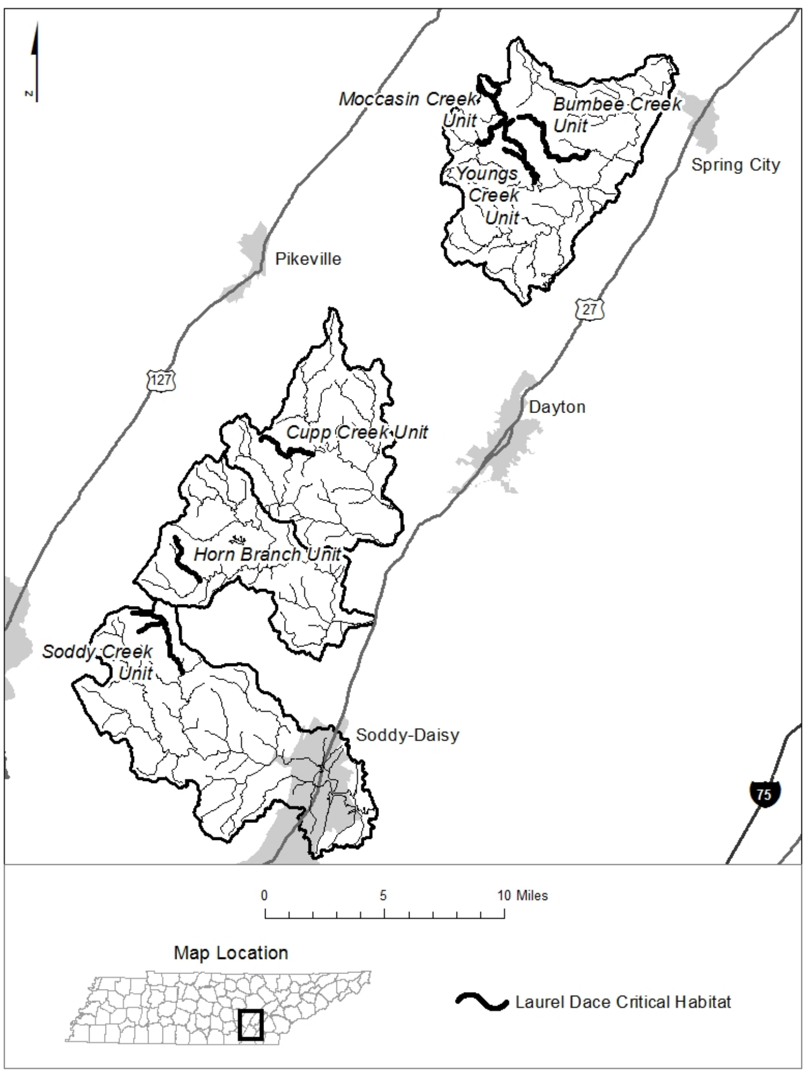

Figure 2. Designated critical habitat units for laurel dace (77 FR 63604).

B. THREAT ASSESSMENT

The TWRA lists the laurel dace as endangered, under the Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act of 1974 (Tennessee Code Annotated §§ 70-8-101-112). A summary of threats affecting the laurel dace and its habitats are outlined below. Primary threats include decreased water and habitat quality resulting from siltation and other non-point source pollution, habitat fragmentation due to the presence of artificial barriers, inadequacy of existing regulatory mechanisms, and restricted range and population size.

Factor A: Present or Threatened Destruction, Modification or Curtailment of its Habitat or Range

The final rule to list laurel dace as endangered (76 FR 48722) identified siltation and other non-point source pollutants, removal or alteration of riparian vegetation, and presence of fish passage barriers created by culverts at road crossings across streams as factors causing the destruction or modification of the species' habitat. In addition to these stressors, conversion of native hardwood forests to residential uses, pasture, crop, and pine monocultures has likely altered hydrology in the catchments of streams where laurel dace occur. Stressors originating from residential development likely will increase, as examination of parcel data in the Piney River and Soddy and Sale Creek drainages reveals that many tracts of land in the uppermost headwaters have been subdivided into smaller parcels for residential development. While development has not yet occurred on many of these parcels, the abundance of parcels that are 1 to 10 acres in size and classified as residential (State of Tennessee 2007a, 2007b, and 2008) indicates that increasing density of residential development could become a threat to aquatic life in these drainages.

While Skelton (2001) concluded that the laurel dace is "presumably tolerant of some siltation, Strange and Skelton (2005) observed levels of siltation they considered problematic during later surveys for the laurel dace and concluded siltation posed a threat in several localities throughout the species' range. Sediment can affect fish through multiple pathways, including reproduction (lack of visual cues; reduction in interstitial spaces for benthic egg deposition or buried nests), feeding (altered prey base, reduced visibility of prey) and physiology (abraded or clogged gills) (Waters 1995, Burkhead and Jelks 2001, Knight and Welch 2001, Sweka and Hartman 2001, Bonner and Wilde 2002, Sutherland and Meyer 2007, Zamor and Grossman 2007). The levels of siltation laurel dace are able to tolerate before populations begin to decline due to siltation-related stressors is not currently known, but the apparent recent decline of populations in Horn Branch, Cupp Creek, and Youngs Creek (Appendix A) indicate that critical thresholds might have been reached in at least some portions of its range (Strange and Skelton 2005).

Strange and Skelton (2005) identified siltation as a threat in all of the occupied Piney River tributaries (Youngs, Moccasin, and Bumbee Creeks). The Bumbee Creek type locality for the laurel dace is located within industrial forest that has been subjected to extensive clear-cutting and forestry-related road construction in close proximity to the stream. Strange and Skelton (2005) noted a heavy sediment load at this locality and commented that habitat conditions in Bumbee Creek in 2005 had deteriorated since the site was visited by Skelton in 2002. Strange and Skelton (2005) also commented on excessive siltation in localities they sampled on Youngs and Moccasin Creeks, and they observed localized removal of riparian vegetation around residences in the headwaters of each of these streams.

Within the range of laurel dace, conversion of native forest to pine monocultures is most prevalent in catchments of Young and Bumbee creeks. In the uppermost headwaters of these streams, forest land also has been converted to pasture or crop fields on several parcels, in some places adjacent to the streams. In addition to increases in siltation that are likely to result from these land use changes, converting land use in catchments from native forest to pine monocultures has been shown to reduce stream flow (Ford et al. 2011).

Ground disturbance during culvert installation at road crossings and lack of effective erosion control following installation also is a source of sediment adversely affecting laurel dace habitat. As of July 2013, all three locations where Summer City Road crosses Moccasin Creek in Bledsoe County were notable for excessive siltation both upstream and downstream of recently replaced culverts; two of these are located within critical habitat for laurel dace. No laurel dace were found at any of these sites in June 2013 sampling (A. George field notes 2013). Laurel dace were last collected at the most upstream crossing on Summer City Road in 2004, but have never been collected at the two lower road crossings. Culvert erosion has also been noted at Cunningham Branch (a tributary to laurel dace critical habitat in Cupp Creek) along Brayton Road (A. George field notes 2013).

Land conversion to row crop agriculture also presents a threat to laurel dace habitat. In 2009, two large pine plantations within the Soddy Creek Watershed were harvested and converted to tomato farms. An irrigation impoundment was built on one Soddy Creek tributary and another was under construction during 2013. These tomato fields have introduced a substantial source of sediment into the Soddy Creek headwaters. In addition to contributing sediment, irrigation and stormwater runoff from crop fields may flow directly into the creek, potentially containing fungicides, herbicides, and fertilizers (Thurman pers. comm. 2009). A tomato farm is also present in the headwaters of Youngs Creek, where a sign was present in July 2013 barring human entrance due to pesticides (Figure 3; George pers. comm. 2013). Based on inspection of aerial imagery, this site on Youngs Creek has been in agricultural production since at least 2004.

Riparian buffers filter sediment and nutrients from overland runoff, allow water to soak into the ground, protect stream banks, and provide shade for streams (Waters 1995). Removal of riparian vegetation near aquatic habitat is problematic not only for its potential to increase siltation, but also for the potential thermal alteration that could result from the loss of canopy cover shading these small headwater streams (Strange and Skelton 2005). Skelton (2001) reported that laurel dace occupy cool streams with a maximum recorded temperature of 26 °C (78.8 °F). Though the species' tolerance of elevated stream temperatures has not been investigated, removal of riparian vegetation along the shallow, headwater streams the species inhabits could potentially increase temperatures above the laurel dace's maximum tolerable limit.

Figure 3. Tomato farm with warning sign about pesticide use in upper Youngs Creek watershed, Bledsoe County, TN. Photo credit A. George, Tennessee Aquarium, 2013.

An emerging threat to laurel dace is the loss of hemlocks from riparian areas due to the hemlock woolly adelgid (*Adelges tsugae*) (HWA), a nonnative insect that infests hemlocks, causing damage or death to trees. HWA increases mortality rates for hemlocks in the southern Appalachians; in North Carolina, more than 85% of infested trees were dead seven years following infestation (Ford et al. 2012). HWA was documented on Walden Ridge in Rhea County in 2008 and Bledsoe County in 2013, with likely infestation of hemlock in riparian forests along laurel dace streams in the future (Johnson pers. comm. 2013). All three watersheds containing laurel dace have known HWA infestations from US Highway 27 up Walden Ridge (D. Godbee pers. comm. 2013), but only hemlocks on state lands have been mapped so far (D. Lincicome pers. comm. 2013).

Because eastern hemlock is primarily found in riparian areas, the loss of this species adjacent to laurel dace streams would be detrimental to fish habitat in a number of ways, including short-term and/or long-term changes to light levels, temperature, average streamflow, allochthonous inputs (inputs originating from outside the aquatic system), and aquatic community assemblage

(Ford and Vose 2007; Siderhurst et al. 2010; Webster et al. 2012; Northington et al. 2013). In the short-term, light levels on streams are expected to increase as the hemlock canopy is lost; this may be mitigated by increased rhododendron thickets over time (Webster et al. 2012). The subsequent impact on stream temperatures is less predictable, as some studies indicate they may be more influenced by groundwater input and understory shading than hemlock shade cover (Roberts et al. 2009; Siderhurst et al. 2010). Hemlocks, through their location in riparian zones and unique transpiration rates as dominant evergreens, have a distinct ecohydrological role in Appalachian forests that influences streamflow. A widespread loss of hemlocks could lead to an increase in streamflow discharge year-round, paired with an even larger increase in discharge in the spring when hemlock transpiration rates are highest (Ford and Vose 2007). Altered streamflows during the spring could affect courtship and spawning behavior of laurel dace. Amounts of large woody debris in streams will initially increase during hemlock die-off, but could decrease over the long-term as riparian vegetation is replaced by the smaller rhododendron (Webster et al. 2012). While an increase in primary production in-stream over the long-term is not expected, based on similar light levels under rhododendron or hemlock canopies, the aquatic community might still be altered (Northington et al. 2013). If hemlocks are replaced by deciduous trees, macroinvertebrate communities could shift to shredders based on the differing allochthonous input, but a change to rhododendrons might have less impact on benthic communities as their leaves are less preferred (Webster et al. 2012). These changes could significantly impact habitat and food availability for laurel dace.

Chemical, biological, cultural, host resistance, and host gene treatments have been employed to manage HWA in the southern Appalachians (Vose et al. 2013). Systemic insecticides, including imidacloprid and dinotefuran, have been applied via soil drench, soil injection, stem injection, or trunk spray (Knoepp et al. 2012; Vose et al. 2013). Because imidacloprid is water soluble, it can leach into soils or surface water and impact both terrestrial and aquatic macroinvertebrates (Knoepp et al. 2012). While most studies to date have found no or minimal impacts of imidacloprid use on long-term composition of terrestrial or aquatic invertebrate communities, the authors caution that site-specific characteristics may reduce the applicability of these studies elsewhere (Churchel et al. 2011; Knoepp et al. 2012; Vose et al. 2013). Both biological (release of introduced predatory beetles) and chemical treatments have been used on state park lands located downstream of laurel dace critical habitat (D. Lincicome pers. comm. 2013); no treatments are currently planned for lands adjacent to stream reaches occupied by laurel dace.

The presence of inadequately sized culverts at one or more road crossings in most of the streams inhabited by laurel dace may disrupt dispersal within those systems (S. Chance pers. obs. 2008). Such dispersal barriers could prevent re-establishment of laurel dace populations in reaches where they suffer localized extinctions due to natural or human-caused events. While replacing inadequately sized or poorly installed or maintained culverts will be necessary to restore connectivity among some currently fragmented stream reaches, care must be taken to minimize soil erosion and stream sedimentation in the course of this work. Several culverts have been replaced since 2012, and sediment deposition as well as future potential for erosion at some of these sites is quite high (Figure 4; George field notes 2013).

(a)

(b)

Figure 4. (a) Newly installed culverts at most downstream Summer City Road crossing on Moccasin Creek. (b) Silt deposition upstream of middle road crossing of Summer City Road and Moccasin Creek, Bledsoe County, TN. Photo credits A. George, Tennessee Aquarium, 2013.

In 2009, coal exploration drilling was done near Horn Branch in the Rock Creek watershed to determine if mining is feasible in this area, and a permit application for drilling was subsequently denied due to deficiencies in the application that were not addressed by the company (Effler pers. comm. 2013). Coal mining could still be approved in the watershed with an appropriate application; therefore, coal mining is a potential threat to this species.

Factor B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Laurel dace are not commercially utilized. Individuals have been taken for scientific studies in the past (Appendix A), including rotenone surveys of Horn Branch and Laurel Branch by the TVA in 1976, but the effects of these collections on populations is not known. Because take for scientific purposes is now strictly regulated by both TWRA and the Service, scientific collecting is not expected to be a cause for decline of the species in the future. There is some risk of take by anglers for bait; anecdotal discussions with landowners suggest that at least some routinely collect bait minnows for angling from streams occupied by laurel dace (George field notes 2013). Active fish trapping efforts were observed at a Clinch dace locality in southwest Virginia in 2010 (Neely field notes 2010).

Factor C: Disease or Predation

Disease is not considered to be a factor in the decline of laurel dace. Predation may be occurring from introduced sunfishes and basses, particularly in Cupp Creek, where surveys in 2013 revealed the presence of large numbers of green sunfish (*Lepomis cyanellus*), bluegill (*L. macrochirus*), and largemouth bass (*Micropterus salmoides*). One landowner mentioned that these species were in the creek due to the frequent flooding of his farm pond (George field notes 2013). Skelton noted an increase in the numbers of sunfishes and basses in pools in Cupp Creek during the early 1990s coinciding with a decline in the numbers of laurel dace observed (Skelton pers. comm. 2006). Sunfishes and basses could be contributing to the decline of laurel dace through predation, particularly in Cupp Creek.

Factor D: Inadequacy of Existing Regulatory Mechanisms

The Tennessee Wildlife Resources Agency (TWRA) lists the laurel dace as endangered, under the Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act of 1974 (Tennessee Code Annotated §§ 70-8-101-112). The laurel dace and its habitats are afforded some protection from water quality and habitat degradation under the Clean Water Act (CWA) and by TDEC's Water Resources Division Control under the Tennessee Water Quality Control Act of 1977 (TWQCA, T.C.A. 69-3-101). However, population declines and degradation of habitat for this species are ongoing despite the protection afforded by these laws. While these laws have resulted in improved water quality and stream habitat for aquatic life, including the laurel dace, they alone have not been adequate to fully protect laurel dace; sedimentation and non-point source pollutants continue to be a significant problem. Sediment is the most visible pollutant in the streams where laurel dace occur and one of the greatest threats to the species. Because sedimentation and other nonpoint source pollutants are not regulated by the Clean Water Act, effective regulatory mechanisms to protect water quality for the laurel dace are not in place.

Factor E: Other Natural or Manmade Factors Affecting its Continued Existence

Restricted Range and Population Size: The laurel dace has an extremely limited geographic range on Walden Ridge. The current distribution of laurel dace comprises six of the seven streams that were historically occupied; the species is considered extirpated from Laurel Branch. Of the streams inhabited by the southern populations of laurel dace (Soddy Creek and the Horn

Branch and Cupp Creek tributaries to Sale Creek) (Strange and Skelton 2005), the reaches from which the species has been collected in Soddy Creek and Horn Branch approach 1 km (0.6 mi) in length. In Cupp Creek, collections of this species are restricted to less than 300 m (984 ft) of stream, despite surveys well beyond the reach known to be inhabited. In each of the streams occupied by the southern populations, Strange and Skelton (2005) identified siltation as a factor that could alter the habitat and render it unsuitable for laurel dace. The restricted distribution of laurel dace in streams inhabited by both the northern and southern populations leaves them highly vulnerable to potential deleterious effects of excessive siltation or other localized disturbances.

Species that are restricted in range and population size are more likely to suffer loss of genetic variation due to genetic drift, potentially increasing their susceptibility to inbreeding depression, decreasing their ability to adapt to environmental changes, and reducing the fitness of individuals (Soule 1980, Hunter 2002, Allendorf and Luikart 2007). It is likely that most of the laurel dace populations are below the effective population size required to maintain long-term genetic and population viability (Soule 1980, Hunter 2002). The long-term viability of a species is founded on the conservation of numerous local populations throughout its geographic range (Harris 1984). These separate populations are essential for the species to recover and adapt to environmental change (Harris 1984, Noss and Cooperrider 1994). The level of isolation seen in laurel dace would make natural repopulation following localized extirpations in most occupied stream reaches virtually impossible without human intervention.

Climate Change: Climate change has the potential to increase the extinction risk for freshwater species, such as the laurel dace, due to changes in stream hydrology and ecology from changing precipitation patterns and evapotranspiration in the riparian zone (IPCC 2007). An increase in both severity and variation in climate patterns is expected, with extreme floods and droughts potentially becoming more common (IPCC 2007, Ford et al. 2011). Impacts of climate change on fishes include disruption to their physiology (such as temperature tolerance, dissolved oxygen needs, and metabolic rates); life history (such as timing of reproduction, growth rate), and distribution (range shifts, migration of new predators) (Jackson and Mandrak 2002, Heino et al. 2009, Strayer and Dudgeon 2010, Comte et al. 2013). While some coldwater fishes have already been found farther north as they respond to the changing climate patterns (Comte et al. 2013), freshwater organisms are particularly susceptible to impacts from climate change, as their dispersal ability is limited by the two-dimensional nature of stream networks (Grant et al. 2007). Headwater species, such as the laurel dace, are at greatest risk of extirpation and extinction as there is no colder water available for dispersal, while more downstream species may migrate to colder waters upstream (Buisson et al. 2008). Human responses to climate change can compound these threats, as anticipated water-supply shortages for agriculture during drought years will further reduce the instream flow available for aquatic organisms (Strayer and Dudgeon 2010).

In the Southeast, stream temperatures have increased roughly 0.2 to 0.4 ^{o}C per decade over past 30 years, and as air temperature is a strong predictor of water temperature, they are expected to continue to rise (Kaushal et al. 2010). Headwater streams in the southern Appalachians are predicted to have increased streamflow in winter and reduced or slightly increased streamflow in summer (Wu et al. 2013). Other impacts on the riparian zones may also influence laurel dace persistence. Simulations for the Cumberland Plateau through 2300 predict a sharp, initial decline in tree biomass (in the next 20 years) from immediate climate change impacts with a slow recovery as new species colonize (Dale et al. 2009). Changes in the riparian zone can cascade through stream communities; a 2007 late spring freeze in Tennessee caused the loss of newly-emerged leaf tissues, allowing higher light levels on the stream, with cascading effects up the food chain from primary production changes (Mulholland et al. 2009). Forest management in anticipation of climate change could help to stabilize streamflow by reducing water loss to evapotranspiration, buffering effects from extreme variability in precipitation (Ford et al. 2011). However, climate change will undoubtedly create more instability in stream ecosystems, which poses a threat to species like the laurel dace with small population sizes.

Competition from Introduced Species: Surveys of Cupp Creek in 2013 revealed the presence of large numbers of sunfish and bass, especially green sunfish, bluegill, and largemouth bass; the presence of these fishes in the system was even mentioned by one landowner discussing the frequent flooding of his farm pond (George field notes 2013). Skelton noted an increase in the numbers of sunfishes and basses in pools in Cupp Creek during the early 1990s coinciding with a decline in the numbers of laurel dace observed (Skelton pers. comm. 2006). The abundance of these introduced species at the site could be contributing to the decline of laurel dace in this system; as noted above, it is unclear if this is due to predation or competition.

Tennessee dace have been collected in the Piney River system in Duskin Creek and may be present through introduction (Strange and Skelton 2005). Although Tennessee dace have not been found in streams occupied by laurel dace they could potentially spread through the system and become a threat. A survey of Duskin Creek down to its mouth in 2013 found Tennessee dace throughout the stream (Kuhajda field notes 2013) indicating either a) they are spreading downstream from the point of introduction or b) they are naturally occurring. Although there is a series of waterfalls at the mouth of Bumbee Creek, dace species are likely good dispersers in headwater habitats and this barrier may be insufficient to restrict them from the range of laurel dace. Further monitoring of this situation is warranted.

C. CONSERVATION ACTIONS

In 2007, the TWRA and Tennessee Tech University (TTU) initiated contact with Timberland Investment Resources (TIR), a company with extensive land holdings in the catchments of Bumbee and Youngs creeks. Through this contact, the TWRA, TTU, and the Service have explored opportunities for conservation agreements and improvements to stream crossings, and attempted to negotiate access to waters passing through TIR lands in order to conduct surveys for laurel dace. Gaining access to reaches of Bumbee and Youngs creek within TIR lands will be essential for effectively monitoring the species and habitat conditions. Due to restricted access, no formal monitoring program has been instituted for the laurel dace. The TWRA and the Service will continue to work on establishing contacts and partnerships with TIR and other landowners in the Piney River and Sale and Soddy creek systems.

During the summer of 2007, TWRA conducted surveys in laurel dace streams using minnow traps. This effort primarily focused on the streams inhabited by the southern populations (the populations in the Sale and Soddy Creek systems), while including some sampling in streams inhabited by the northern population (in the Piney River system). While conducting these surveys, TWRA biologists reconnoitered land use in the watersheds containing laurel dace to identify private lands towards which future cooperative efforts should be directed. Future efforts will include working cooperatively with private landowners to protect water quality by reducing nonpoint sources of sediment. During 2012-2013, TNACI staff sampled laurel dace streams across the range of laurel dace and determined that the species still persists in the southern population, though only one individual was collected from Horn Branch. High levels of sedimentation were observed in designated critical habitat, both in the southern critical habitat as well as Youngs Creek and Moccasin Creek from the first Summer City Road crossing downstream.

II. RECOVERY

A. RECOVERY STRATEGY

The recovery strategy for laurel dace is to ensure that viable populations exist in all streams where the species is known to have been present historically, by conserving existing populations and restoring or augmenting populations as needed. To ensure the long-term viability of laurel dace, it will be necessary to protect, and in some cases restore, habitat in the headwater streams of the three drainages where the species currently is found: Piney River (Bumbee, Moccasin, and Youngs creeks), Soddy Creek, and Sale Creek (Cupp Creek and Horn Branch). Protecting and restoring habitat would also be necessary in any additional drainages where populations are found or established in the future. To implement this strategy, the Service will work with TWRA, Natural Resources Conservation Service (NRCS), TNACI, and other partners to inform citizens in these drainages about the:

- presence of laurel dace in streams where it occurs
- importance of providing adequate flows, water quality, and habitat connectivity for the species' conservation
- role of best management practices (BMPs) for agriculture, forestry, and construction or maintenance of roads or utilities in maintaining suitable habitat conditions
- options available for assistance in implementing BMPs or securing long-term protection of lands in these drainages

Land protection within these drainages could be accomplished via multiple mechanisms, including but not limited to land acquisition, conservation easements, conservation enhancement agreements, and habitat conservation plans. Existing laws, regulations, and policies must be enforced or used to protect water quality by minimizing erosion and sedimentation in catchments of laurel dace streams.

In addition to informing the public and promoting compatible land uses and habitat protection in the drainages where laurel dace occurs, it will be necessary to conduct research about the species' life history, interactions with other species, and tolerances to factors that degrade habitat quality. Captive propagation will be necessary to support research and potentially for reintroducing and/or augmenting populations to recover this species. The Service will work with TWRA, TNACI, Conservation Fisheries, Inc. (CFI), and others as appropriate to develop and implement a plan for propagating, reintroducing, and where necessary, augmenting laurel dace populations. Establishing and maintaining an ark population might also be necessary for populations in Sale and Soddy Creeks until such time as viable populations are restored in these systems through augmentation or reintroduction.

B. RECOVERY GOAL AND CRITERIA

The goal for this recovery plan is to conserve and recover populations of laurel dace to the point that listing under the Act is no longer necessary, which will require the following objectives to be accomplished. In order to recover laurel dace to the point that listing under the Act is no longer necessary, it will be necessary to conserve all existing populations by maintaining, and in some cases, restoring suitable habitat conditions in all streams where the species currently occurs. It will also be necessary to discover or establish one additional population. Because recovery and delisting will be a long, and potentially unachievable goal, an intermediate goal for this recovery plan is to recover the species to the point that it could be reclassified from endangered to threatened. Reclassification to threatened status will be possible when habitat conditions in occupied streams are suitable for the conservation of the species, and viable populations are present throughout suitable habitat in five of the six currently occupied streams.

The following criteria will be used to determine whether the objectives above for reclassification and delisting have been met. The criteria will be achieved by reducing or removing threats to the species' habitat and conserving or establishing viable populations throughout the species' range, as determined by monitoring of demographic and genetic parameters.

Criteria for Reclassification from Endangered to Threatened

<u>Criterion 1</u>: Suitable instream habitat, flows, and water quality for laurel dace, as defined by recovery tasks 5.1 and 5.2, exist in occupied streams.

<u>Criterion 2</u>: Viable populations* are present throughout suitable habitat in Bumbee, Moccasin, and Youngs creeks, and at least two of the following streams: Soddy or Cupp creek or Horn Branch.

Criteria for Delisting

<u>Criterion 1</u>: Suitable instream habitat, flows, and water quality for laurel dace exist in all occupied streams, and mechanisms exist to ensure that land use activities (including road maintenance) in catchments of streams inhabited by laurel dace will be compatible with the species' conservation for the foreseeable future. Such mechanisms could include, but are not necessarily limited to, conservation agreements, conservation easements, land acquisition, and habitat conservation plans.

<u>Criterion 2</u>: Viable populations* are present throughout suitable habitat in Bumbee, Moccasin, Youngs, Soddy, and Cupp creeks and Horn Branch, and one additional viable population exists, either through reintroduction into Laurel Branch or discovery of an additional wild population.

*Populations will be considered viable when the following demographic and genetic conditions exist:

- Demographics – monitoring data demonstrate that (a) populations are stable or increasing, (b) two or more age-classes are consistently present over a period of time encompassing five generations (i.e., 15 years), and (c) evidence of recruitment is not absent in more than three years or during consecutive years at any point within that period of time.
- Genetics – populations will be considered to have sufficient genetic variation to be viable if measurements of observed number of alleles and estimates of heterozygosity and effective population size have remained stable or increased during the five generations used to establish demographic viability.

Listing/Recovery Factors Addressed by Recovery Actions: Actions listed below with each listing/recovery factor are examples of actions that could reduce or remove the identified threats. These tasks are described in more detail in the Narrative Outline section that follows.

Listing Factor A: Present or Threatened Destruction, Modification or Curtailment of its Habitat or Range

This factor will be considered addressed when habitat quality for both instream and riparian tributary habitats in the historic and contemporary range is sufficient to meet all life-history requirements of laurel dace. The primary constituent elements listed in the Critical Habitat section above describe the physiological and biological features that are essential to the species' conservation. Actions that would serve to maintain or restore these habitat features include the following:

(a) Protecting and restoring riparian and instream habitats. (Actions 1.1 through 1.5)
(b) Mapping suitable habitat and spatial distribution of laurel dace within occupied streams and surveying for previously undetected populations in unoccupied streams with suitable habitat. (Actions 2.1 through 2.3)
(c) Monitoring laurel dace populations and habitat conditions. (Actions 3.1 through 3.4)
(d) Determining life history characteristics of laurel dace and assessing vulnerability of various life history stages to threats related to habitat quality. (Actions 5.1, 5.2, and 5.5)
(e) Identifying threats associated with stream crossings at roads and reducing impact. (Actions 6.1 through 6.3)
(f) Propagating laurel dace or surrogate species to fulfill research needs. (Action 7.1)
(g) Conducting outreach to encourage public participation in recovery effort. (Action 8)

Listing Factor B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Contemporary overutilization is not implicated in the restriction of the species' range or population sizes; though, it is possible that limited numbers of laurel dace are used for bait each year. If bait collection of laurel dace is observed in the future, a public outreach campaign on bait collection in Rhea and Bledsoe Counties should be conducted. (Action 8)

Listing Factor C: Disease or Predation

Disease is not implicated as a threat to the species. Prior to implementing management actions for predation, studies should be completed to determine the impact of non-native sunfishes and basses on laurel dace. If sunfishes and basses are found to have an impact, their presence in the watershed should be reduced through removals, and outreach programs to local landowners to reduce stocking and accidental releases from ponds should be implemented. The following actions can be taken to address the threat of predation by native or introduced species:

(a) Monitoring laurel dace populations and associated fish communities. (Actions 3.1 through 3.3).
(b) Determining life history characteristics of laurel dace and assessing potential negative interactions with or predation threat posed by basses and sunfishes. (Actions 5.1, 5.3, and 5.4)
(c) Propagating laurel dace or surrogate species to fulfill research needs. (Action 7.1)
(d) Conducting outreach to encourage public participation in recovery effort. (Action 8)

Listing Factor D: Inadequacy of Existing Regulatory Mechanisms

One of the greatest threats to the laurel dace is sedimentation and other nonpoint source pollution from the surrounding watershed. Because the CWA does not address nonpoint source pollution, there is no existing regulatory mechanism to control the amount of sediment entering critical habitat. This factor will be considered addressed when habitat protection efforts, regulations, and enforcement ensure that nonpoint source pollution is below the threshold that laurel dace can tolerate, as identified through captive studies. The following actions can be taken to address this threat:

(a) Protecting and restoring riparian and instream habitats. (Actions 1.1 through 1.5)
(b) Mapping suitable habitat and spatial distribution of laurel dace within occupied streams and surveying for previously undetected populations in unoccupied streams with suitable habitat. (Actions 2.1 through 2.3)
(c) Monitoring laurel dace populations and habitat conditions. (Actions 3.1 through 3.4)
(d) Determining life history characteristics of laurel dace and assessing vulnerability of various life history stages to threats related to habitat quality. (Actions 5.1, 5.2, and 5.5)
(e) Identifying threats associated with stream crossings at roads and reducing impact. (Actions 6.1 through 6.3)
(f) Propagating laurel dace or surrogate species to fulfill research needs. (Action 7.1)
(g) Conducting outreach to encourage public participation in recovery effort. (Action 8)

Listing Factor E: Other Natural or Manmade Factors Affecting its Continued Existence

Laurel dace populations are small and the species is geographically restricted, two conditions that are often correlated with reduced genetic variation. Extinction and extirpation are demographic processes; however, small populations are often vulnerable to random fluctuations in demographic, environmental, and genetic processes – all of which are not mutually exclusive and can influence the rate of extinction (Gilpin and Soule 1986; Reed 2010). As the threats to each population are minimized and habitat quality improves, each population should increase in census size, eventually reaching the carrying capacity of their respective streams. Once carrying capacity is reached, loss of genetic variaton due to genetic drift and the effects of inbreeding should be minimized.

Climate change has the potential to increase the vulnerability of freshwater species, such as laurel dace, to extinction due to changes in stream hydrology and ecology from changing precipitation patterns and evapotranspiration in the riparian zone (IPCC 2007). Additionally, the laurel dace faces potential threats of competition from introduced fishes including green sunfish, bluegill, and largemouth bass. Tennessee dace are not present in laurel dace streams currently, but are found in a nearby tributary to the Piney River and could present a threat if they disperse or are introduced to streams where laurel dace occur.

Establishing demographically viable populations throughout suitable habitat that sustain themselves via natural recruitment should function to minimize the loss of genetic variation due to processes of genetic drift or inbreeding. Monitoring to determine whether levels of genetic variation in laurel dace populations are maintained or increase will be necessary to determine whether achieving the demographic objective we have established for laurel dace is effective for maintaining genetic variation and structure and reducing extinction risk. Conserving viable populations that fully occupy suitable habitat will be necessary to provide the redundancy and representation needed to reduce vulnerability to potential threats associated with climate change. The following actions can be taken in an effort to conserve viable laurel dace populations and reduce threats from introduced fish species:

(a) Protecting and restoring riparian and instream habitats. (Actions 1.1 through 1.5)
(b) Mapping suitable habitat and spatial distribution of laurel dace within occupied streams and surveying for previously undetected populations in unoccupied streams with suitable habitat. (Actions 2.1 through 2.3)
(c) Monitoring demography and genetic variation and structure of laurel dace populations. (Actions 3.1, 3.2, and 4.1 through 4.3).
(d) Identifying sources of introduced fishes in laurel dace streams and working with landowners to minimize potential for further introductions.(Action 3.3)
(e) Determining life history, interspecies interactions, and tolerance to environmental stressors of laurel dace, and conducting population viability analysis. (Actions 5.1 through 5.5)
(f) Identifying threats associated with stream crossings at roads and reducing impact. (Actions 6.1 through 6.3)
(g) Developing and implementing a propagation, reintroduction, and augmentation plan, if warranted. (Actions 7.2 and 7.3)

C. RECOVERY OUTLINE/NARRATIVE

1. Protect laurel dace habitat via land acquisition, conservation easements, or other mechanisms to reduce threats to instream and riparian habitat. There are no protected lands adjacent to or upstream of known locations for laurel dace, leaving instream and riparian habitats vulnerable to threats from land use activities in these catchments. The highest level of protection for laurel dace habitat would be to bring lands into conservation ownership or establish conservation easements to protect water quality in catchments where laurel dace occurs. Habitat conservation plans, safe harbor agreements, or conservation enhancement agreements also could be used to reduce potential threats from land uses in these catchments. The Service and TWRA should work with the Natural Resources Conservation Service (NRCS) and other partners to identify owners of lands in catchments of laurel dace streams who could benefit from assistance for riparian and upland forest restoration or implementing best management practices to minimize erosion, sedimentation, and pesticide or fertilizer runoff.

1.1. Through fee acquisition or conservation easements, protect land in catchments of laurel dace streams, and manage protected lands appropriately to reduce or prevent erosion, sedimentation, and alteration of riparian and upland vegetation. Protecting land in the headwaters of Bumbee, Moccasin, and Young Creeks, where laurel dace have been more frequently collected is the highest, short-term priority for this action.

1.2. Determine extent of farming practices, especially those associated with tomato production, within catchments of laurel dace streams. Characterize standard practices for fertilizing and managing pests for various cropping systems and identify best management practices for reducing threats associated with erosion, sedimentation, and contamination from fertilizer or pesticide application.

1.3. Use data from land use characterization and monitoring (see task 3.4) to prioritize parcels and work cooperatively with land owners to protect or restore native riparian and upland forest or implement best management practices for agriculture to reduce input of sediment and chemical pollutants into surface waters.

1.4. Determine extent of hemlocks and HWA infestation and develop and implement a plan for control efforts in catchments of laurel dace streams.

1.5. Use and enforce existing laws (e.g., Clean Water Act), regulations, and policies to protect and/or enhance laurel dace populations, habitat, and water quality by reducing erosion and sedimentation.

2. Map suitable habitat in streams where laurel dace are extant or occurred historically, identify streams on Walden Ridge with suitable habitat but no known records of occurrence, and periodically conduct surveys for previously undetected populations and to determine whether populations are still extant in occupied streams. Laurel dace are known to have historically occurred in seven headwater streams, and are considered extant in six of these streams. However, recent data are lacking from several of the streams where the species is considered extant (Appendix A). And, surveys have in many cases been limited to short stream reaches in close proximity to access points where these streams are crossed by roads. Current data are needed to verify the species' persistence in streams considered occupied, most notably Horn Branch, Cupp Creek, and Soddy Creek, and to determine whether a population might be present in Laurel Branch. To determine the proportion of suitable habitat that the species is utilizing in occupied streams, it is necessary to map the distribution of suitable habitat within all streams where laurel dace are present or occurred historically and to determine where the species is present within these streams. While surveys of Skelton (1997) and Strange and Skelton (2005) have covered many Walden Ridge streams beyond those known to harbor laurel dace (Figure 1, Appendix A), it is possible that populations exist in unsampled streams or have gone undetected in streams where sampling efforts have been limited.

2.1. Conduct surveys in and characterize reaches of all laurel dace streams according to their habitat suitability for laurel dace and develop a GIS dataset depicting habitat suitability in mapped reaches. Laurel dace have been most often collected from pools or slow runs from undercut banks or beneath slab boulders, typically in first or second order, clear, cool (maximum temperature 26 °C or 78.8 °F) streams. Substrates in streams where laurel dace are found typically consist of a mixture of cobble, rubble, and boulders, and the streams tend to have a dense riparian zone consisting largely of mountain laurel (*Kalmia latfolia*), but also including eastern hemlock (*Tsuga canadensis*), mixed hardwoods, and pines (*Pinus* spp.) (Skelton 2001).

2.2. Prioritize suitable, but apparently unoccupied, streams on Walden Ridge and conduct surveys to determine whether previously undetected populations of laurel dace exist. Predictive GIS models, such as MaxEnt, could be used to identify streams on Walden Ridge with characteristics similar to those where laurel dace occur. Higher priority should be assigned to streams where suitable habitat is present, little survey effort has been expended in the past, and in catchments where forested cover is greatest.

2.3. Conduct surveys of occupied streams at least once every five years to determine whether populations are persisting and to evaluate whether suitable habitat is fully occupied by laurel dace. If large proportions of suitable habitat are unoccupied, determine whether barriers are present that cause fragmentation of suitable habitat reaches.

3. Develop a program to monitor trends in distribution and demographic structure of laurel dace populations, habitat conditions, and land use in catchments of laurel dace streams. A monitoring program should be developed for the laurel dace that incorporates multiple, habitat-specific sampling techniques. Sampling for laurel dace has most often involved use of backpack electroshockers. To minimize stress to laurel dace and increase likelihood of detecting fish less than one year in age, sampling should be conducted during the period from October through mid-March, when air and stream temperatures are lower and larval development has been completed. Electroshocking should not be used during late-March through June in order to avoid the peak spawning season. Minnow traps should be deployed in pool habitats, where electroshocking gear or seining are not effective. Data concerning associated species should be recorded in order to document relative abundance of species that may be interacting with laurel dace, whether as nest associates or as predators. Monitoring efforts should include assessing substrate embeddedness in sampled reaches and analyzing land use change either through direct, field-based observation or indirectly using remote sensing technology.

Because of the apparently low levels of abundance in the Sale and Soddy creek systems, the southern populations should be monitored annually in an attempt to determine whether natural interannual fluctuations in population density or abundance have been overlooked by less frequent efforts. Less frequent monitoring might be effective for the purpose of detecting gross trends in abundance within the northern populations; however, biennial or annual monitoring will be necessary to provide data to evaluate the species' status with respect to recovery criteria. Access to most populations is at road crossings or from private land and will require developing relationships and working in close cooperation with landowners. Landowners of properties where ponds have been constructed in or adjacent to laurel dace streams should be surveyed to gain information about stocking rates and frequency of breaches of these impoundments due to flood conditions or inadequate maintenance.

3.1. Work cooperatively with landowners to gain access for monitoring laurel dace.

3.2. Develop and implement a monitoring program that establishes standardized protocols, sampling frequencies, and locations for evaluating distribution and abundance of laurel dace and associated species, and assessing instream habitat conditions, including substrate type, degree of embeddedness, water temperature, turbidity, and other relevant parameters.

3.3. Identify sources of sunfishes and basses in laurel dace streams and work with landowners whose ponds drain into these streams to minimize threats from potential introduced predators.

3.4. Use remote-sensing data to understand land-use practices in catchments of laurel dace streams over the past 20 years. Continue review of land-use practices at five-year intervals to monitor landscape-level habitat changes.

4. Conduct baseline genetic analysis and establish protocol for periodic monitoring to detect trends in genetic variation and structure among populations. Strange and Skelton (2005) recommended treating the northern and southern populations as two distinct management units based upon analysis of mitochondrial DNA variation. Further analysis of population genetic structure using microsatellites, or another genetic marker sensitive to intraspecific variation, will be necessary to confirm whether populations from these systems should be managed separately and to establish baseline data against which changes in genetic variation and structure among populations can be monitored. Until such studies have been completed, fishes from the northern and southern populations will be kept separate if captive propagation is initiated. Because of the small size of laurel dace populations and the importance of genetic variation in providing potential for populations to respond to environmental change, genetic monitoring will be necessary to determine whether genetic diversity is being lost as a result of genetic drift or inbreeding. Genetic monitoring also will be needed to minimize risk of altering genetic structure of populations augmented with hatchery reared fishes, should this be necessary. In the event laurel dace are reintroduced into Laurel Branch, it will be necessary to establish goals for genetic variation and structure of the reintroduced population and monitor progress of the reintroduction.

4.1. Coordinate collection of fin clips, or other suitable tissue for extracting DNA, during population surveys and monitoring and ensure that the tissue is curated for long-term storage.

4.2. Evaluate current genetic structure and variation in laurel dace populations using microsatellite loci to establish baseline for monitoring and determine whether separate populations should be recognized for the purpose of broodstock management for a captive propagation and reintroduction program.

4.3. Periodically monitor genetic diversity of wild populations (i.e., observed number of alleles, heterozygosity, and effective population size) to determine whether genetic variation is being lost due to processes of genetic drift or inbreeding. Monitor genetic variation and structure of restored or augmented populations to determine whether the captive propagation program is successful at maintaining representative genetic diversity in managed populations.

5. Determine life history, interspecies interactions, and tolerance to environmental stressors of the laurel dace, and conduct population viability analysis. Little is known about the life history of laurel dace other than the few observations made by Skelton (2001) concerning spawning behavior, limited stomach contents analysis, and simultaneous presence of three year-classes. More detailed information on the reproductive behavior, fecundity, longevity, food habits, habitat preference, and predator-prey interactions would be necessary for determining which life history and ecological traits influence the vulnerability of laurel dace to various threats. Effects to laurel dace from siltation, altered temperature regimes, and pesticides used in agriculture and HWA control should be investigated. Population viability analysis methods should be used to integrate data from research, monitoring, and threats assessments. Results from the PVA should be used to evaluate extinction risk for the species and individual populations, prioritize management needed to reduce threats, and identify information gaps most critical for improving precision of estimates of extinction risk.

5.1. Determine life history and microhabitat preferences of laurel dace through studies of more robust populations in the Piney River drainage.

5.2. Use hatchery-propagated laurel dace or surrogate species to evaluate silt and thermal tolerance of laurel dace and potential toxicity and exposure risk to the species from pesticides used for control of agricultural pests and HWA.

5.3. Determine if hatchery-propagated laurel dace have negative behavioral interactions with sunfishes or basses in captivity.

5.4. Conduct a diet study on sunfishes and basses in laurel dace streams to determine if interactions are competitive and/or predatory.

5.5. Conduct a population viability analysis (PVA) to understand extinction risk for the species and each population.

6. Evaluate stream crossings as fish passage barriers or nonpoint pollutant sources and reduce impact if necessary. Skelton (pers. comm. 2006) observed that culverts are in place at road crossings in many of the streams inhabited by laurel dace, some of which might function as barriers to within-stream dispersal by laurel dace. Additionally, low-water crossings on logging haul roads or skid trails could present barriers to dispersal or be a source of sediment input to streams. Road crossings at streams within and upstream of the species' extant range should be inventoried, to prioritize those that should be replaced or improved to restore fish passage or minimize erosion and sedimentation. Information from an inventory of road crossings should be used to inform county road departments of the potential impact of poorly designed and maintained structures and encourage replacement of structures over time through planned maintenance schedules. The Service and TWRA should proactively pursue cost-share programs to help replace or improve these structures, such as grants from the Service's Fish Passage Program or the Southeast Aquatic Resources Partnership.

6.1. Complete inventory of road crossings to assess threats from fragmentation and sedimentation on laurel dace streams and tributaries, noting type of crossing (e.g, culvert, low water crossing), culvert size, flow rates, substrate, upstream and downstream microhabitat, erosion susceptibility, and potential for disrupting within-stream fish dispersal.

6.2. Conduct outreach meetings with county road departments or private landowners, as appropriate, to explain the potential threat that road crossings pose to laurel dace and other fish populations. Develop plans for replacing culverts, improving low water crossings, or stabilizing soils, as needed, as part of road maintenance programs.

6.3. Utilize Fish Passage Program, or other funding, to replace culverts where the conservation benefit would be greatest, as determined by inventory results and meetings with county road departments.

7. Establish protocols and plan for captive propagation to support research and reintroduction or augmentation. Protocols for captive propagation and a propagation plan should be established in order to (1) provide fish for research needs identified in Recovery Action 5, (2) develop techniques for maintaining an ark population, if necessary, or (3) to support opportunities for reintroduction or augmentation. Strange and Skelton (2005) recognized the northern and southern populations within the species as separate entities. Further investigation of population genetic structure in laurel dace using microsatellites or other markers sensitive to intraspecific variation (task 4.2) should be completed prior to propagating the species for reintroduction or augmentation purposes. Conservation efforts should initially focus on protecting and restoring suitable habitat conditions for laurel dace rather than reintroducing or augmenting populations, because poor habitat quality limits the potential for these population management tools to be successful.

7.1. Develop and implement protocols for captive propagation of laurel dace to fulfill research needs under recovery action 3.2 and 3.3.

7.2. Develop and implement a propagation and reintroduction plan, if warranted, following fulfillment of actions identified in recovery actions 1 and 2 and the identification of suitable habitat for reintroductions.

7.3. Develop and implement a population augmentation plan if determined to be necessary based on results from monitoring and PVA.

8. Develop informational materials and conduct outreach to encourage public participation in laurel dace recovery effort. Because laurel dace are found in headwater streams completely surrounded by privately owned land, it will be necessary to develop materials to inform the general public and local governments about the species and measures that should be taken to protect its habitat. Specifically, outreach should be conducted to encourage landowners to restore native forested habitat in uplands and to implement best management practices to minimize erosion, sedimentation, and introduction of pollutants into streams. Best management practices should be identified for use in agriculture, forest management, and construction and maintenance of stream crossings.

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IV. IMPLEMENTATION SCHEDULE

Recovery plans are intended to assist the Service and other stakeholders in planning and implementing actions to recover and/or protect endangered and threatened species. The following Implementation Schedule indicates recovery tasks, task priorities, task descriptions, task duration; potential stakeholders and responsible agencies; and estimated costs. It is a guide for planning and meeting the objectives discussed in Part II of this plan. The Implementation Schedule outlines recovery actions and their estimated costs for the first 5 years of this recovery program. The cost estimates provided in the Schedule identify foreseeable expenditures that could be made to implement the specific recovery tasks during a 5 year period. Actual expenditures by identified agencies/partners is contingent upon appropriations and other budgetary constraints.

The identification of agencies and other stakeholders within the Implementation Schedule does not constitute any additional legal responsibilities beyond existing authorities (e.g., , Endangered Species Act, Clean Water Act, Federal Land Policy and Management Act., etc). Recovery plans do not obligate other parties to implement specific tasks and may not represent the views, nor the official positions, or approval of any stakeholder groups or agencies involved in developing the plan, other than the Service.

Recovery tasks are assigned numerical priorities to highlight the relative contribution they may make toward species recovery. Priority numbers in column 1 of the schedule are defined as follows:

Priority 1: All actions that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

Priority 2: All actions that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.

Priority 3: All other action necessary to meet the recovery objective.

Laurel Dace Recovery Plan Implementation Schedule

Task Priority	Task number	Task description	Years/ Duration	Responsible Agency (* = lead)	Cost estimate (1,000 units)						Comments
					Total	2015	2016	2017	2018	2019	
1	1.1	Protect land in catchments of laurel dace streams through fee simple acquisition and conservation easements and manage protected lands	5	FWS, TWRA, NRCS, LTT	390	70	80	80	80	80	
1	1.2	Evaluate threats from farming practices and identify best management practices to reduce them	2	FWS, NRCS	5	5					
1	1.3	Prioritize parcels and work cooperatively with landowners to reduce land use threats	1	*FWS, NRCS, TWRA	50	10	10	10	10	10	
2	1.4	Develop and implement plan for hemlock woolly adelgid control program	Ongoing	FWS, TDEC, TDF, TWRA	30	10	5	5	5	5	
1	1.5	Enforce existing laws and regulations	Ongoing	*FWS, TWRA, TDEC, OSM	25	5	5	5	5	5	
2	2.1	Map and survey suitable habitat in laurel dace streams and develop a GIS database	1	FWS, TWRA, TNACI, TTU	10	10					

Task Priority	Task number	Task description	Years/ Duration	Responsible Agency (* = lead)	Cost estimate (1,000 units)						Comments
					Total	2015	2016	2017	2018	2019	
2	2.2	Prioritize and survey unoccupied streams to find new populations	Ongoing	*TNACI, TTU	5		5				
2	2.3	Periodically resurvey all suitable habitat in occupied streams looking for threats	Ongoing	FWS, TNACI, TWRA	5				5		
1	3.1	Work with landowners to gain access for monitoring	2	*FWS, TTU, TWRA	4	2	2				
1	3.2	Develop and implement monitoring program	Ongoing	*FWS, TTU, TWRA	42	10	6	10	6	10	Southern populations only during years 2 and 4
1	3.3	Identify sources of introduced fishes and work with landowners to prevent future introductions	Ongoing	FWS, *TWRA, TNACI	4	2	2				
3	3.4	Periodically evaluate land-uses	Ongoing	FWS	10	5				5	
1	4.1	Coordinate collection of tissue for genetic monitoring	Ongoing	*FWS, TWRA, TNACI	4	2				2	
1	4.2	Evaluate baseline genetic variation and structure	1	*FWS, TNACI, TWRA	18	18					

Task Priority	Task number	Task description	Years/ Duration	Responsible Agency (* = lead)	Cost estimate (1,000 units)						Comments
					Total	2015	2016	2017	2018	2019	
2	4.3	Monitor genetic variation and structure	Ongoing	FWS, TNACI, TWRA	18					18	
2	5.1	Conduct life history and microhabitat studies	3	FWS, TNACI, *TTU, TWRA	60	40	20				
1	5.2	Evaluate silt and thermal tolerances and assess toxicity and exposure risk of pesticides	2	*FWS, TNACI, TTU	70			40	30		
2	5.3	Assess behavioral interactions with introduced fishes	1	TNACI, CFI	10				5	5	
2	5.4	Conduct diet study of potential introduced predators	1	FWS, TNACI, *TWRA	10	10					
2	5.5	Conduct PVA	2	FWS, *TTU	10				5	5	
1	6.1	Inventory road crossings to assess threats from fragmentation and sedimentation	1	*FWS, TWRA	10	10					
2	6.2	Inform county road departments and landowners about threats from road crossings and correct problems	Ongoing	*FWS, TWRA	10	2	2	2	2	2	

Task Priority	Task number	Task description	Years/ Duration	Responsible Agency (* = lead)	Cost estimate (1,000 units)						Comments
					Total	2015	2016	2017	2018	2019	
2	6.3	Replace culverts where most needed	Ongoing	FWS, NRCS, county road departments	290		200	50	20	20	
1	7.1	Develop and implement propagation protocols and produce fish for research	2	CFI, FWS, *TNACI, TWRA	50	30	20				
3	7.2	Develop and implement propagation and reintroduction plan	5	CFI, FWS, *TNACI, TWRA	25				10	15	
2	7.3	Develop and implement population augmentation plan	5	CFI, FWS, *TNACI, TWRA	75		10	30	20	15	
3	8	Inform the public about laurel dace and encourage participation in recovery effort	Ongoing	FWS, TNACI, *TWRA	15	3	3	3	3	3	

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Appendix A. Survey and Collection Records for Laurel Dace (Skelton 1996 and 1997, Strange and Skelton 2005, USFWS unpublished data, A. George field notes 2013, B. Kuhajda field notes 2013, Kuhajda and Neely 2013, D. Neely field notes 2010 and 2013, USFWS unpublished data)

Site Name	Latitude	Longitude	Begin Date	SampleType	Negative Survey	Number Collected	Field Notes
Big Brush Creek ca. 0.6 km upstream of confluence with Glady Fork	35.54083	-85.43525	7/16/1996	Electroshocking	Yes		CES 96-55
Big Brush Creek just downstream of Van Buren Co. Line	35.56612	-85.42374	7/16/1996	Electroshocking	Yes		CES 96-57
Big Possum Creek at road crossing 1.4 km N Jones Gap Rd.	35.36718	-85.19365	3/31/1995	Electroshocking	Yes		CES 95-34
Big Possum Creek ca. 1.6 km upstream of Hamilton-Bledsoe Co. line	35.37593	-85.22576	4/7/1995	Electroshocking	Yes		CES 95-41
Bird Fork ca. 0.6 km upstream from confluence with Long Fork	35.49581	-85.42821	7/4/1996	Electroshocking	Yes		CES 96-44
Blair Creek just above confluence with Big Brush Creek	35.51931	-85.40811	7/4/1996	Electroshocking	Yes		CES 96-46
Board Camp creek just upstream from TN Hwy 111	35.34146	-85.20487	8/25/1996	Electroshocking	Yes		CES 96-75
Bonine Creek at Bill Vaughn Rd.	35.60107	-85.00342	3/3/1996	Electroshocking	Yes		
Bonine Creek at Liberty Hill Rd	35.58500	-84.99914	9/4/1994	Electroshocking	Yes		CES 94-34
Boston Branch ca. 0.3 km upstream of Boston Branch Lake	35.24741	-85.27242	3/9/1995	Electroshocking	Yes		CES 95-4
Bridge Creek at Owl Hollow Rd	35.22796	-85.54651	7/23/1996	Electroshocking	Yes		CES 69-71
Brimer Creek ca 2.9 km upstream of its confluence with Standifer Creek	35.23535	-85.37609	3/9/1995	Electroshocking	Yes		CES 95-9
Brush Creek at Ogden Rd	35.49773	-85.11265	6/27/1996	Electroshocking	Yes		CES 96-34
			8/18/2011	Electroshocking	Yes		
Brush Creek Below Confluence with Miller Branch	35.50483	-85.11035	8/18/2011	Electroshocking	Yes		
Bumbee Creek above confluence with Maplelush Creek	35.66830	-84.94696	11/16/1996	Electroshocking	Yes		
Bumbee Creek at Pine Creek Rd	35.66340	-84.96901	5/10/1996	Electroshocking	No	16	UT 44.7293 (6) Specimens deposited in UT collection. CES 96-14. CES Notes 10 specimens released
			5/23/1996	Electroshocking	No	37	UT 44.7292 (2) Specimens deposited in UT collection. CES Notes 2 retained and 35 released
			6/1/1996	Electroshocking	No	8	UT 44.7301 (2) Specimens deposited in UT collection. CES Notes 2 retained and 6 released.

Site Name	Latitude	Longitude	Begin Date	SampleType	Negative Survey	Number Collected	Field Notes
Bumbee Creek at Pine Creek Rd	35.66340	-84.96901	6/5/1996	Electroshocking	No	10	UT 44.7322 (1) Specimen deposited in UT collection. CES Notes 1 retained and ~9 released
			10/24/1996	Electroshocking	No	15	UT 44.7305 (5) Specimens deposited in UT collection. CES Notes 10 retained and 5 released
			3/15/1997	Electroshocking	No	7	CES Notes Retained 3 and released 4 specimens
			5/16/1997	Electroshocking	No		UT 44.7615
			6/6/1997	Electroshocking	No	21	CES Notes 6 retained and 15 released
			5/23/2004	Electroshocking	No		Laurel Dace present (3-4) at this site during this survey. Also historically known to exist here. Observed creek from Lat/Long with binoculars. Surveyed either May 23-27, 2004 or July 19-22, 2004.
			6/10/2010	Electroshocking	No	1	DAN10-79
			6/4/2011	Electroshocking	No	1	DAN11-60
Coal Creek upstream of TN Hwy 68	35.78643	-84.88395	7/5/1996	Electroshocking	Yes		CES 96-51
Coalbank Branch ca. 5.1 air mi E Pikeville	35.61042	-85.09903	9/4/1994	Electroshocking	Yes		
Cooper Branch at Cooper Branch Rd.	35.66258	-85.03763	8/23/1996	Electroshocking	Yes		CES 96-73
Cooper Creek off of Pete Lewis Road	35.32459	-85.32807	3/23/1995	Electroshocking	Yes		CES 95-22
Cupp Creek 1.0 km NE of intersection of Hendon and Brayton Rds	35.48730	-85.17680	3/31/1995	Electroshocking	No	8	UT 44.7300 (6) Specimens deposited in UT collection. CES 95-33. CES Notes 5 retained and 3 released
			6/27/1996	Electroshocking	No	11	UT 44.7341 (2) Specimens deposited in UT collection. CES Notes 6 retained and 9 released
			5/23/2004	Electroshocking	Yes		Historically present at this site. From Lat/Long, worked ca. 700m downstream. Surveyed May 23-27, 2004 or July 19-22, 2004.

Site Name	Latitude	Longitude	Begin Date	SampleType	Negative Survey	Number Collected	Field Notes
Day Branch ca. 100 m upstream of confluence with Fall Creek	35.83863	-84.79784	4/8/1996	Electroshocking	Yes		CES 96-10
Dunlap Creek just below confluence of Jewett Branch and Pond Cove Creek	35.76522	-84.93663	7/5/1996	Electroshocking	Yes		CES 96-50
Duskin Creek at Shut-in Gap Road	35.71043	-84.98853	5/14/1996	Electroshocking	Yes		CES 96-18
Duskin Creek at Walden Mountain Rd	35.68988	-84.95065	5/10/1996	Electroshocking	Yes		CES 96-13
Fall Creek between US Hwy 70 and I-40	35.88304	-84.81165	4/8/1996	Electroshocking	Yes		CES 96-11
Flatrock Branch above and below confluence with Rattlesnake Branch	35.51006	-85.38415	7/16/1996	Electroshocking	Yes		CES 96-58
Frederick Creek at Frederick Creek road crossing	35.25959	-85.36471	3/17/1995	Electroshocking	Yes		CES 95-20
Glady Fork above and below confluence with Spring Branch	35.53357	-85.45356	7/16/1996	Electroshocking	Yes		CES 96-56
Glady Fork downstream of TN Hwy 111	35.52497	-85.46821	7/3/1996	Electroshocking	Yes		CES 96-42
Gray Creek above Lewis Chapel Rd	35.37118	-85.29436	4/7/1995	Electroshocking	Yes		CES 95-37
Gray Creek and unnamed trib. To Gray Creek	35.36150	-85.29580	5/23/2004	Electroshocking	Yes		Beginning at Lat/Long worked 400m downstream in unnamed tributary, and then 400m upstream in Gray Creek. Surveyed either May 23-27, 2004 or July 19-22, 2004.
Gray Creek ca. 1.77 air upstream of Lewis Chapel Rd	35.37118	-85.29436	7/22/1996	Electroshocking	Yes		CES 96-65
Grays Creek at logging rd ca. 5 air km above confluence with Little Sequatchie River	35.26326	-85.58620	7/23/1996	Electroshocking	Yes		CES 96-69
Griffith Creek ca. 6.4 air km N Whitwell	35.27413	-85.51056	7/23/1996	Electroshocking	Yes		CES 96-68
Henderson Creek at Liberty Hill Road	35.60674	-85.06171	6/27/1996	Electroshocking	Yes		CES 96-36
Henderson Creek at logging rd crossing ca. 0.5 km above confluence with Mitts Creek	35.63173	-85.09324	12/12/1993	Electroshocking	Yes		
Henderson Creek just above confluence with Double Branch	35.61157	-85.06220	6/27/1996	Electroshocking	Yes		CES 96-37
Hixson Branch 1.2 km upstream of confluence with N. Chickamauga Creek	35.23361	-85.29941	3/9/1995	Electroshocking	Yes		CES 95-5
Horn Branch of Rock Creek above and below Hendon Rd.	35.41480	-85.24330	7/29/1976	Electroshocking	No	47	UT 44.4789 (47) Specimens deposited in UT collection

Site Name	Latitude	Longitude	Begin Date	SampleType	Negative Survey	Number Collected	Field Notes
Horn Branch of Rock Creek above and below Hendon Rd.	35.41480	-85.24330	6/19/1991	Electroshocking	No	23	UT 44.5884 (23) Specimens deposited in UT collection
			8/29/1993	Electroshocking	No	29	UT 44.7339 (21) Specimens deposited in UT collection. CES Notes 29 retained
			2/5/1994	Electroshocking	No	1	CES Notes 1 specimen retained
			5/15/1994	Electroshocking	No	1	CES Notes 1 specimen retained
			5/24/1994	Electroshocking	No	96	CES Notes 50 retained and 46 specimens released. Saw another school of about 50.
			5/31/1994	Electroshocking	No	52	UT 44.7304 (2) Specimens deposited in UT collection. CES Notes 2 retained and 50 released
			6/10/1994	Electroshocking	No	1	UT 44.7306 (1) Specimen deposited in UT collection
			6/29/1994	Electroshocking	No	30	CES Notes 30 specimens released and ~20 observed with binoculars
			7/1/1994	Electroshocking	No	30	CES Notes 30 specimens released
			2/24/1995	Electroshocking	No	45	CES Notes 15 specimens retained and ~30 released
			3/16/1995	Electroshocking	Yes		CES Notes: none found shocking
			4/7/1995	Electroshocking	No	1	CES Notes 1 specimen released
			4/14/1995	Electroshocking	No	16	CES Notes 16 specimens released
			4/23/1995	Electroshocking	No	115	CES Notes 4 specimens retained and 111 specimens released
			5/6/1995	Electroshocking	No	47	CES Notes 47 specimens released
			5/13/1995	Electroshocking	No	10	CES Notes approx 10 specimens released
			5/22/1995	Electroshocking	No	39	CES Notes 39 specimens released
			8/1/1995	Electroshocking	No		CES Notes observed ~20 yoy with binoculars
			9/24/1995	Electroshocking	No	35	CES Notes approx 35 specimens released

Site Name	Latitude	Longitude	Begin Date	SampleType	Negative Survey	Number Collected	Field Notes
Horn Branch of Rock Creek above and below Hendon Rd.	35.41480	-85.24330	10/22/1995	Electroshocking	No	24	CES Notes 24 specimens released
			11/7/1995	Traps	Yes		CES Notes minnow trap set 2 hr and no fish
			5/28/1996	Traps	Yes		CES Notes minnow trap set 1 hr and no fish
			6/26/1996	Traps	Yes		CES Notes minnow traps set 7 hrs and no fish
			7/16/1996	Traps	No	1	CES Notes set minnow traps overnight, released 1 specimen
			7/23/1996	Traps	No	1	CES Notes 2 minnow traps overnight, released 1 specimen
			9/13/1996	Electroshocking	No	4	CES Notes released 4 specimens
			6/16/1997	Electroshocking	No	4	CES Notes released 4 specimens
			5/23/2004	Electroshocking	No	1	Historically present. From Lat/Long, worked ca. 900m upstream and 300m downstream; also worked ca. 300m of an unnamed trib to Horn Branch that enters 150m downstream of Lat/Long. Surveyed either May 23-27, 2004 or July 19-22, 2004.
			7/3/2013	Seining	No	1	BRK13-102. Specimen captured about 450 m upstream of road in pool with many boulders. Water clear. Current slow.
Hunt Branch just above confluence with Smith Creek	35.45518	-85.21004	8/2/1994	Electroshocking	Yes		
Hunt Branch upstream of confluence with Hail Creek	35.45230	-85.21230	5/23/2004	Electroshocking	Yes		From Lat/Long, worked ca. 1.3 km upstream. Surveyed either May 23-27, 2004 or July 19-22, 2004.
Hurricane Creek at northern boundary of Prentice-Cooper State Forest	35.16673	-85.42384	3/10/1995	Electroshocking	Yes		CES 95-12
Johns Branch at Pocket Creek Rd	35.24285	-85.55704	7/23/1996	Electroshocking	Yes		CES 96-70
Kelley Creek just above confluence with Dicks Branch	35.32019	-85.52765	7/17/1996	Electroshocking	Yes		CES 96-61
Kelly Creek ca. 2.7 km upstream from confluence with Big Brush Creek	35.47652	-85.42607	7/4/1996	Electroshocking	Yes		CES 96-43

Site Name	Latitude	Longitude	Begin Date	SampleType	Negative Survey	Number Collected	Field Notes
Laurel Branch of Rock Creek above Blane Smith Rd	35.40501	-85.24141	3/7/1995	Electroshocking	Yes		CES 95-44
Laurel Branch of Rock Creek above Hendon Road	35.40103	-85.25320	3/16/1995	Electroshocking	Yes		CES 95-17
			5/23/2004	Electroshocking	Yes		From Lat/Long, worked ca. 1200m upstream. Surveyed either May 23-27, 2004 or July 19-22, 2004.
Laurel Creek at logging rd. 0.8 km downstream of Sinclair Lake	35.59419	-85.02743	3/3/1996	Electroshocking	Yes		CES 96-6
Laurel Creek ca. 3.9 km downstream of Sinclair Lake	35.57629	-85.01053	6/5/1996	Electroshocking	Yes		CES 96-27
Lick Creek (Trib to Moccasin Creek) off Swafford Rd	35.68322	-85.03232	6/10/2010	Electroshocking	No	6	DAN10-78
Licklog Branch at Dogwood Rd	35.82662	-84.81753	4/8/1996	Electroshocking	Yes		CES 96-9
Little Brush Creek above and below confluence with Roberson Fork	35.43924	-85.44798	7/3/1996	Electroshocking	Yes		CES 96-40
Little Brush Creek ca. 300m above TN Hwy 111	35.40907	-85.37916	7/22/1996	Electroshocking	Yes		CES 96-66
Little Piney Creek at TN Hwy 68 crossing	35.74518	-84.84027	7/5/1996	Electroshocking	Yes		CES 96-49
Little Possum Creek at Hughes Branch	35.38047	-85.19428	3/23/1995	Electroshocking	Yes		CES 95-24
Long Branch, tributary to Stinging Fork at road crossing	35.71555	-84.94448	5/23/2004	Electroshocking	Yes		From Lat/Long, worked ca. 140m upstream. Surveyed either May 23-27, 2004 or July 19-22, 2004.
Long Fork just above confluence with Big Brush Creek	35.50052	-85.40751	7/4/1996	Electroshocking	Yes		CES 96-45
Lowry Creek at Summer City Road	35.60203	-85.07833	6/27/1996	Electroshocking	Yes		CES 96-35
Mammys Creek adjacent to US Hwy 70	35.87321	-84.78463	4/8/1996	Electroshocking	Yes		CES 96-7
Maple Branch of Piney Creek, at logging road crossing	35.63417	-84.97384	5/23/1996	Electroshocking	Yes		CES 96-22
Maplelush Creek above confluence with Bumbee Creek	35.66883	-84.94783	11/16/1996	Electroshocking	Yes		
McGill Creek ca. 1.1 km upstream from Hendon Rd crossing	35.48053	-85.19250	3/31/1995	Electroshocking	Yes		CES 95-32
McGrew Creek ca 1.1 km upstream of confluence with Frederick Creek	35.25572	-85.34679	3/17/1995	Electroshocking	Yes		CES 95-21
McSherley Branch at logging rd crossing	35.62804	-85.00744	5/23/1996	Electroshocking	Yes		

Site Name	Latitude	Longitude	Begin Date	SampleType	Negative Survey	Number Collected	Field Notes
Mill Creek at Lester Cemetery Rd	35.66280	-85.05200	5/23/2004	Electroshocking	Yes		From Lat/Long, worked upstream ca. 100m. Surveyed either May 23-27, 2004 or July 19-22, 2004.
Miller Branch pool 1	35.50595	-85.11168	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them
Miller Branch pool 10	35.50991	-85.11816	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them
Miller Branch pool 11	35.50986	-85.11848	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them
Miller Branch pool 12	35.51024	-85.11851	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them
Miller Branch pool 13	35.51077	-85.11865	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them
Miller Branch pool 14	35.51088	-85.11892	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them
Miller Branch pool 15	35.51516	-85.12180	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them
Miller Branch pool 16	35.51504	-85.12225	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them
Miller Branch pool 17	35.51543	-85.12254	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them
Miller Branch pool 18	35.51650	-85.12344	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them
Miller Branch pool 19	35.51719	-85.12360	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them
Miller Branch pool 2	35.50606	-85.11205	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them
Miller Branch pool 20	35.51741	-85.12366	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them
Miller Branch pool 3	35.50668	-85.11305	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them
Miller Branch pool 4	35.50702	-85.11311	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them
Miller Branch pool 5	35.50707	-85.11356	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them

Site Name	Latitude	Longitude	Begin Date	SampleType	Negative Survey	Number Collected	Field Notes
Miller Branch pool 6	35.50734	-85.11539	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them
Miller Branch pool 7	35.50769	-85.11587	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them
Miller Branch pool 8	35.50766	-85.11640	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them
Miller Branch pool 9	35.50822	-85.11617	8/18/2011	Electroshocking	Yes		20 small pools of water with no flow between them
Mocassin Creek at 2nd Summer City Road crossing	35.67532	-85.02174	5/14/1996	Electroshocking	Yes		CES 96-16
			11/16/1996	Electroshocking	Yes		
Mocassin Creek at 3rd Summer City Road Crossing	35.66942	-85.02836	5/14/1996	Electroshocking	Yes		
Mocassin Creek at logging road crossing	35.64932	-84.96783	5/23/1996	Electroshocking	Yes		CES 96-21
Moccasin Creek and unnamed trib	35.70150	-85.01780	5/23/2004	Electroshocking	No		Laurel Dace were common at this site during this survey. This was a new site surveyed for 2004. From Lat/Long, worked downstream ca. 25m. Surveyed either May 23-27, 2004 or July 19-22, 2004.
			7/1/2013	Seining	No	37	BRK13-98. All specimens captured in four seine hauls, very abundant in Moccasin Creek proper. Water clear. Current slow-moderate.
Moccasin Creek at end of Dunn Road	35.70440	-85.02340	5/23/2004	Electroshocking	No	1	New Laurel Dace site survey in 2004. Worked pool right at Lat/Long. Surveyed either May 23-27, 2004 or July 19-22, 2004.
Moccasin Creek at northernmost Summer City Road crossing, Milo	35.69082	-85.00922	5/14/1997	Electroshocking	No	9	UT 44.7320 (7) Specimens deposited in UT collection.CES 96-17. CES Notes 2 released and not sure how many kept

Site Name	Latitude	Longitude	Begin Date	SampleType	Negative Survey	Number Collected	Field Notes
Moccasin Creek at northernmost Summer City Road crossing, Milo	35.69082	-85.00922	5/23/2004	Electroshocking	No		Laurel Dace fairly common at this site during survey. Laurel Dace are historically present at this site. From Lat/Long, worked 10m upstream and 20m downstream. Surveyed either May 23-27, 2004 or July 19-22, 2004.
Morgan Creek at Jewel Rd	35.52299	-85.07177	12/12/1993	Electroshocking	Yes		CES 93-20
Mullens Creek at Persimmon Branch Rd	35.12199	-85.44308	3/10/1995	Electroshocking	Yes		CES 95-15
Newby Branch at Newby Branch Forest Camp, Forest Camp Rd	35.70223	-84.95550	5/10/1996	Electroshocking	Yes		CES 96-12
North Suck Creek just downstream of Johnson Spring	35.22499	-85.42202	3/9/1995	Electroshocking	Yes		CES 95-10
North Tributary to Miller Branch	35.51305	-85.12116	8/18/2011	Electroshocking	Yes		
Northernmost branch of Mullens Creek off of Dixie Lane	35.18311	-85.43838	3/10/1995	Electroshocking	Yes		CES 95-11
Piney Creek at Nelson-Harrison Rd	35.61058	-85.02612	3/3/1996	Electroshocking	Yes		CES 96-5
Polebridge Creek at Summer City Rd	35.57501	-85.11398	11/17/1995	Electroshocking	Yes		CES 95-73
Pond Creek downstream of logging rd crossing	35.51108	-85.34679	7/17/1996	Electroshocking	Yes		CES 96-59
Rattlesnake Branch above confluence with Flatrock Branch	35.51055	-85.38406	7/17/1996	Electroshocking	Yes		
Reynolds Creek below confluence with unnamed tributary and ca. 2.3 km upstream of Hurricane Branch	35.45470	-85.40904	7/16/1996	Electroshocking	Yes		CES 96-53
Right unnamed tributary to Board Camp Creek just upstream from TN Hwy 111	35.34156	-85.20436	8/25/1996	Electroshocking	Yes		CES 96-74
Roaring Creek 1.6 km above New Harmony Rd	35.53130	-85.16070	8/27/1993	Electroshocking	Yes		CES 94-33
			5/23/2004	Electroshocking	Yes		From Lat/Long, worked down the unnamed trib ca. 200m to Roaring Creek and then up Roaring Creek ca. 300m. Surveyed either May 23-27, 2004 or July 19-22, 2004.
Roaring Creek at New Harmony Rd.	35.52090	-85.15760	8/27/1993	Electroshocking	Yes		

Site Name	Latitude	Longitude	Begin Date	SampleType	Negative Survey	Number Collected	Field Notes
Roaring Creek at New Harmony Rd.	35.52090	-85.15760	5/23/2004	Electroshocking	Yes		From Lat/Long, worked ca. 350m upstream. Surveyed either May 23-27, 2004 or July 19-22, 2004.
Roaring Creek at Wooden Loop Rd.	35.54815	-85.13970	12/12/1993	Electroshocking	Yes		CES 93-22
Roberson Fork above confluence with Little Brush Creek	35.43935	-85.44967	7/3/1996	Electroshocking	Yes		CES 96-41
Rock Creek above confluence with Stewart Branch	35.40983	-85.23227	3/7/1995	Electroshocking	Yes		CES 95-43
Rockhouse Branch about 120 m downstream of confluence with Little Rockhouse Branch	35.69890	-84.92330	5/23/2004	Electroshocking	Yes		From Lat/Long, worked ca. 150m downstream. Surveyed either May 23-27, 2004 or July 19-22, 2004.
Sale Creek above intersection of Cranmore Cove Rd and Cove Loop Lower Rd	35.47710	-85.07270	5/23/2004	Electroshocking	Yes		From Lat/Long, worked ca. 1.8 km upstream. Surveyed either May 23-27, 2004 or July 19-22, 2004.
Sale Creek at Upper Cove loop Rd	35.51012	-85.05148	5/23/2004	Electroshocking	Yes		From Lat/Long, worked ca. 100m upstream and 100m downstream. Surveyed either May 23-27, 2004 or July 19-22, 2004.
			8/31/2011	Electroshocking	Yes		
			4/18/2012	Electroshocking	Yes		
Sale Creek upstream permit area - Station SWI-1	35.51840	-85.05312	8/31/2011	Electroshocking	Yes		
			4/18/2012	Electroshocking	Yes		
Sandy Creek at Alloway Rd	35.81381	-84.85824	2/17/1996	Electroshocking	Yes		CES 96-2
Sandy Creek at mouth of unnamed tributary	35.82918	-84.85376	4/8/1996	Electroshocking	Yes		CES 96-8
Sawmill Creek 3.0 km downstream of Lewis Chapel Rd.	35.33250	-85.29510	5/23/2004	Electroshocking	Yes		Worked 100m upstream beginning at Lat/Long reading. Surveyed either May 23-27, 2004 or July 19-22, 2004.
Sawmill Creek above Henson Gap Rd	35.34010	-85.31167	3/23/1995	Electroshocking	Yes		CES 95-23
Second unnamed tributary to Hixson Branch looking downstream	35.22496	-85.29117	3/9/1995	Electroshocking	Yes		CES 95-7
Short Creek at only road crossing	35.14337	-85.41786	3/10/1995	Electroshocking	Yes		CES 95-14

Site Name	Latitude	Longitude	Begin Date	SampleType	Negative Survey	Number Collected	Field Notes
Skiles Creek above confluence with Reel Creek	35.46080	-85.23160	5/23/2004	Electroshocking	Yes		From Lat/Long worked ca. 900m downstream to confluence with Reel Creek. Surveyed either May 23-27, 2004 or July 19-22, 2004.
Skiles Creek just above confluence with Reel Creek	35.46177	-85.22486	3/24/1995	Electroshocking	Yes		CES 95-25
Skillern Creek at Yeargan Rd	35.56162	-85.15083	11/17/1995	Electroshocking	Yes		CES 95-72
Sloan Creek, trib. To Roaring Creek, adjacent to Shaver Road	35.50640	-85.14930	5/23/2004	Electroshocking	Yes		From Lat/Long, worked ca. 800m upstream. Surveyed either May 23-27, 2004 or July 19-22, 2004.
Smith Creek above confluence with Hunt Branch	35.45542	-85.21113	8/2/1994	Electroshocking	Yes		
Soak Creek just above confluence with Sweeney Branch	35.74297	-84.94894	6/28/1996	Electroshocking	Yes		CES 96-39
Soddy Creek above TN Hwy 111	35.34584	-85.25382	8/25/1996	Electroshocking	Yes		
Soddy Creek at Wolf Branch Rd	35.38612	-85.26476	11/19/1993	Electroshocking	No	37	UT 44.6003 (30) specimens deposited in UT collection. CES Notes 37 retained
			12/4/1993	Electroshocking	No	19	UT 44.7340 (18) Specimens deposited in UT collection. CES Notes 19 retained
			2/5/1994	Electroshocking	No	5	CES Notes collected 5 adults- not sure if kept but probably
			4/2/1994	Electroshocking	No	6	CES Notes 6 specimens retained
			5/15/1994	Electroshocking	No	12	CES Notes 4 specimens retained and 8 specimens released
			5/24/1994	Electroshocking	No	2	CES Notes 2 specimens released
			5/31/1994	Electroshocking	No	13	UT 44.7303 (2) Specimens deposited in UT collection. CES Notes 2 retained and 11 released
			6/10/1994	Electroshocking	No	2	UT 44.7307 (2) Specimens deposited in UT collection
			6/29/1994	Electroshocking	No	20	CES Notes approx 20 specimens released
			2/24/1995	Electroshocking	No	27	CES Notes 2 specimens retained and ~25 specimens released
			3/16/1995	Electroshocking	No	3	CES Notes 3 specimens released

Site Name	Latitude	Longitude	Begin Date	SampleType	Negative Survey	Number Collected	Field Notes
Soddy Creek at Wolf Branch Rd	35.38612	-85.26476	4/7/1995	Traps	Yes		CES Notes minnow traps set no Laurel Dace
			4/14/1995	Traps	No		CES Notes that several Laurel Dace were seen with binoculars
			4/23/1995	Electroshocking	No	14	CES Notes 14 specimens released
			5/6/1995	Electroshocking	No	5	CES Notes 5 specimens released
			5/13/1995	Electroshocking	No	4	CES Notes 4 specimens released
			5/22/1995	Electroshocking	No	6	CES Notes 6 specimens released
			5/24/1995	Electroshocking	No	6	CES Notes 6 specimens released
			8/1/1995	Electroshocking	No	20	CES Notes approx 20 specimens released
			9/24/1995	Electroshocking	No	8	CES Notes 8 specimens released
			10/22/1995	Electroshocking	No	5	CES Notes 5 specimens released
			4/29/1996	Seining	No	15	UAIC 11401.01. BRK96-31, AMS96-2, RLM96-34. Water clear. Current slow-moderate. Specimens found mostly in pool just below road, mostly along edge. One specimen kicked out of riffle area.
			5/28/1996	Electroshocking	No		CES Notes several specimens released. No exact number given
			6/1/1996	Electroshocking	No	12	UT 44.7294 (2) Specimens deposited in UT collection. CES Notes 10 released
			7/22/1996	Electroshocking	No	25	CES Notes 25 specimens released
			9/13/1996	Electroshocking	No	4	CES Notes 4 specimens released
			5/16/1997	Electroshocking	No		CES Notes observed 4-5 with bins.
			6/16/1997	Electroshocking	No	5	CES Notes 3 specimens retained and 2 specimens released

Site Name	Latitude	Longitude	Begin Date	SampleType	Negative Survey	Number Collected	Field Notes
Soddy Creek at Wolf Branch Rd	35.38612	-85.26476	5/23/2004	Electroshocking	No	1	Historically present. From Lat/Long, worked ca. 400m downstream and 200m upstream. Surveyed either May 23-27, 2004 or July 19-22, 2004.
South Tributary to Miller Branch	35.51127	-85.12067	8/18/2011	Electroshocking	Yes		
Standifer Creek ca. 3.2 air km upstream of its confluence with Brimer Creek	35.23638	-85.49445	3/9/1995	Electroshocking	Yes		CES 95-8
Stewart Branch of Rock Creek downstream of Blane Smith Rd	35.40709	-85.23239	3/7/1995	Electroshocking	Yes		CES 95-42
Stinging Fork ca. 1.6 km upstream of Stinging Fork Falls	35.71467	-84.93831	6/27/1996	Electroshocking	Yes		CES 96-36
Stinging Fork just below and above Rhea/Bledsoe line	35.72290	-84.95190	5/23/2004	Electroshocking	Yes		From Lat/Long, worked ca. 500m upstream. Surveyed either May 23-27, 2004 or July 19-22, 2004.
Sulpher Creek 1.8 km upstream of confluence with Suck Creek	35.13865	-85.40265	3/10/1995	Electroshocking	Yes		CES 95-13
Suzanne Branch above Suzanne Rd	35.43462	-85.22989	3/30/1995	Electroshocking	Yes		CES 95-30
Suzanne Branch at Hendon Rd	35.43370	-85.23563	3/16/1995	Electroshocking	Yes		CES 95-19
			5/23/2004	Electroshocking	Yes		From Lat/Long, worked 400m upstream and 100m downstream. Surveyed either May 23-27, 2004 or July 19-22, 2004.
Tigues Creek at Riggs Rd	35.55610	-85.09424	12/12/1993	Electroshocking	Yes		CES 93-21
Tom Harris Branch at Alloway Rd	35.81387	-84.86103	2/17/1996	Electroshocking	Yes		CES 96-1
Tributary to Sale Creek - Station SW-3	35.51636	-85.05199	8/31/2011	Electroshocking	Yes		
			4/18/2012	Electroshocking	Yes		
Unnamed Tributary to Big Possum Creek	35.36861	-85.22417	6/29/1994	Electroshocking	Yes		
			4/7/1995	Electroshocking	Yes		
Unnamed Tributary to Double Branch ca. 1 km downstream of Frazier Spring	35.62062	-85.06519	6/5/1996	Electroshocking	Yes		CES 96-29
Unnamed Tributary to Gray Creek	35.36620	-85.28326	7/22/1996	Electroshocking	Yes		CES 96-64
Unnamed Tributary to Gray Creek at Lewis Chapel Rd	35.34783	-85.30417	4/7/1995	Electroshocking	Yes		CES 95-38

Site Name	Latitude	Longitude	Begin Date	SampleType	Negative Survey	Number Collected	Field Notes
Unnamed Tributary to Laurel Creek ca. 4.8 km downstream of Sinclair Lake	35.55399	-85.02063	6/5/1996	Electroshocking	Yes		CES 96-28
Unnamed tributary to McGill Creek at Graysville Rd	35.49140	-85.20100	3/31/1995	Electroshocking	Yes		CES 95-31
			5/23/2004	Electroshocking	Yes		From Lat/Long, worked ca. 300m downstream. Surveyed either May 23-27, 2004 or July 19-22, 2004.
Unnamed Tributary to Mocassin Creek at Fire Tower Rd	35.67247	-85.03269	5/14/1996	Electroshocking	Yes		CES 96-15
Unnamed Tributary to N. Chickamauga Creek	35.24173	-85.30520	3/9/1995	Electroshocking	Yes		CES 95-6
Unnamed Tributary to Reynolds Creek	35.45755	-85.41904	7/16/1996	Electroshocking	Yes		CES 96-53
Unnamed Tributary to Roaring Creek adjacent to New Harmony Rd	35.50728	-85.17399	6/26/1996	Electroshocking	Yes		CES 96-32
Unnamed Tributary to Soddy Creek	35.26016	-85.25404	7/18/1996	Electroshocking	Yes		CES 96-62
Walkertown Branch at Walkertown Rd	35.53690	-85.08464	12/12/1993	Electroshocking	Yes		CES 93-19
Whites Creek at Possum Trot Rd	35.79697	-84.81170	2/17/1996	Electroshocking	Yes		CES 96-3
Youngs Creek at Cherokee Ridge Road	35.67980	-85.00910	7/1/2013	Seining	No	4	BRK13-95. Water clear. Current slow-moderate. Heavily silted site, both above & below road; looks like the coastal plain. Tomato farm on hill upstream, likely contributing to silt.
Young's Creek at end of Kerley Road	35.67230	-84.99910	5/23/2004	Electroshocking	No		Laurel Dace fairly common here during survey. This is a new site sampled for 2004. From Lat/Long, worked 100m upstream and 150m downstream. Surveyed either May 23-27, 2004 or July 19-22, 2004.
Youngs Creek ca. 0.6 km upstream of confluence with Moccasin Creek	35.65468	-84.98620	7/4/1996	Electroshocking	No	9	UT 44.7320 (9) Specimens deposited in UT collection.CES 96-47. CES Notes 9 retained (Phoxinus abundant)
			3/15/1997	Electroshocking	No	2	CES Notes 2 specimens retained
			5/16/1997	Electroshocking	No	10	CES Notes approx 10 specimens released