Reassessment of the Historical and Search for New Localities of the Tennessee Cave Salamander *(Gyrinophilus palleucus)* in Alabama

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James C. Godwin
Alabama Natural Heritage ProgramSM
Huntingdon College
Montgomery, AL 36106-2148

Introduction

The Tennessee cave salamander *(Gyrinophilus palleucus)* was described by McCrady (1954) from seven specimens collected in Sinking Cove Cave, Franklin County, Tennessee. Three subspecies are currently recognized (Lazell and Brandon, 1962; Brandon, 1965; Brandon, 1966; Conant and Collins, 1991). G. *palleucus palleucus,* the nominate form occurs in Alabama and is the most widespread subspecies. G. *palleucus gulolineatus* and G. *palleucus necturoides* are primarily found in Tennessee, although the influence of G. *p. necturoides* is evident in some Alabama populations (A. Wynne, pers. comm.).

A neotenic, stygobitic salamander, G. *palleu(:us* reaches a maximum size of about 180 mm total length. The overall coloration of the body may be a salmon to pale flesh-pink. In those individuals exhibiting G. *p. necturoides* influence, vague indistinct dorsal spots may be present. The eyes are reduced, the snout is spatulate, and the tail is compressed with a well-developed caudal fin. Throughout life the salamander retains its gills, which may be reduced in size or large and feathery. The sensory pores of the lateral line system are quite evident along the snout, side of head, and body (Mount, 1975; Ashton, 1986; Conant and Collins, 1991).

G. *palleucus* is an inhabitant of subterranean waters in caves. Individuals may be found in rimstone pools, stream runs and pools, and pools isolated from receding waters. Substrate types that G. *palleucus* is associated with include rock, gravel, sand, and mud. The waters of the caves inhabited by G. *palleucus* tend to be clear and sediment-free. On occasion salamanders have been found at the mouth of springs (Brandon, 1965; Cooper and Cooper, 1968).

The life history and ecology of G. *palleucus* are poorly known. Simmons (1975) has completed the most detailed study of the ecological aspects of this species. Food items reported from G. *palleucus* include amphipods, isopods, ostracods, crayfish, insects (coleoptera, plecoptera, ephemeroptera, trichoptera, thysanura, and diptera), earthworms, and other salamanders (Brandon, 1967; Cooper and Cooper, 1968; Simmons 1975). Other stygobitic species often found in association with G. *palleucus* include *Asellus alabamensis, Cambarus jonesi, Orconectes australis,* and *Typhlichthys subterraneus* (Cooper and Cooper, 1968).

Simmons (1975) hypothesized that breeding takes place in the late summer or early fall with egg deposition and hatching occurring sometime later. Lower water levels during this time would concentrate individuals in pools thus promoting intraspecific contact. With hatching coinciding with higher water levels during winter, predator density would be lower and nutrient input

higher.

G. *palleucus* is known from karst regions of Alabama, Tennessee, and Georgia (Conant and Collins, 1991; Cooper 1968). Mount (1975) showed eight populations for G. *palleucus* in Alabama, with all but one north of the Tennessee River. Five of these populations were in Jackson County, with one each in Colbert, Limestone, and Madison County. A query of the Alabama Natural Heritage (ALNHP) database yielded 14 mapped Element Occurrences. Four localities not in the ALNHP database were obtained from the National Museum of Natural History, and two probable sites were included to bring the total of known or possible localities for G. *palleucus* in Alabama to 20. Although Simmons (1975) hypothesized that as many as 130 populations of G. *palleucus* may exist, only 18 historical localities are known in Alabama. Colbert County contains two, DeKalb County one, Jackson County eight, Limestone County one, Madison County two, and Marshall County three. Two sites in Madison County were included because of the possibility of the occurrence of G. *palleucus* in these caves and surveys of these caves were already underway. A list of caves potentially containing G. *palleucus* was later developed raising the total number of caves under consideration to 33.

Through its Heritage Programs The Nature Conservancy assigns global and state ranks for degrees of rarity to species of plants, animals, and natural communities. *Gyrinophilus palleucus* has been given a global rank of G2 and a state rank of S2. The global ranks are determined by considering the number of occurrences of the species rangewide, and the ranking system is as follows in which a rank of G 1 = 1 - 5 occurrences, G2 = 6 - 20 occurrences, G3 = 21 - 100 occurrences, (for state ranks substitute S for G). G4 and G5 ranks are applied to more common species. Although approximately 30 occurrences are known for G. *palleucus* rangewide it has been given the rank ofG2 due to its overall small range and the tenuous condition of many sites. Threats to G. *palleucus* and the ecological functioning of the subterranean systems include flooding following dam construction, the introduction of sewage into aquifers, mining, sedimentation, and the filling and dumping of trash in sinkholes.

Objectives

The objectives of the study were to assess and rank the h~torical *Gyrinophilus palleucus* sites and search for new localities in Alabama so that recommendations can be developed for its conservation.

Materials and Methods

Before the visitation of sites Element Occurrence Specifications (EO Specs) were written, and later modified based on data collected during field surveys. The EO Specs follow Natural Heritage format, define the parameters for an Element Occurrence (EO) for this species, and provide a standardized approach to the assessment of each EO. Each EO is assigned a rank related to its degree of size and stability. The ranking system ranges from A, an excellent population, to D, a population of very poor quality and small size. Table 1 presents the definition for the EO Specs. Each historical site was compared with the EO Specs to decide whether it should be regarded as a separate EO.

Table 1. Element Occurrence Specifications for the Tennessee cave salamander, *Gyrinophilus palleucus* following standard Natural Heritage Network methodology.

Element Occurrence Specifications:	
Stygobitic populations that occur as a group of individuals in a hydrologically distinct cave system. Each EO should include the entire mapped aquatic portion(s) of the subterranean system.	
Element Occurrence Rankings:	
ARANKSPECS:	EO includes more than five individuals per 300 m of surveyed cave passage, or 0.0167 individuals/m or higher. (Downrank to "B" if occupied habitat is degraded (e. g., moderate levels of siltation and sedimentation within cave streams; moderate pollution from trash dumped into sinkholes; human and animal wastes dumped into sinkholes).
BRANKSPECS:	EO includes three to four individuals per 300 m of surveyed cave passage, or between 0.0100 to 0.0166 individuals/m. Downrank to "C" if occupied habitat is degraded (e. g., large amounts of siltation and sedimentation within cave streams; moderate to severe pollution from trash dumped into sinkholes; significant amounts of human and animal wastes dumped into sinkholes).
CRANKSPECS:	EO includes one or two individuals per 300 m of surveyed cave passage, or between 0.0067 and 0.0099 individuals/m. Downrank to "D" if occupied habitat is degraded (severe sedimentation and siltation within cave streams; severe pollution from trash dumped into sinkholes; large amounts of human and animal wastes dumped into sinkholes).
DRANKSPECS:	EO includes fewer than two individuals per areas greater than 300 m of surveyed cave passage, or less than 0.0067 individuals/m.

In addition to site assessments based on EO Specs for G. *palleucus,* each site received a Biodiversity Rank which took into account other rare species which were associated with the cave and their respective GRANKS, SRANKS, and EORANKS. Table 2 provides definitions for the Biodiversity Ranks, which are a measure of the biological importance of the site.

Table 2. Definitions of Biodiversity Ranks

Bl: A site of outstandinlZ significance, such as the only known occurrence of any Element,

the best or an excellent (A-ranked) occurrence of a G1 Element, or a concentration (4+) of high-ranked (A- or B.,.ranked)occurrences of G1 or G2 Elements. Site should be viable and defensible for targeted Elements and ecological processes contained.

B2: A site of very high significance, such as one of the most outstanding occurrences of any Element (regardless of its Element rank). Also includes areas containing any other (B-, C-, or D-ranked) occurrence of a G1 Element, a good (A- or B-ranked) occurrence of a G2 Element, an excellent (A-ranked) occurrence of a G3 Element, or a concentration (4+) of B ranked G3 or C-ranked G2 Elements).

B3: A site of high significance, such as any other (C- or D-ranked) occurrence of a G2 Element, a B-rankedoccurrence of a G3 Element, an A-ranked occurrence of any community, or a concentration (4+) of A- or B-ranked occurrences of (G4 or G5) SI Elements.

B4: A site of moderate significance, such as a C-ranked occurrence of a G3 Element, an A-ranked or B-ranked or only state (but at least C-ranked) occurrence of a (G4 or G5) SI Element, an A-ranked occurrence of an S2 Element, or a concentration (4+) of good (B-ranked) S2 or excellent (A-ranked) S3 Elements.

B5: A site of lZeneralbiodiversity interest or ODenSDace.

Caves were surveyed by entering at the most appropriate entrance (often there was only one) and slowly walking (or at times crawling) upstream or downstream and carefully searching for and counting salamanders. Time spent in the cave was recorded and the distance covered was estimated based on available maps. During later surveys an attempt was made to standardize the counts by extent of habitat examined, and while this adds a level of quantification it is still imprecise and a more robust measure of quantification is needed. It was beyond the scope ofthis project to estimate the .area of potential habitat associated with the target caves, as much of the habitat available to G. *palleucus* is unreachable by humans. In general, salamanders were only counted while working from the entrance inward. However, on a few occasions after once reaching the endpoint and moving back through the cave toward the entrance, individuals were observed in stream runs, pools, or rimstone pools where no salamander had been previously observed. These individuals were then included in the total count. Cave surveys were conducted from the entrance to the farthest point in the cave feasible for biological exploration. Generally the endpoint was reached when the cave passage rose above the stream and terminated, or the stream sumped below the ceiling of the cave passage. Conditions for observation ranged from excellent in the shallow quiet pools to very poor in deep turbid waters. In shallow water crisscrossed wave patterns produce excessive reflections inhibiting adequate observation. Thus it is likely that, during any particular survey, individuals were overlooked.

Results and Discussion

A total of 33 caves have been considered. Surveys were conducted in 23 of 29 historical or potential caves for G. *palleucus,* and credible but unverified reports have been received for four caves (Table 3). No survey was conducted in six caves due to a failure to establish landowner contact. Of the 13 current or historical caves for G. *palleucus* in which entry was gained G. *palleucus* was observed in eight, or 61.5%. The first survey to McFarland Cave was

unproductive while one individual was seen during the second survey. The lack of salamander sightings in two caves was attributable to poor viewing conditions at the time of visitation. House of Happiness cave was surveyed following heavy rainfall which produced an elevated and murky flow in the streams. The water level in Shelta Cave was extremely low which dramatically reduced the amount of available surveyable habitat. These caves should be resurveyed under more favorable conditions.

Table 3. Survey results of known and likely *Gyrinophilus palleucus* caves, aquatic associates, number of individual G. *palleucus* observed per trip, and the Element Occurrence Rank for each site.

County	Cave	Species Reported from Cave	Date(s) Surveyed	# Obs	EORank *GyrinopJ palleuc*
Colbert	Elbow Cave	*Typhlichthys subterraneus* *Cambarus jonesi* and/or *Procambarus pecki* *Palaemonias* sp.	9 November 1999 23 February 2000	0	no
Colbert	McKinney Pit	*Gyrinophilus palleucus* *Typhlichthys subterraneus* *Cambarus tenebrosus* *Procambarus pecki* *Palaemonias* sp.	28 September 1995 9 April 1996 7 July 1999 22 September 1999 9 November 1999 23 February 2000	0	no rank, to resu
Colbert	Thomason's	*Gyrinophilus palleucus* *Typhlichthys subterraneus* *Cambarus tenebrosus*	23 September 1995	2	
Dekalb	Deer Head Spring	*Gyrinophilus palleucus*	30 September 1995		no rank, not acce
Jackson	Bouldin Spring	*Gyrinophilus palleucus*		not given	cre(observa n verific~
Jackson	Guess Creek	*Gyrinophilus palleucus*		not given	cre(observa n verific~
Jackson	Horseskull	*Cambarus hamulatus*	12 December 1996		no! !in habitat f(*valle*
Jackson	House of Happiness	*Gyrinophilus palleucus* *Cambarus tenebrosus* *Orconectes australis australis*	9 August 1995	0	no rank, to resu
Jackson	Jess Elliot (includes Iron Hoop & Tate)	*Gyrinophilus paUeucus* *Cambarus hamulatus* *Cambarus tenebrosus* *Orconectes australis australis*	23 June 1995 21 March 1997	26,5	
Jackson	Kennamer	*Orconectes australis australis*	6 December 1996		no
Jackson	Kyles	*Gyrinophilus palleucus* *Typhlichthys subterraneus*	28 October 2000	not given	cree observa n verific~

County	Cave	Species Reported from Cave	Date(s) Surveyed	#Obs	EORan~ *Gyrinop, valleu(*
Jackson	Lim Rock Blowing	*Gyrinophilus palleucus* *Typhlichthys subterraneus* *Orconectes australis australis*	19 May 1995	1	
Jackson	McBrides	*Gyrinophilus palleucus*		not given	cre observ~) verific
Jackson	McFarland	*Gyrinophilus palleucus* *Orconectes australis australis*	10 August 1995 19 June 1999	0, I	
Jackson	Ranie Willis	*Gyrinophilus palleucus*	18 May 1995	0	no rank, to rest
Jackson	Russell	*Gyrinophilus palleucus* *Typhlichthys subterraneus* *Cambarus hamulatus* *Orconectes australis australis*	21 October 1999	3	
Jackson	Salt River	*Gyrinophilus palleucus* *Typhlichthys subterraneus* *Orconectes australis australis*	18 May 1995 11 August 1995	5;0	
Jackson	Sauta (= Blowing, Saltpeter)	*Gyrinophilus palleucus*	29 June 1995 27 March 1999	17,8	
Jackson	Tumbling Rock	*Cambarus hamulatus*	20 November 1996		no rank, to rest
Jackson	Valhalla	*Gyrinophilus palleucus*			no rank, not vi
Lauderdale	Key	*Speoplatyrhinus poulsoni* *Typhlichthys subterraneus* *Cambarus jonesi* *Procambarus vecki*	10 April 1996 21 October 1997		no
Lauderdale	Watkins Lake	*Typhlichthys subterraneus* *Cambarus ionesi*	10 November 1999	0	no rank, to rest
Limestone	Robinson Sinks	*Gyrinophilus palleucus*	23,24,28 September 1995		no rank, not acc(
Limestone	Rockhouse	*Gyrinophilus palleucus* *Typhlichthys subterraneus* *Cambarus jonesi*	23 September 1995 8 July 1999 28 September 1999 18 February 2000 19 February 2000	0	no rank, to rest
Madison	Beasley	*Gyrinophilus palleucus* ? *Typhlichthys subterraneus* *Orconectes australis australis*			no rank, not vi
Madison	Bobcat	*Typhlichthys subterraneus* *Orconectes australis australis* *Palaemonias alabamae*	July, August, December 1994; May, June, July, August, September 1995	0	no un!ike ha1 *pallei*
Madison	Matthews	*Typhlichthys subterraneus* *Orconectes australis australis*	July, August, December 1994; May, June, July, August, September 1995	0	no] un!ike ha, *palle*

County	Cave	Species Reported from Cave	Date(s) Surveyed	#Obs	EORank *GyrinopJ valleuc*
Madison	Shelta	*Gyrinophilus palleucus* *Typhlichthys subterraneus* *Cambarus jonesi* *Orconectes australis australis* *Orconectes sheltae* *Palaemonias alabamae*	14 September 1995	0	no rank, to resu
Marshall	Dunham	*Gyrinophilus palleucus*	30 September 1995		no rank not acce
Marshall	King's School	*Gyrinophilus palleucus* *Cambarus hamulatus*	30 September 1995 17 November 1995 4 December 1996	0,6,3	
Marshall	*Gyrinophilus palleucus* cave	*Gyrinophilus palleucus*	30 September 1995		no rank, not acce
Morgan	Cave Spring	*Typhlichthys subterraneus* *Cambarus jonesi* *Procambarus pecki*	19 February 2000 25 February 2000	0	no rank, to resu
Morgan	Talucah	*Typhlichthys subterraneus* *Cambarusjonesi*	1 August 1996		no rank, to resu

Cave Types

G. *palleucus* inhabits two generalized cave types, phreatic and vadose (Anonymous, 1999, Klimchouk et al., 2000). Phreatic caves have voids below the water table where, within the cave, there are zones of permanently saturated rock. These caves have pools with extremely clear water and an extremely slight, almost imperceptible flow. Depths of pools may be in excess of 3 m, and undercutting of walls further adds to the difficulty in sampling these habitats. Phreatic caves are more common along the Tennessee Valley than on the Cumberland Plateau. Caves with primarily phreatic waters include Elbow, McKinney Pit, Key, Watkins Lake, Rockhouse, Bobcat, and to some extent Cave Spring.

Vadose caves are ones that have developed above the water table, and drainage is free-flowing with the underground water being moved by gravity (Anonymous, 1999, Klimchouk et aI., 2000). These include stream caves of the type inhabited by G. *palleucus.* Vadose are the typical cave type on the Cumberland Plateau and include Bouldin Spring, Guess Creek, Horseskull, House of Happiness, Jess Elliot, Iron Hoop, Tate, Kennamer, Kyles, Lim Rock Blowing, McFarland, Rainie Willis, Russell, Salt River, Sauta, Tumbling Rock, Matthews, Shelta, King's School, and Talucah. Thomason's is in the Interior Low Plateau. Cave Spring, also of the Interior Low Plateau has a well-developed stream with phreatic windows along the banks.

A significant difference between the two cave types is the association of large sinks with vadose caves. Sinks located at higher elevations than the stream base level provide a source of energy input into the cave system. Of the eight caves in which G. *palleucus* was seen, there is a large sink nearby. The presence or absence of a sink was determined by examining topographical maps. If a sink was near a cave and in the same cove as a cave or on a plateau above the cave it was considered to be associated with that cave. Several of the caves have pit entrances but these

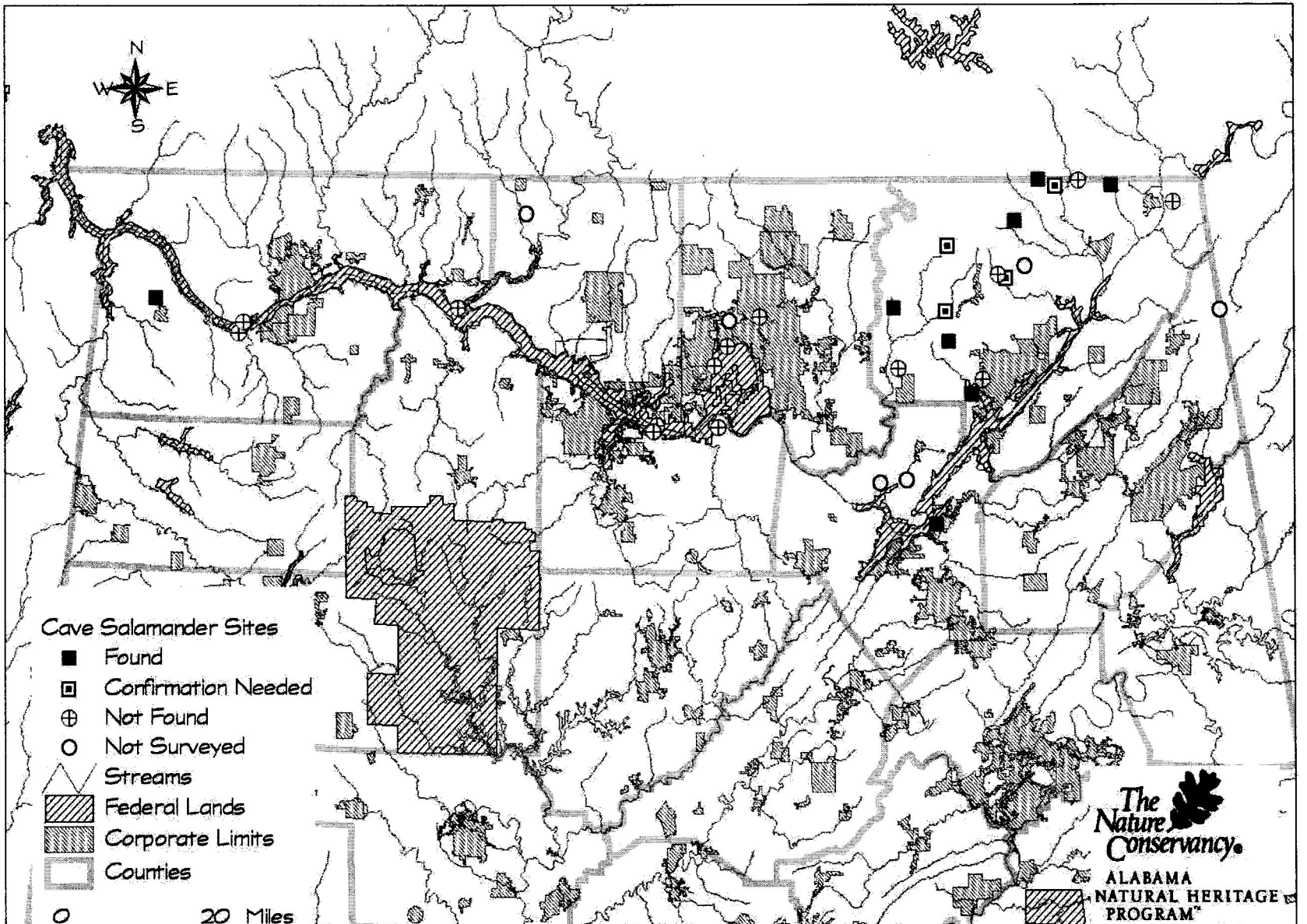
were not considered to have a significant influence as far as energy input is concerned. The majority of sink/cave associations were on the Cumberland Plateau. Since sinks appear to provide an extremely important above ground link to the cave systems it is imperative to protect the sink if the cave system is to be protected.

G. *palleucus* was only observed in vadose caves; it was not seen in any of the historical phreatic localities. This is not to imply that G. *palleucus* no longer occurs in these phreatic caves. Streams, with their attendant pools, runs, and riffles are easy to survey. Pools are often shallow, rocks in runs and riffles can be overturned, and in general there is more habitat that can be actively searched than in phreatic caves. Pools in phreatic caves are often in excess of 1 m deep and while the water may be exceptionally clear, light penetration is still reduced. Survey methods in these caves are more passive with long periods of visually searching pools. Pools in the caves are large enough for snorkeling but again a passive approach is needed as the species inhabiting the waters are very sensitive to vibration. Undoubtedly the phreatic pools represent only a small window, no matter how large the pool, into the associated aquifer where the majority of habitat exists. Table 4 and Figure 1 present the caves, general location, and cave type for caves in which *Gyrinophilus palleucus* has been confirmed, and those caves with reliable but unconfirmed sightings.

Table 4. Caves, general location, and cave type for caves in which *Gyrinophilus palleucus* has been confirmed, and those caves with reliable but unconfirmed sightings.

County	Cave	Physiographic Province	Township-Range-Section	Sink associated with cave	Cave type where known
Colbert	McKinney Pit	Interior Low Plateau	T4S Rl2W Sec 10	no	phreatic
Colbert	Thomason's	Interior Low Plateau	T3S Rl4W Sec 22	yes?	vadose
Dekalb	Deer Head Spring	Cumberland Plateau	T3S RI0E Sec 22	no	vadose
Jackson	House of Happiness	Cumberland Plateau	T5S RSE Sec 4	no	vadose
Jackson	Jess Elliot (includes Iron Hoop & Tate)	Cumberland Plateau	TIS R6E Sec 31	yes	vadose
Jackson	Kyles	Cumberland Plateau	TIS RSE Sec 36	no	vadose
Jackson	Lim Rock Blowing	Cumberland Plateau	T4S R4E Sec 11	yes	vadose
Jackson	McFarland	Cumberland Plateau	T3S R3E Sec 22	yes	vadose
Jackson	Ranie Willis	Cumberland Plateau	TIS R7E Sec 3	no	vadose
Jackson	Russell	Cumberland Plateau	TIS R8E Sec 5	yes?	vadose
Jackson	Salt River	Cumberland Plateau	TIS R6E Sec 2	yes	vadose
Jackson	Sauta	Cumberland Plateau	T5S RSE Sec 7	yes	vadose
Jackson	Valhalla	Cumberland Plateau	TIS R6E Sec 29	yes?	vadose?
Limestone	Robinson Sinks	Interior Low Plateau	TI S R6W Sec 26	no	phreatic?
Limestone	Rockhouse	Interior Low Plateau	T5S R3W Sec 34	no	phreatic
Madison	SheIta	Cumberland Plateau	T3S Rl W Sec 27	no	vadose
Marshall	Dunham	Cumberland Plateau	T7S R3E Sec 2	no	vadose
Marshall	King's School	Cumberland Plateau	T7S R4E Sec 34	no	vadose
Marshall	*Gyrinophilus /alleucus* cave	Cumberland Plateau	T7S R3E Sec 5	yes?	phreatic?

Figure 7. Tennessee Cave Salamander Survey Sites in Northeastern Alabama



Priority Caves

G. *palleucus* was documented from caves in Colbert, Jackson, and Marshall counties, which encompasses the western, southern, northern, and eastern limits of its range in Alabama.

Jess Elliot, Iron Hoop, Tate

The greatest number of salamanders observed was in the Jess Elliot, Iron Hoop, Tate cave system, which has over 20,000 feet of mapped cave passage. Currently this is considered to be the most significant site in Alabama for G. *palleucus.* This system, based on the large number of G. *palleucus* that were observed, the presence of *Neotoma magister,* the stygobitic crayfish *Cambarus hamulatus* and *Orconectes australis australis,* and 10 terrestrial troglobitic invertebrates, two of which are only known from Jess Elliot Cave, is given a Biodiversity Rank ofBI.

Sauta

The count of G. *palleucus* in Sauta Cave was the second highest number recorded. Sauta Cave also contains *Myotis grisescens, Myotis sodalis, Corynorhinus rafinesquii,* and three terrestrial, troglobitic invertebrates, one which is known only from this cave. Based on the occurrences of these species this site is given a Biodiversity Rank of B1. Sauta receives protection by its inclusion in Wheeler National Wildlife Refuge.

Russell

While this cave system has not been fully surveyed for G. *palleucus* it is nonetheless being regarded as an important site for G. *palleucus.* Much of the cave is within Russell Cave National Monument and is afforded protection.

King School

Although this is a small cave, King's School Cave, is one of the important localities for G. *palleucus,* as it represents one of the few localities south of the Tennessee River and is one of the southernmost localities. Being on Guntersville State Park this cave should be relatively protected, although it appears that visitation is uncontrolled. It has been given a Biodiversity Rank of B2, since it also harbors *M grisescens, M sodalis,* and the stygobitic crayfish C. *hamulatus.*

Thomason's

While only two individuals of G. *palleucus* were observed during the survey of Thomason's Cave, this site is regarded as being important because it is south of the Tennessee River and is the westernmost known locality. *Typhlichthys subterraneus* was also present within the cave. This site has been given a Biodiversity Rank ofB3. This site is on private property and at the time of the survey was well protected. Entry is controlled by the landowner and no detrimental practices were observed to be taking place on the property.

Caves Requiring Additional Survey

Salt River

Salt River Cave was surveyed twice. During the first survey, five G. *palleucus* were counted. The second survey produced no observations of the salamander and the causative factor was deemed to be poor visibility due to high water levels in the cave. The Biodiversity Rank for this cave is B3. Salt River Cave supports *T. subterraneus,* C. *hamulatus,* 0. *a. australis* and eight terrestrial troglobitic invertebrates. The habitat in this cave is extensive and in good condition, and with the presence of the aquatic obligate cave species may be a more important site than the current information suggests.

Lim Rock Blowing

During the survey of Lim Rock Blowing Cave only one G. *palleucus* was counted. The cave is in good condition, the extent of habitat within the cave is extensive, and the numbers of G. *palleucus* are most likely higher. During the survey numerous deeper pools were encountered thus hampering the survey effort. *T. subterraneus* and 0. *a. australis* are two stygobites inhabiting this system with G. *palleucus.* As with Salt River Cave Lim Rock Blowing may sustain a more substantial salamander population than is suggested by the available information.

McFarland

McFarland was resurveyed in 1999 and one individual of G. *palleucus* was seen. The salamander is still present at this site, and is most likely present in higher numbers than indicated. The accessible cave passage of McFarland is at the lower end of a more extensive cave system.

Caves which need to be resurveyed include McKinney Pit, House of Happiness, Ranie Willis, and Shelta. The lack of sightings of G. *palleucus* in these caves was based on environmental influences which produced poor survey conditions, except in McKinney Pit in which the extensive amount of habitat in phreatic pools hampered survey efforts. Snorkeling is the best technique for surveying in McKinney Pit but this method was not used until late in the study. Each of these caves contains an adequate to extensive amount of habitat in good to excellent condition. During the surveys I did not see the results of any obvious detrimental impact which would have extirpated G. *palleucus* from any of these caves. A reliable but unverified report of the salamander was received for Bouldin Spring, Guess Creek, Kyles, and McBrides caves. Additional or initial surveys should document the salamander at these four localities.

Rockhouse Cave

The following was written in 1995:

"Rockhouse Cave may be the one historical locality in which G. *palleucus* no longer is present, although further survey work should be done before such a determination is made. This cave is at the edge of and is influenced by Wheeler Lake. During the survey the waters of the cave appeared to be of poor quality. Also a large amount of trash which had washed in from the backwaters of the reservoir was present in the cave."

Rockhouse Cave was resurveyed in 1999 and 2000. While G. *palleucus* was not seen, two stygobites, *T. subterraneus* and C. *jonesi* were. Because of the presence of these species it is quite likely that G. *palleucus* has not been extirpated from this cave, and that ecologically the cave is in better condition than suggested during the early survey. Rockhouse Cave is on Wheeler National Wildlife Refuge and protective measures could be increased with little effort.

Bobcat and Matthews caves on Redstone Arsenal in Madison County were surveyed at least12 times during 1994 and 1995. No G. *palleucus* were observed in either cave though both have well-developed aquatic habitats and support such species as 0. *a. australis* and *T. subterraneus.* Both species are associates of G. *palleucus* but I do not think that G. *palleucus* is present in either cave.

Caves which still require an initial survey are Deer Head Spring, Valhalla, Robinson Sinks, Beasley, *Gyrinophilus palleucus,* and Dunham.

The Biodiversity Ranks of these sites may change in the future as additional surveys may document G. *palleucus* in caves where none were seen during this survey effort. Also, the identification and ranking of rare species may elevate the Biodiversity Rank (i.e. a B3 may become a B 1) for any site. Conversely, ranks may be lowered if species are lost following detrimental impacts.

Recommendations

Much of the biology, natural history, ecology, and population dynamics of G. *palleucus* is unknown, and information is needed on this salamander before any conservation actions can be evaluated. But in the interim complete protection of the priority caves is needed, and following that monitoring should be implemented to track numerical trends of the salamander and to assess the effectiveness of cave protection. The caves should be viewed as systems that are integral with the surface. While this report focuses on one species that is a cave obligate there are a host of other obligate cave species that occur with G. *palleucus,* and many of these species are as equally rare as G. *palleucus,* if not more so. Jackson County, Alabama has over 1500 caves and 66 stygobitic and troglobitic species; these are more caves and cave obligate species than any other county in the nation (Culver et al. 1999). A number of these species have been reported from only one or a few caves (Peck, 1989, 1995) and 24 species are endemic to Jackson County (Culver et ai. 2000). Nationally, northeast Alabama has three of the four most specious counties for cave obligates. Madison and Marshall counties are ranked at second and fourth respectively. Thus, Jackson, Madison, and Marshall counties represent a hotspot for underground biological diversity, and include the majority of historical and confirmed populations of G. *palleucus.*

Therefore, protection needs to be in the context of cave systems to encompass the range of unique biodiversity that sets these subterranean ecosystems apart.

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