

DESCRIPTION OF *LIRCEUS FOUSHEENSIS*, N. SP., THE FIRST TROGLOMORPHIC ISOPOD OF THE GENUS *LIRCEUS* (*HOPPINELLUS*) FROM THE OZARKS (CRUSTACEA: ISOPODA: ASELLIDAE)

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Abstract

Troglomorphic, stygobiontic asellid isopods of the genera *Caecidotea* and *Conasellus* are widespread in the Ozark physiographic province of the central United States. In contrast, numerous species of *Lirceus* are common in springs and seeps where groundwaters emerge, but none are particularly morphologically adapted to caves. Herein, we describe and figure *Lirceus fousheensis*, the first troglomorphic (and presumably stygobiontic) species of the genus in the Ozarks, from Foushee Cave, Independence County, Arkansas. It is a species of the *Lirceus bicuspidatus* clade and is viewed as an isolated cave invasion arising by an adaptive shift from a common spring-dwelling species. Compared with seven cavernicolous species of *Lirceus* from southwestern Virginia caves, *Lirceus fousheensis* is intermediate in the degree of troglomorphy.

INTRODUCTION

Among the asellid isopods of North America, there are many species believed to be widespread. In some cases, like *Lirceus louisianae*, the validity of the broad range was re-affirmed by genetic sequencing of far-flung populations that demonstrated minimal divergence (Lewis et al., 2023). That species occurs in a variety of aquatic habitats, although its wide range is probably attributable to not being particularly restricted to any of them. In contrast, it is becoming increasingly apparent that many of the purportedly widespread species associated with karst habitats, particularly caves and springs, are revealed by genetic sequencing to be complexes of cryptic species. As a case in point, *Lirceus hargerii* Hubricht and Mackin (1949) was discovered to be such a complex. Rather than a single species, it is now characterized as a subgenus (*Hargerellus*) of 18 described species spanning an area from southwestern Virginia to northern Georgia, with more taxa awaiting description (Lewis et al., 2023).

In the Interior Highlands region, Hubricht and Mackin (1949) described *Lirceus bicuspidatus* from springs spanning the southern Ozarks as well as the Ouachita Mountains, a range essentially encompassing all the Arkansas uplands. The initial sampling for molecular analysis in this region demonstrated that southern populations of *Lirceus bicuspidatus* in the Ouachitas were genetically divergent, which were described as *Lirceus robisoni* (Lewis and Lewis, 2023).

Herein, we separate and describe a second new species within the *Lirceus bicuspidatus* clade, the first troglomorphic *Lirceus* discovered in the Ozarks.

SYSTEMATICS

Lirceus (*Hoppinellus*) *fousheensis*, New Species

Lirceus bicuspidatus—McDaniel and Smith, 1976: 58; Graening, 2003: 195; Graening et al., 2011: 159, 175; Lewis and Lewis, 2023: 97–98.

Material examined.—ARKANSAS: Independence County: Foushee Cave, M. Slay, 14 Jun 2011, 7♂8♀; same locality, M. Slay, P. Ardapple, J. Baxter, 25 Feb 2020, 30♂♀.

The holotype is a 6.1 mm ♂ collected from Foushee Cave on 25 February 2020, and the other specimens from this locality are designated paratypes. The specimens were deposited in the collection of the National Museum of Natural History, Smithsonian Institution, Washington, DC.

Material for molecular analysis.—ARKANSAS: Independence County: Foushee Cave 3♂♀ (site code: FOUCHECA); deposition of material and analysis at Université Lyon 1, Lyon, France. All metadata associated with molecular analyses are stored in the World Asellidae Database (Saclier et al., 2024).

Diagnosis.—*Lirceus fousheensis* is most closely related to *Lirceus bicuspidatus*, which occurs in springs and small streams in the Ozark Boston Mountains and the adjacent Springfield Plateau in northern Arkansas. *Lirceus fousheensis* is separable from *L. bicuspidatus* by its small size, the longest specimen is 8.2 mm compared to 18 mm for *L. bicuspidatus* (Hubricht and Mackin, 1949); the marked depigmentation of the body in dorsal view; and the presence of a

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Figure 1. *Lirceus fousheensis*, n. sp., from Foushee Cave, Independence County, Arkansas (photograph by Michael Slay).

single small triangular process on the palmar margin of the propodus of the first pereopod, as opposed to two prominent bicusped processes as the name implies for *L. bicuspidatus*.

Description.—Length of males is 6.6 mm, the longest female is 8.2 mm, and the body is about 2.5× as long as wide. Eyes present and well formed, dorsal pigmentation reduced, light brown or tan, present on the head and longitudinal midline of pereonites, and pleotelson. Lateral margins of pereonites depigmented, pleotelson with pigment granular in appearance (Fig. 1).

Head broad, about 2.5× as wide as long, anterior margin with medial–lateral carinae broadly rounded, about equal in height with medial carina, lateral margin entire, post-mandibular lobes, and lateral incisions not apparent (Fig. 2). Lateral margins of head, pereonites, and pleotelson moderately setose and spinose. Antenna 1 short, reaching to about midlength of penultimate article of antenna 2 peduncle, flagellum with 5 articles, with aesthetes on distal 4 articles. Antenna 2, flagellum with about 45 articles. Mandible with 3-merous palp, setose on all articles.

Pereopod 1 of male, propodus about 1.7× as long as wide, palmar margin with one large and one smaller stout proximal spines, medial process small, subtriangular; dactyl flexor margin with stout subungual spine, plus about 12 smaller spines descending in size toward the propodus. Female pereopod 1, sexual dimorphism present, propodus about 2.6× as long as wide, palmar margin flat, 3 stout proximal spines present, processes absent, comb spines in row along margin. Pereopod 4, carpus of male 2.2× as long as wide, dactyl flexor margin with stout subungual spine, plus 3 smaller stout spines. Pereopod 4 of female, sexual dimorphism present, carpus 2.6× as long as wide, dactyl flexor margin with stout subungual spine, plus 3 smaller stout spines.

Pleotelson widest anteriorly, tapering distally, about 1.1× wider than long, caudomedial lobe broadly rounded, uropodal sinuses slightly produced. Pleopod 1 (Fig. 3) protopod mesial margin with 2 retinaculæ and 1 small seta; exopod about 1.7× as long as wide,

1.2× length of protopod, and lateral and distolateral setae longer than apical setae. Pleopod 2, protopod without setae; exopod, proximal article without setae; distal article trapezoidal, about 1.1× longer than proximal article, about 1.6× as long as wide, with about 6 elongate setae along the proximolateral margin, 5 longer setae along the apical margin; endopod tip with cannula extending across the axis of the endopod, cylindrical, arising from the base of broad, digitiform, dentate, and scalloped lateral process, with shelf extending to a broadly rounded mesial process; caudal margin of endopod broadly rounded, sclerotized. Pleopod 3 exopod, anterior surface moderately setose, and lateral and apical margins densely setose. Pleopod 4 exopod, lateral margin setose, setae formula 30–14–11. Pleopod 5 exopod, proximolateral margin with 2 elongate setae.

Total length of male uropod is about 0.55× the length of the pleotelson in ventral view, in dorsal view extending about 0.5× the length of pleotelson; protopod flattened, about 0.7× of the length extending beyond the margin of the pleotelson; exopod and endopod slightly flattened; exopod about 0.8× the length of endopod; and endopod about 1.4× longer than protopod.

Etymology.—This species is named after the type-locality, Foushee Cave. Suggested vernacular name is the Foushee cave isopod.

Habitat and range.—*Lirceus fousheensis* is known only from Foushee Cave, where the isopods occur in the cave stream. McDaniel and Smith (1976) first noted the presence of what they characterized as a troglolithic “unpigmented and minutely eyed isopod” from Foshee [sic] Cave and reported the same species from Hell Creek Cave, Stone County, Arkansas. As to the latter, the junior author has entered Hell Creek Cave on numerous occasions and has not seen any *Lirceus*, nor have we been able to locate specimens or other references in unpublished reports or the literature. McDaniel and Smith cited the late Thomas E. Bowman as identifying their specimens, but we have been unable to locate the Stone County material in the collection of the Smithsonian Institution, where Dr. Bowman worked for his entire career.

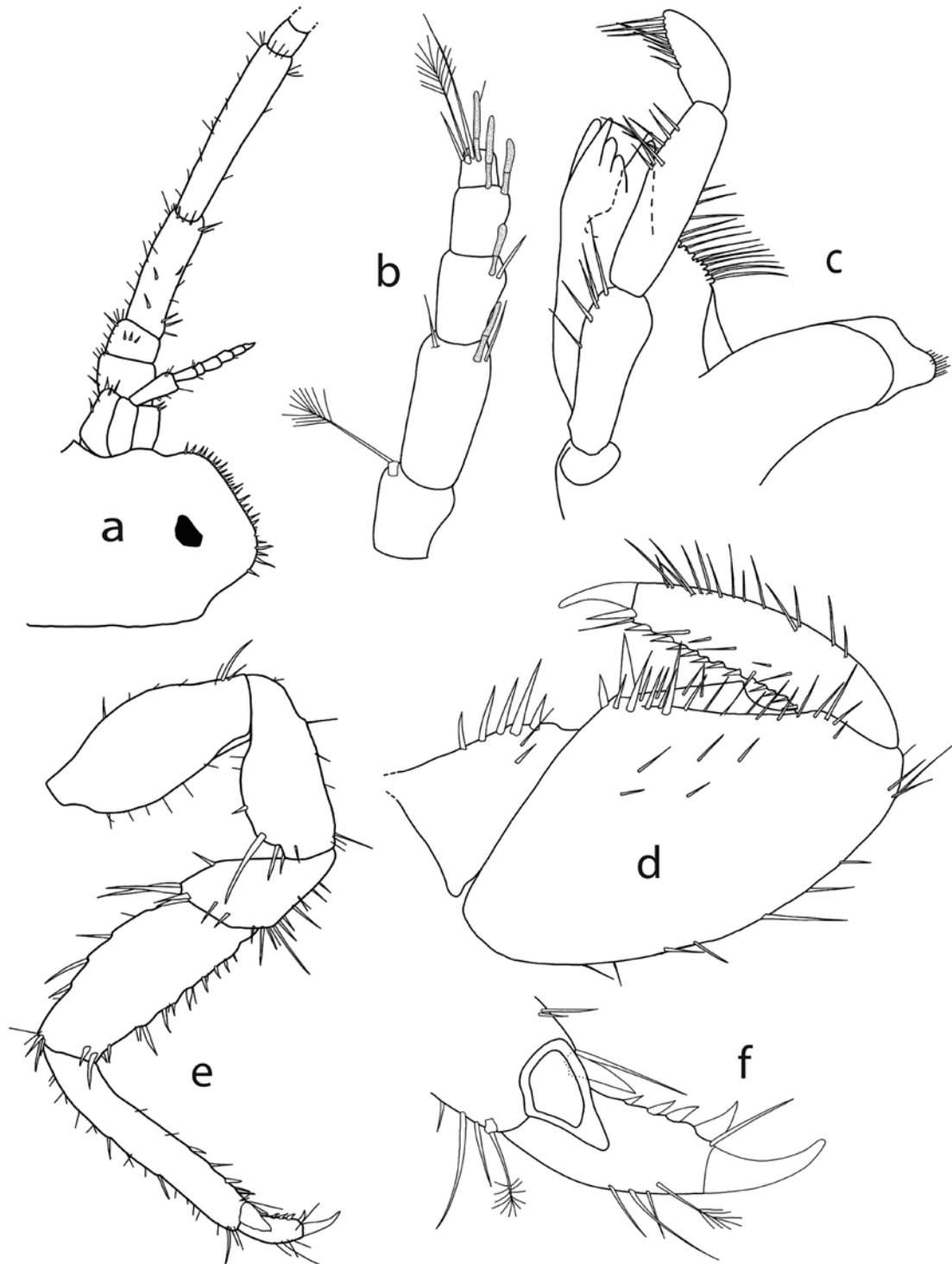


Figure 2. *Lirceus fousheensis*, n. sp., male paratype from Foushee Cave, Independence County, Arkansas: (a) head, antenna 1 and peduncle of antenna 2, pigmentation omitted; (b) distal articles of antenna 1; (c) mandible; (d) pereopod 1, distal articles; (e) pereopod 4; and (f) same, dactylus.

The location of Foushee Cave is indicated on the U.S. Geological Survey Concord quadrangle 7.5-min topographic map as Blowing Cave. The cave is gated, and permission from the Arkansas Natural Heritage Commission is required for entry. Foushee Cave was formed in a narrow band of Mississippian limestone in the Springfield Plateau along the eastern part of the Ozark physiographic province in Arkansas (Fig. 4).

Relationships and evolution.—From a morphological standpoint, the most obvious differences separating *Lirceus fousheensis* from *L. bicuspidatus* are troglomorphisms, notably the pronounced depigmentation. Certain considerations

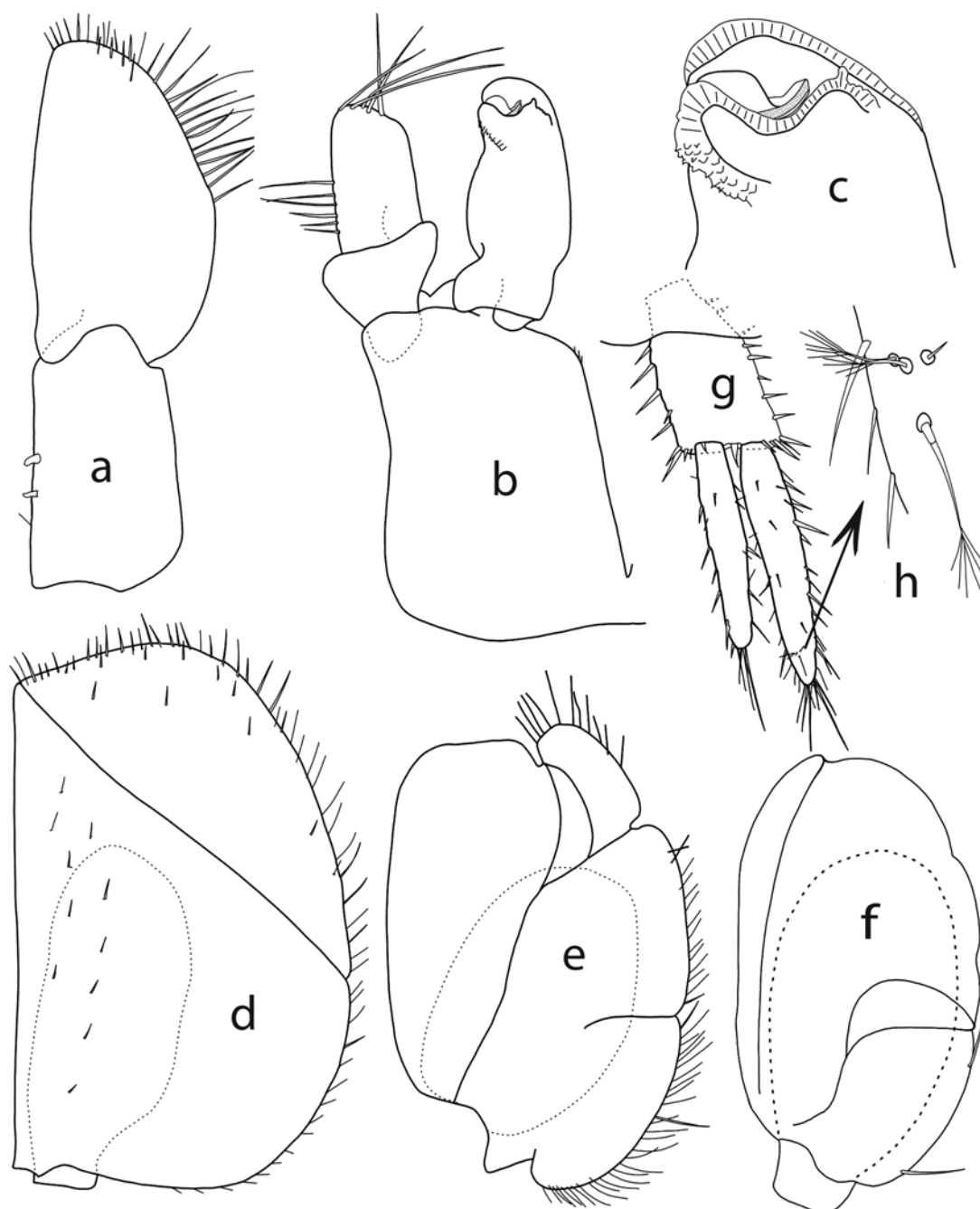


Figure 3. *Lirceus fousheensis*, n. sp., male paratype from Foushee Cave, Independence County, Arkansas: (a) pleopod 1, (b) pleopod 2, (c) same, endopodite tip, (d) pleopod 3, (e) pleopod 4, (f) pleopod 5, (g) uropod, and (h) uropod endopodite detail of row of plumose setae.

must be taken when using troglomorphisms for taxonomic separation of species. Among asellids of eastern North America, in species of the genus *Conasellus*, there is significant plasticity in the presence or absence of eyes and pigmentation. For example, the shallow groundwater species *Conasellus hobsoni* exhibits morphs that range from eyed and pigmented to eyeless and unpigmented, with no discernible genetic divergence nor other morphological differentiation (Lewis et al., 2023).

In contrast, seven troglomorphic species of *Lirceus* were reported by Lewis et al. (2023) and in each the presence of troglomorphisms was linked with speciation through independent means, e.g., other morphological differences and genetic sequencing. Likewise, changes in pigmentation were equally important among the epigean, spring-dwelling species of *Lirceus* in Virginia and Tennessee. The presence of changes in pigmentation patterns, including troglomorphisms, appears to be important as a taxonomic characteristic in *Lirceus*. This was first noted by Hubricht and Mackin

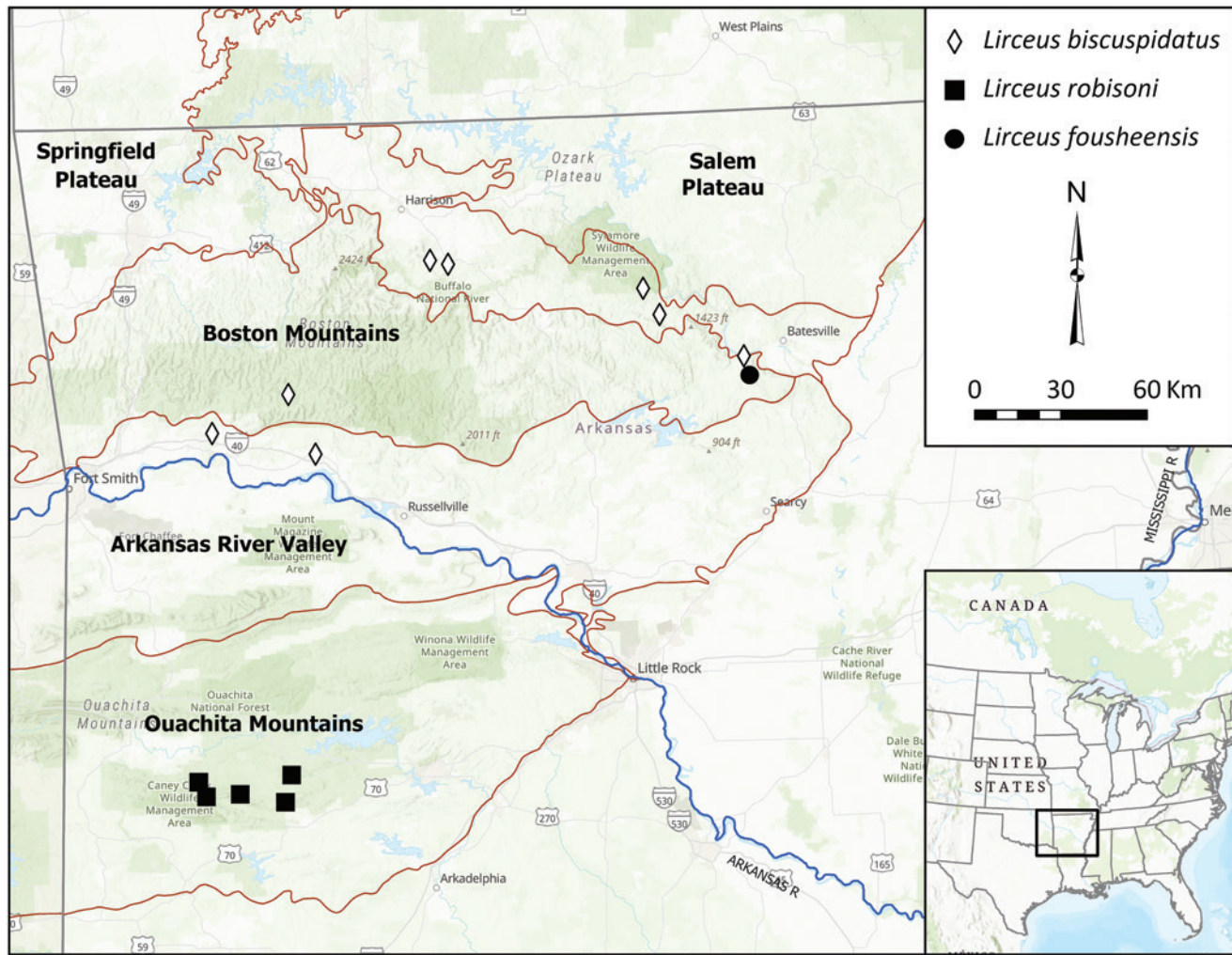


Figure 4. Distribution of species of the *Lirceus bicuspidatus* clade.

(1949), although their assessment that “the differences are difficult to describe and must be seen to be really understood” falls short of being helpful.

Lirceus fousheensis joins an assemblage of seven Appalachian species (Lewis et al., 2023), where a continuum of troglomorphisms is exhibited (Fig. 5). Of these, *Lirceus fousheensis* most closely resembles *L. bisetus*, a species endemic to Lane Cave, in Scott County, Virginia, in its degree of troglomorphy (Fig. 6).

Another morphological phenomenon associated with troglomorphic *Lirceus* species is paedomorphism, particularly in secondary sexual characteristics. This is seen most obviously in the propodus of the first pereopod, which in males of *Lirceus bicuspidatus* is bulbous and displays large, bicuspid processes along the palmar margin. In *Lirceus fousheensis*, the prominent processes are reduced to a single small subtriangular process.

From an ecological perspective, *Lirceus fousheensis* has undergone an adaptive shift from the epigeal ancestor inhabiting spring streams to those in Foushee Cave, which is now a reproducing population that is abundant in the dark zone of the cave. The presence of a presumed stygobiontic *Lirceus* in Foushee Cave is unique among the cave communities of the southern Ozarks, the result of an isolated cave invasion.

The speciation of *Lirceus fousheensis* may be in part attributable to its isolation in the karst of the eastern edge of the Springfield Plateau, where it is largely separated from other populations of *L. bicuspidatus* from which it was derived. This endemism is shared with the aquatic cavesnail *Amnicola cora*, another stygobiontic species known only from Foushee Cave.

Concerning molecular genetic analysis, we have sequence data of the mitochondrial 16S gene from nine samples of isopods of the *Lirceus bicuspidatus* clade. Five of these samples were provided through collections made by Dr. Henry Robison and were referable to populations of *Lirceus robisoni* in the Ouachita Mountains (Lewis and Lewis, 2023). The other four were collected from populations in the southern Ozarks: (1) Foushee Cave; (2) the spring stream below the

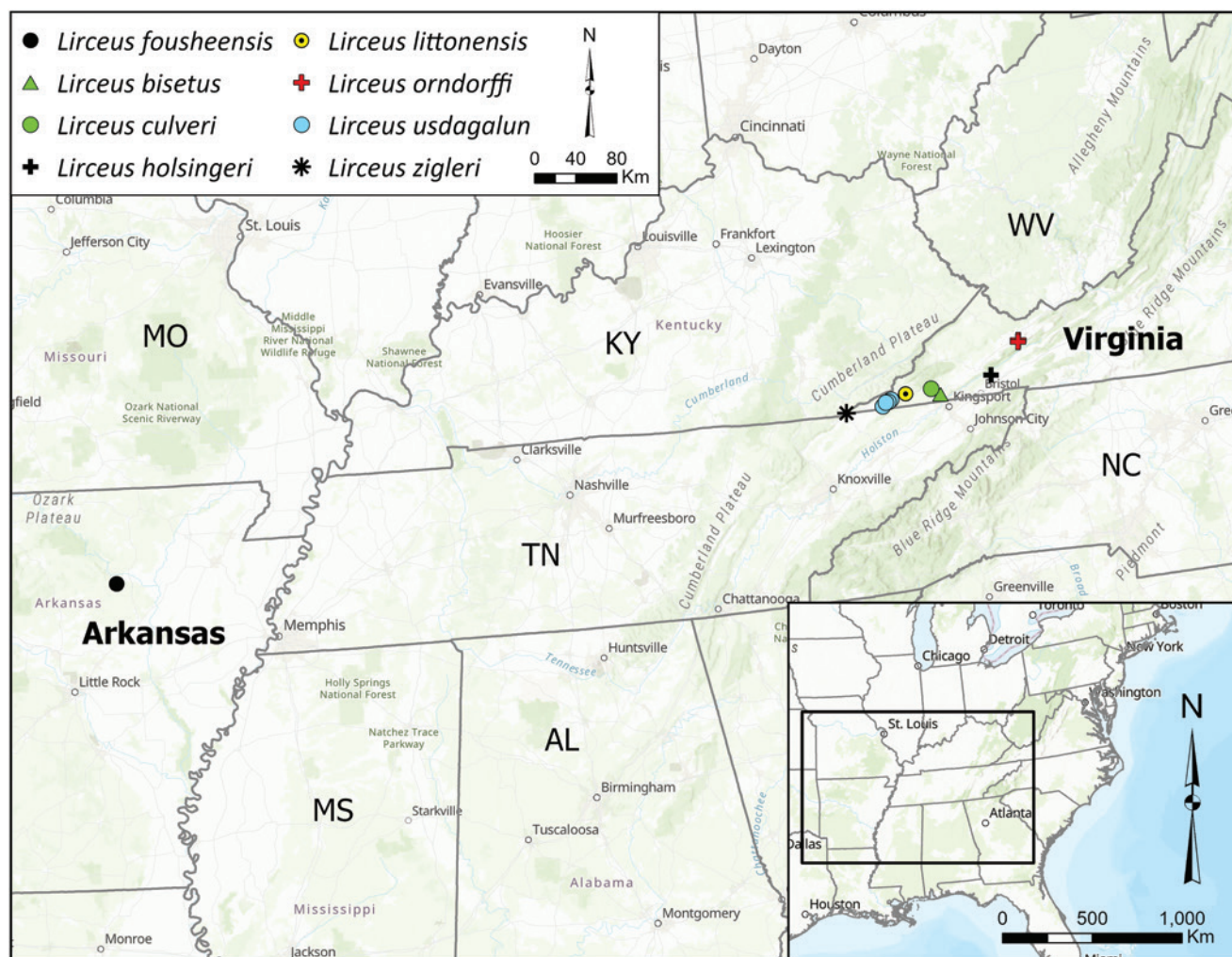


Figure 5. Distribution of troglomorphic *Lirceus* in the eastern United States.



Figure 6. Examples of pigmentation patterns and troglomorphy in isopods of the genus *Lirceus*, from left to right: *Lirceus bicuspidatus*, Johnson County, Arkansas; *Lirceus fousheensis*, Foushee Cave, Independence County, Arkansas; *Lirceus bisetus*, Scott County, Virginia; *Lirceus orndorffi*, Tazewell County, Virginia; and *Lirceus littonensis*, Lee County, Virginia.

entrance of Foushee Cave; (3) the type-locality of *Lirceus bicuspidatus* from a spring in Clarksville, Johnson County, Arkansas; and (4) a spring near Yardelle, Newton County, Arkansas. The sequence data are sparse, but the most significant result was that the troglomorphic isopods in Foushee Cave occur in a separate clade from the fully pigmented specimens taken from the spring stream flowing from the cave.

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