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Limnodrilus hoffmeisteri (ANNELIDA: OLIGOCHAETA: TUBIFICIDAE) IN POP'S CAVE, WISCONSIN, USA

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Aquatic oligochaete worms identified as Limnodrilus hoffmeisteri *were collected from rimstone pools in Pop's Cave, Richland County, Wisconsin, USA, in 1998. This represents the first record of aquatic oligochaetes from a cave in the state.*

Information on Wisconsin's caves and associated biological communities is limited at best. The karst in the southwestern part of the state – the Wisconsin Driftless Area – escaped the ravages of direct Pleistocene glaciation, but experienced the accompanying periglacial climate, which was followed by low mean annual temperatures in the Holocene. Cave air temperatures currently are about 10°C (Mueller & Day 1997). Moreover, the caves have been dismembered by valley incision, leaving them as ridgetop remnants without stream inputs (Day & Reeder 1989; Day *et al*. 1989). This combination of harsh Quaternary climatic conditions and restricted nutrient inputs has rendered Wisconsin's cave fauna impoverished. Barden (1980) described Wisconsin's caves as "…relatively lifeless", although they do provide habitats for various troglophiles, including insects, arachnids, millipedes, as well as rodents, bats, and some larger overwintering mammals. We know from other papers (e.g., Peck & Christiansen 1990; Webb *et al*. 1993; Culver *et al*. 2000; Buhlmann 2001; Culver 2001; Culver *et al*. 2003) that caves commonly support several other groups of troglophiles.

Despite their anonymity, the over 200 caves in southwestern Wisconsin are of scientific interest (Day 1986a,b,c). They are integrated into the regional karst hydrologic system (Reeder 1992; Reeder & Day 1993), and they provide evidence about former surface environments (Day 1988; Oh & Day 1990, 1991; Oh *et al*. 1991, 1993).

The presence of aquatic oligochaetes in Pop's Cave was first discovered by Hope and Jeff Swayne during a visit to the cave in June 1997 as part of a University of Wisconsin-Milwaukee Geography Department fieldwork course. The oligochaetes, estimated at 650 individuals in this population, were observed protruding from accumulated sediment in a series of small pools located about 60 m into the cave. These pools, each approximately 10 cm in depth, were impounded by rimstone (tufa) dams, and ranged in size from 20 to 50 cm in width and 0.5 to 2 m in length.

SITE DESCRIPTION

Pop's Cave, also known as Big Bear Cave, is located in Richland County, Wisconsin, 20 km west-northwest of the county seat of Richland Center. It is similar to other caves in southwestern Wisconsin, although it is consistently wetter than most, contains extensive breakdown, and lacks (in most sections) the ubiquitous, viscous red-brown silt and clay that characterizes other caves in the Wisconsin Driftless Area. Located on a ridge top south of and about 80 m above the valley of the West Branch of Mill Creek, the cave is developed in the Oneota member of the Lower Ordovician Prairie du Chien Group of carbonates (Paull & Paull 1977; Wisconsin Geological and Natural History Survey 1970) and is approximately 196 m in surveyed length, with main passages trending approximately north-south or northwest-southeast (Olmstead & Borman 1968). The elevation of the cave entrance is approximately 326 m a.m.s.l.; maximum depth of the cave is about 12 m.

The development of Pop's Cave was outlined by Olmstead and Borman (1968, 1980), who interpreted it as being of phreatic origin, with two main passage levels that were later connected through vadose collapse. Only the lowest, southwest section of the cave was infilled with sediment; elsewhere the breakdown deposits are being modified by calcite deposition, notably in the form of rimstone dams.

The cave is one of southwestern Wisconsin's most heavily visited; entries in the cave visitor registration book document at least 3000 visitors to the cave annually. Land use overlying and adjacent to the cave has three distinct components. The area above the northern third of the cave is wooded and is part of a Richland County scientific area. The land overlying the remainder of the cave was formerly in agricultural use, but has been enrolled in Wisconsin's Conservation Reserve Program for the past decade, and is now ungrazed grassland with encroaching trees and shrubs. By contrast, a 20-year old unof-

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ficial garbage dump, littered with discarded appliances, abandoned vehicles, and decaying household refuse, is located immediately south of the cave. Organic contamination from this dump may provide nutrition to the oligochaetes via vadose seepage into the cave.

METHODS

Aquatic oligochaetes were collected from Pop's Cave by Hope and Jeff Swayne on 1 July 1998. Specimens and associated sediments were obtained from small rimstone pools using a kitchen ladle. Specimens were then isolated from the sediment by straining the water and sediment through a cotton cloth, and fixed in 10% formalin solution. After fixation for at least 24 hours, samples were rinsed in tap water, and transferred to 70% ethanol.

The specimens were permanently mounted on microscope slides and identified using compound microscopes equipped with phase and Nomarski differential interference contrast optics. Identifications followed Kathman and Brinkhurst (1998). Most of the specimens collected during this study are deposited in the INHS Annelida Collection in Champaign; several voucher specimens have been retained by the senior author.

RESULTS

Of the 112 oligochaete specimens collected, only 21 were sexually mature, all identified as *Limnodrilus hoffmeisteri* Claparède, 1862 (Oligochaeta: Tubificidae); no other tubificid species or representatives of other families of aquatic oligochaetes were collected. All immature specimens (n=91) were determined to be unidentifiable immature tubificids without capilliform chaetae.

DISCUSSION

Tubificids are a major component of the benthos in most freshwater environments, and are often abundant in polluted areas (Brinkhurst 1980; Brinkhurst & Cook 1974). They feed by ingesting sediment–anterior end buried in the sediment, posterior end protruding out of thin tubes of fine organic and inorganic material into the sediment-water interface. While feeding in a near-continuous, conveyor-like fashion, nutrition is extracted from the bacteria and organic matter associated with the sediments, and from their own fecal pellets that settle to the sediment-water interface (Brinkhurst 1974; Brinkhurst & Gelder 2001).

Limnodrilus hoffmeisteri, a cosmopolitan species occurring in a wide variety of surface water habitats, is perhaps the most ubiquitous and commonly collected freshwater tubificid worldwide. Both *L. hoffmeisteri* and *Tubifex tubifex* can be indicators of organic pollution and low levels of dissolved oxygen (Brinkhurst & Gelder 2001; Chapman & Brinkhurst 1984; Lauritsen *et al*. 1985), when they reach very high abundance (Brinkhurst 1975; 1996). However, each of these species also has been associated with clean water benthic assemblages (Brinkhurst 1974).

Although this is the first published record of *L. hoffmeisteri* from a cave in Wisconsin, it has been reported from inland surface waters elsewhere in the state (Howmiller 1974, 1977; Howmiller & Loden 1976), in Illinois (Wetzel 1992), and is widespread throughout the Great Lakes (Spencer & Hudson 2003) and elsewhere in North America (Kathman & Brinkhurst 1998).

The presence of *Limnodrilus hoffmeisteri* and other oligochaete species in caves, springs, and groundwater habitats elsewhere in North America recently was reviewed in Wetzel & Taylor (2001), although only a few papers included species-level identifications of aquatic annelids among the often-extensive lists of reported taxa. In their limited surveys of eight caves in Illinois and Missouri, all associated with loess-covered karst terranes developed in Ordovician and Mississippian age bedrock (Panno *et al*. 1999), Wetzel and Taylor (2001) reported 15 taxa representing nine genera in five families. The abundance of new records reported by Wetzel and Taylor (2001) emphasizes the paucity of available information on aquatic Oligochaeta in North American caves; one and 10 species they collected were new records for the states of Illinois and Missouri, and several had never been reported from caves prior to their study.

We believe that tubificids and other aquatic oligochaetes are likely present, at least temporarily, in caves and other subterranean habitats elsewhere in the state into which surface and groundwater flows and accumulates, and where there are discrete connections between surface and underground streams.

Collecting techniques specifically designed for aquatic oligochaetes and other small invertebrates, in consultation with biologists who have taxonomic expertise with these groups, undoubtedly will result in the documentation of many new records for taxa from caves and associated groundwater habitats.

Culver *et al*. (2000) noted that under-representation of groups such as the aquatic oligochaetes in published accounts might alter our understanding of the taxonomic pattern of cave biodiversity in the United States. We therefore encourage use of appropriate collecting techniques for – and species-level identifications of – aquatic oligochaetes and other annelids in ecological studies of cave environments because they may comprise a significant and prevalent component of aquatic cave communities. The results of our preliminary research in Pop's Cave support continued study of Wisconsin's cave fauna – to determine if other oligochaete species are present in the caves, and to assess the status, distribution, and diversity of all aquatic invertebrates associated with or restricted to cave habitats.

The presence of *L. hoffmeisteri* in Pop's Cave suggests that the local cave and karst environment may reflect organic enrichment associated with fecal contamination such as that observed by Taylor *et al*. (2000) in their analyses of bacterial

fauna and water, sediment, and amphipod tissue chemistry of caves in the karst region of southwestern Illinois. Patterns of contamination arising from local agricultural activities deepen this concern (Day & Reeder 1989; Reeder 1992; Reeder & Day 1993), as does the widespread detection of regional groundwater contamination (Kammerer 1981).

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