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Secondary Predation on the Horsehair Worm *Gordius Robustus* (Nematomorpha: Gordiida)

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SECONDARY PREDATION ON THE HORSEHAIR WORM *GORDIUS ROBUSTUS* (NEMATOMORPHA: GORDIIDA)

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ABSTRACT

The gut contents of a brown trout (*Salmo trutta*) included horsehair worms (*Gordius robustus,* Nematomorpha: Gordiida) emerging from a camel cricket (*Ceuthophilus* sp., Orthoptera: Gryllacrididae). This provides more evidence of secondary ingestion than most previous reports of predation on horsehair worms, but it also illustrates the difficulty of distinguishing in practice between direct and secondary predation.

The term "secondary ingestion" has been used when food items in a predator's gut were not eaten directly by that predator but were consumed instead by one of its prey (e.g., Neill and Allen 1956). The same term may be appropriately applied to parasites in the gut of a predator that are released from the body of one of its prey, at least when those parasites do not survive the digestive process.

The life cycles of horsehair worms (Phylum Nematomorpha) include a juvenile stage parasitic within terrestrial insects and a free-living aquatic adult stage (Poinar 2001, Hanelt and Janovy, Jr. 2003). In at least some species, terrestrial hosts infected by maturing horsehair worms are more likely than uninfected individuals to enter water (Thomas et al. 2002). The slow-moving adult worms do not feed and sometimes are found in clumps of from several to many individuals (Cochran et al. 2004).

Predation on horsehair worms was reviewed by Cochran et al. (1999). Subsequently, Poinar (2001) reported that an adult *Gordius* was brought to nestlings by a bird in Chile. Kinziger et al. (2002) provided additional accounts of predation in Minnesota and Missouri but overlooked an earlier mention of an unidentified horsehair worm in the gut of a hellbender (*Cryptobranchus alleganiensis*) from the latter state (Peterson et al. 1989). Schmidt-Rhaesa et al. (2003) and Martin and Cochran (2005) reported additional cases of horsehair worms recovered among the gut contents of trout.

Most previously reported cases of predation on horsehair worms involved fish, and most were interpreted to have resulted from fish having preyed directly upon free-living adult worms. However, Cochran et al. (1999) observed that many fish tested in laboratory trials rejected adult horsehair worms, and they recognized the possibility that at least some horsehair worms found among the gut contents of fish may have been ingested secondarily (i.e., before having emerged from their invertebrate hosts). Ponton et al. (2006) staged secondary predation in the laboratory by generalist predators (fishes and ranid frogs) consuming crickets infected by horsehair worms. Depending on the predator, 18-35% of the worms were able to escape by wriggling out through the predator's mouth, nose, or gills, but most of them were presumably digested.

There is some evidence for secondary predation on horsehair worms in the field. Bolek's (2000) report of a dog regurgitating a *Gordius robustus* suggests the possibility that it had eaten an insect containing the worm. Bolek and Coggins

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(2002) found *G. difficilis* within carabid beetles among the gut contents of two green frogs (*Rana clamitans*). The purpose of this note is to describe another apparent case of secondary predation on a horsehair worm.

On 31 August 2006, at approximately 20:00, I collected a brown trout (*Salmo trutta*) by angling in Gilmore Creek below the spillway at the south end of the Saint Mary's University Campus in Winona, Winona County, Minnesota. The trout measured 32 cm in total length. In addition to fragments of a dragonfly nymph, the trout contained in its stomach a partially digested camel cricket (Orthoptera: Gryllacrididae: *Ceuthophilus* sp.), from which a living male horsehair worm (*Gordius robustus* Leidy) had partially emerged. Two female *G. robustus* extended from the stomach into the intestine, which also contained snails. At some point after the gut contents of the trout were initially examined and preserved in ethanol, a second male *G. robustus* partially emerged from the camel cricket. The camel cricket and *G. robustus* have been placed in the Milwaukee Public Museum invertebrate collection.

The gut contents described above are consistent with a scenario by which the trout consumed the camel cricket just prior to the emergence of the male *G. robustus*. It is also possible that the female worms emerged from the same cricket. Thomas et al. (2002) determined that 5 of 41 crickets infected by *Paragordius tricuspidatus* contained more than one worm. Hanelt and Janovy, Jr. (2004) observed in a laboratory study the successful maturation of multiple *P. varius* within individual crickets. They did not indicate whether these worms were smaller than single worms that matured within separate hosts, but the female worms in the present study were notably short (120 and 123 mm).

Although direct and secondary predation would seem to be mutually exclusive events, an intermediate scenario is possible. A predator might consume both horsehair worm and its insect host during the time that the worm is emerging, as observed in the laboratory by Ponton et al. (2006). Indeed, the emergence itself might draw the attention of the predator, and natural selection might therefore favor rapid emergence and separation from the host. Hanelt and Janovy, Jr. (2004) reported that *P. varius* in laboratory studies began emerging from their hosts within two seconds of the hosts being placed in water and that most worms had exited completely within 90 seconds. However, they also stated that worms formed mating aggregations even while emerging from hosts. Thomas et al. (2002) stated that emergence from a host could be immediate or could take several minutes after the host entered the water, and Ponton et al. (2006) stated that emergence may take as long as 10 minutes.

Neill and Allen (1956) discussed the difficulty of interpreting items that are resistant to digestion and that persist for relatively long times in digestive tracts. For example, vertebrate prey may be digested much more quickly than the invertebrates they themselves have consumed, and it might be wrongly concluded that the invertebrates were preyed upon directly. In the case of insect hosts containing horsehair worms, differences in digestibility are possibly not as extreme, and it might be less likely to find secondarily ingested horsehair worms in the absence of at least some remains of their invertebrate hosts. However, given recent advances in the culture of horsehair worms in captivity (Hanelt and Janovy, Jr. 2004), it would be desirable to test this possibility via laboratory experiments.

Gordius robustus has not been previously reported to parasitize camel crickets but has been reported from other orthopterans (Schmidt-Rhaesa et al. 2003). The camel cricket *Ceuthophilus stygius* is parasitized by *Chordodes morgani* in Kentucky (Studier et al. 1991).

Although *Gordius robustus* has been reported recently at several locations in Minnesota (Martin and Cochran 2005), this is the first collection from Gilmore Creek. An earlier report of *G. robustus* from Gilmore Creek (Cochran

et al. 1999) was revised to *G. difficilis* by Cochran et al. (2004), and Martin and Cochran (2005) found the latter species to be more common in cold spring-fed streams in southeast Minnesota. Indeed, on 30 June 2006, while angling in the same pool where the trout containing the *G. robustus* was collected during the present study, I collected two separate *G. difficilis* that became entangled in the treble hook of my lure while it was being retrieved. Moreover, Martin and Cochran (2005) listed several prior collections of *G. difficilis* among the gut contents of brown trout collected in Gilmore Creek. Two of the trout were captured in the same pool as the trout that contained a *G. robustus* during the present study (19 July 2003 and 18 June 2004). The two *Gordius* species can be distinguished by differences in diameter, color, and, in males, the presence or absence of a parabolic fringe of hairlike processes anterior to the cloaca (Bolek and Coggins 2002, Martin and Cochran 2005).

Additional specimens of *G. robustus* were collected farther downstream on the Saint Mary's University campus on 22 September 2006 and 30 October 2007. The worm collected on the latter date, an adult female, was of special interest because it was found moving in a terrestrial environment, a steep shaded bank approximately 1 meter above the waterline. No host was evident in the immediate vicinity.

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