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New Records of Hair Follicle Mites (Demodecidae) from North American Cervidae

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ABSTRACT: Individuals of three species of cervids, with varying degrees of alopecia, were examined for ectoparasites: Rocky Mountain elk (*Cervus elaphus nelsoni*) and mule deer (*Odocoileus hemionus hemionus*) in Colorado and white-tailed deer (*Odocoileus virginianus*) in South Dakota. Hair follicle mites were recovered and identified as *Demodex kutzeri*, a species originally described from the European red deer (*Cervus elaphus*, from Austria) and the sika deer (*Cervus nippon pseudaxis*, captive in Germany). These findings expand the geographic range of *D. kutzeri* to North America and extend its host range to include the genus *Odocoileus*. Thus, the host range for *D. kutzeri* spans two subfamilies of cervids. Additionally, *D. kutzeri* was identified in material from a white-tailed deer collected in South Carolina in 1971, indicating this parasite has been present, but unrecognized, on US cervids for some time.

Key words: *Cervus elaphus*, *Demodex kutzeri*, *Demodex odocoilei*, ectoparasites, host specificity, *Odocoileus hemionus*, *Odocoileus virginianus*, synhospitalic.

The hair follicle mites of the genus *Demodex*, first described from humans (Simon, 1842), are now known to infest host species in three of seven marsupial orders and in 11 of 18 eutherian orders. This range of host orders encompasses 97% of all living mammalian species. Currently, 88 species of *Demodex* have been described from 83 host species, with over half the mite species from just two host orders, the rodents (28 mite species from 29 host species) and the chiropterans (17 mite species from 13 host species). This widespread occurrence of *Demodex* throughout the class Mammalia, and their specialization for inhabiting the host's pilosebaceous complex, most likely indicates that these mites co-evolved with the hair follicle (Nutting, 1985; Bukva, 1991). Thus, their association with mammals is an ancient one, and the genus *Demodex* is most likely a monophyletic group.

Demodectic mites are highly specialized for their microhabitat, the hair follicle complex; this specialization includes miniaturization and an extreme reduction of legs and setation. Most adult *Demodex* are cigar-shaped and 100–300 μm long. Except for salivary glands, internal organs are unpaired. The adult legs are reduced to three short, movable segments, and the largest setae, the supracoxal spines, typically are only 2–3 μm long. These reductions result in a paucity of characters suitable for taxonomy.

Until the 1980s, all described *Demodex* species were from taxonomically disparate hosts, with each mite species being morphologically distinct; thus, it was presumed that the hair follicle mites were host-species specific. Over the past 25 yr, this strict host specificity has been challenged by the discovery of instances of a (morpho) species of *Demodex* on multiple host species. These examples include *Demodex sabani*, hosted by seven species of Malaysian rats in five genera (Desch et al., 1984); *Demodex nanus* from the brown rat, *Rattus norvegicus* and the black rat, *Rattus rattus* (Desch, 1987); and *Demodex kutzeri* from the European red deer, *Cervus elaphus* and the sika deer, *Cervus nippon pseudaxis* (Bukva, 1987).

Thorough ectoparasite surveys of mam-

mals reveal that many host species harbor two or three species of *Demodex*. In every such instance, these synhospitalic *Demodex* species (Eichler, 1966 and modified by Nutting, 1985) are morphologically distinct. The synhospitalic species occupy different microhabitats on the skin (e.g., on the domestic cat, *Felis catus*, *Demodex cati* resides in the hair follicles and *Demodex gatoi* in the epidermal pits; Desch and Stewart, 1999); on the pteropodid blossom-bat, *Macroglossus minimus*, from Australia, *Demodex macroglossi* inhabits the hair follicles (Desch, 1981) and *Demodex bicaudatus* is restricted to the meibomian glands (Kniest and Lukoschus, 1981). Triads of synhospitalic species of *Demodex* are known from cattle, *Bos taurus* (Bukva, 1986), European red deer (Bukva and Preisler, 1988), sheep, *Ovis aries* (Bukva, 1990a), and the domestic cat (Desch and Stewart, 1999). The brown rat hosts a tetrad of synhospitalic *Demodex* (Bukva, 1995).

Demodex odocoilei from the white-tailed deer, *Odocoileus virginianus*, was the first hair follicle mite described from a North American cervid and is associated with sporadic cases of mange in this host. Infested white-tailed deer have been reported from the southeastern and north-central United States (Desch and Nutting, 1974; Jacques et al., 2001; Turner and Cano, 2008). The known geographic and host distribution has expanded with the confirmation of *D. odocoilei* infesting Columbian black-tailed deer, *Odocoileus hemionus columbianus*, in eastern Oregon and Washington (Bildfell et al., 2004). Nymphal mites, morphologically compatible with *D. odocoilei*, were reported from a mule deer, *O. hemionus hemionus*, in Saskatchewan, Canada (Gentes et al., 2007).

Although *Demodex* have been known to infest a variety of Eurasian cervids for more than 120 yr, *D. kutzeri* is the only species from this region to be satisfactorily described in all life stages from a correctly and positively identified host (Bukva, 1987). *Demodex kutzeri* was described from European red deer from Austria and a captive sika deer in Berlin, Germany (Bukva, 1987). We document *D. kutzeri* (originally considered restricted to Eurasia) from three cervid species in North America.

Two hunter-harvested animals, one mule deer and one Rocky Mountain elk (*Cervus elaphus nelsoni*), from Colorado were acquired from the southwestern portion of the state. The game management units (GMU) from which they were harvested are given (Table 1); however, the precise location at which each animal was taken is unknown. The white-tailed deer was collected by personnel of the National Park Service in Wind Cave National Park, South Dakota (43°34′N, 103°29′W). Although the mule deer exhibited patchy alopecia, the elk was described as normal in appearance. The white-tailed deer was described as being in very poor condition and missing large patches of hair (Fig. 1). Further histories and diagnostic test results are presented in Table 1. In addition, mites collected from a hunter-harvested white-tailed deer in Orange County, South Carolina in 1971 were available for examination. Histologic techniques and procedures for examining mites were as described (Desch and Nutting, 1974; Jacques et al., 2001).

Mites from all four animals were identified as *D. kutzeri* (Fig. 2) and were the only species present in the Colorado and South Carolina cervids. This extends the range of *D. kutzeri* to North America and to the host genus *Odocoileus*. Given the previous examples of a single (morpho) species of *Demodex* infesting multiple, closely related host species, it is not surprising that *D. kutzeri* occurs on European red deer and Rocky Mountain elk. However, it is unexpected that *D. kutzeri* also parasitized *O. virginianus* and *O. hemionus*, in that these two host species are in different subfamilies.

The family Cervidae arose in the Late Miocene (7.7–9.6 mya) in central Asia and

TABLE 1. Pertinent history and diagnostic test results from three cervids harboring demodectic mites.[a]

	Mule deer	Elk	White-tailed deer
Origin	GMU 072[b]; Colorado, collected 29 October 2006	GMU 61[b]; Colorado, collected 6 November 2007	Wind Cave National Park, South Dakota; collected 9 April 2009
Sex and age	Mature male, age unknown	Yearling female	3-yr-old male
Body condition	Normal; occasional areas of alopecia	Normal	Emaciated; extensive alopecia of ventral abdomen, hindquarters
Chronic wasting disease	Not detected	Test not performed	Not detected
Skin: macroscopic	Generalized thickening of the skin with patchy alopecia and moist crusts; multiple, large nodules (~1 mm) present on cut section	Multiple, large (~2 mm) nodules present on cut section	Generalized alopecia, extending in front from shoulders to carpi, in hindquarters to hocks, and on ventral abdomen
Skin: microscopic	Markedly dilated follicular structures packed with mites; moderate, mixed inflammatory cell infiltrates encircling many affected follicles; abundant keratin debris and inflammatory crusts cover the epidermal surfaces; bacterial colonies in surface crusts but no fungal organisms detected in surface or follicular structures	Markedly dilated follicular structures packed with mites; mild lymphoplasmacytic infiltrate in connective tissue surrounding follicles; mild inflammatory changes present within overlying superficial dermis	Markedly dilated follicular structures packed with mites; mild inflammation—multinucleated giant cells, lymphocytes, and plasma cells and macrophages (or both)—encircling many affected follicles; mites occasionally present in dermis, surrounded by multinucleated giant cells, plasma cells, and lymphocytes
Other testing or comments	Not performed	Not performed	Extensive serous atrophy of fat; lymph nodes normal, not active; spleen normal; epizootic hemorrhagic disease serology: negative; parasites, external: *Dermacentor albipictus*; *Lipoptena depressa depressa*; parasites, internal: strongyles (31 eggs/gram)

[a] Hunter-killed white-tailed deer from South Carolina not included due to lack of available information.

[b] See http://wildlife.state.co.us/Hunting/GMUnitMaps.htm for Game Management Unit maps.

FIGURE 1. White-tailed deer from South Dakota exhibiting extensive alopecia of lateral thigh and ventral abdomen associated with hair follicle mites (*Demodex kutzeri*).

diverged there into major lineages (Gilbert et al., 2006). Based on the results of a study of mitochondrial and nuclear DNA from 25 cervid species, Gilbert et al. (2006) proposed a new classification of Cervidae with two subfamilies, Cervinae (including elk and red deer) and Capreolinae (including mule deer and white-tailed deer). The tribe Odocoleini, within the Capreolinae, arose in the Early Pliocene and migrated to North America 4.2–5.7 mya. Even though Cervinae and Capreolinae diverged in the Early Pliocene, both subfamilies are hosts for *D. kutzeri*. This likely indicates that the cervid pilosebaceous complex is a stable habitat with little selection pressure to bring about change in mite morphology, even though the mites on different host species are reproductively isolated. Because hair follicle mites are transferred between hosts by direct physical contact (mating, nursing, mutual grooming; see Bukva, 1990b), it is unlikely that interspecific host transfer accounts for the occurrence of *D. kutzeri* on multiple host species.

FIGURE 2. *Demodex kutzeri*, wet mount of follicular material from an elk. Bar=50 μm.

An alternative explanation for the presence of *D. kutzeri* on multiple host species could be that the mites in North America are not *D. kutzeri*, but are morphologically indistinguishable from *D. kutzeri*. Although possible, our current understanding of the species distribution of *Demodex* (based on morphologic criteria) and the concept of synhospitality leads to the identification of *D. kutzeri*.

In addition to *D. kutzeri*, the white-tailed deer from South Dakota also harbored *D. odocoilei*. Thus, *D. kutzeri* and *D. odocoilei* appear to be synhospitalic. It remains to be determined whether or not they occupy different microhabitats, as has been described for other synhospitalic species.

Lesions of demodicosis in cervids vary from mild to moderate alopecia, with or without associated inflammation (Fig. 3A),

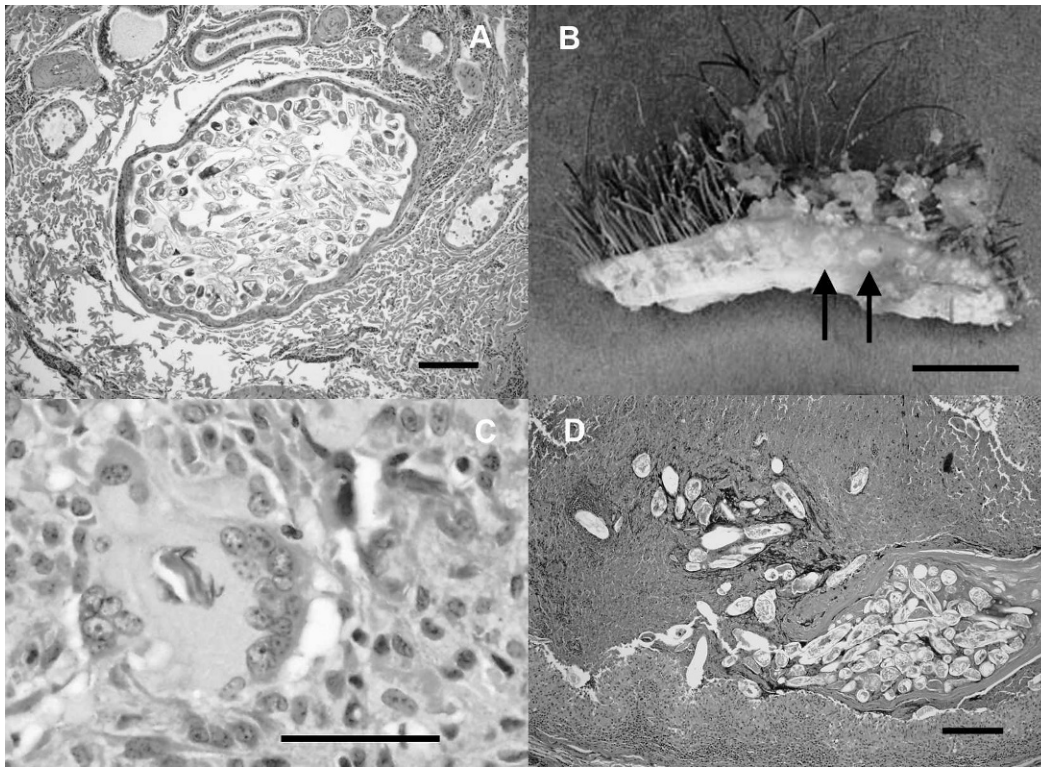

FIGURE 3. Gross and histologic features of demodicosis in cervids. (A) Follicle packed with mites and no associated inflammatory response (white-tailed deer). Bar=200 μm. (B) Cross-section of skin showing nodules (arrows) and surface crusts (mule deer). Bar=500 μm. (C) Mite fragment in dermis surrounded by multinucleated giant cell (white-tailed deer). Bar=50 μm. (D) Ruptured follicle releasing mites into dermis with mixed inflammatory response (white-tailed deer). Bar=200 μm.

to alopecia characterized by nodular dermatitis (Fig. 3B), purulent folliculitis, and mixed inflammation within the surrounding dermis (Fig. 3C). Variable numbers of mites are found in affected follicles. Inflamed follicles may rupture, releasing mites and inflammatory cells into the surrounding dermis (Fig. 3D), which may result in discrete pyogranulomas (Desch and Nutting, 1974; Bukva, 1987; Bildfell et al., 2004; Gentes et al., 2007). Nodular dermatitis tends to be associated with *D. kutzeri*, but not with *D. odocoilei* (Desch and Nutting, 1974; Bukva, 1987). The lesions in the mule deer and elk reported here are consistent with previous reports of *D. kutzeri*-associated nodular dermatitis, while the lesions in the white-tailed deer may reflect the mixed *D. kutzeri* and *D. odocoilei* infestation.

Clinical demodicosis is considered to be a secondary disorder in which the baseline parasite population expands as a result of poor host nutrition, immunosuppression, or concomitant disease (see Gentes et al., 2007). Other than the presence of mites, no other health issues could be identified in the mule deer or the elk (Table 1). Data were not available on the white-tailed deer from South Carolina. However, demodectic mites were not the only parasites present in the white-tailed deer from South Dakota. Ticks (*Dermacentor albipictus*), keds (*Lipoptena depressa depressa*), and strongylid nematodes were also present. Parasitism, combined with the nutritional challenges of winter, may have contributed to immunosuppression, resulting in overt demodicosis in this animal. Alternatively, the presence of

multiple ectoparasites (*Demodex* spp. and *Dermacentor albipictus*) capable of causing alopecia may have resulted in more-extensive hair loss than either parasite would have produced alone.

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