REVIEW OF DEER KED (*LIPOPTENA CERVI*) ON MOOSE IN SCANDINAVIA WITH IMPLICATIONS FOR NORTH AMERICA

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ABSTRACT: The deer ked (*Lipoptena cervi*) is an Old World dipteran ectoparasite of moose (*Alces alces*) and other Cervidae. It has undergone significant expansion in distribution on moose of Scandinavia in recent decades. This has been accompanied by much published research dealing with the range expansion and possible factors involved, problems for moose, exposure of northern populations of reindeer (*Rangifer rangifer tarandus*), and public health issues. Apparently, *Lipoptena cervi* was introduced into northeastern United States in the late 1800s, presumably on an unknown species of European deer, and it soon spread to white-tailed deer (*Odocoileus virginianus*). We review the current situation in Scandinavia and North America and document the first record of *L. cervi* on moose in northeastern United States.

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The deer ked, *Lipoptena cervi* (Insecta, Diptera, Hippoboscidae) is a widely distributed, blood-sucking, reddish-brown, dorsoventrally flattened ectoparasite that occurs on Old and New World members of the Cervidae. Notable hosts include red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), fallow deer (*Dama dama*), and especially moose (*Alces alces*) in Finland, Sweden, and Norway. *Lipoptena cervi* was described by Linnaeus (1758) as *Pediculus cervi*, probably basing his description on examination of published figures, not specimens (see Bequaert 1957, pp. 488-489). It is an ancient fly found associated with the remains of a Late Neolithic human mummy in an Italian glacier (Gothe and Schöl 1994).

Lipoptena cervi has undergone rapid and ongoing west and northward expansion of its distribution in Scandinavia in recent decades (Välimäki et al. 2010). This has been accompanied by emerging public health and conservation issues, mostly in Finland, including dermatitis on increasing numbers of rural people bitten by deer keds (Härkönen et al. 2009), exposure of northern reindeer (*Rangifer rangifer tarandus*) herds (Kaitala et al. 2009), as well as an epizootic of hair-loss and deaths of moose in southeastern Norway and mid-western Sweden in 2006 and 2007 (Madslien et al. 2011). The objectives of this paper are to briefly review current issues involving deer keds on moose in Scandinavia and to provide information about its occurrence in northeastern United States.

LIFE CYCLE

All species of deer keds, including *L. cervi*, are viviparous and produce one larva at a time. Winged young adults of *L. cervi* emerge from pupae on the ground from late summer through autumn. They do not fly far in seeking hosts, which in Scandinavia is usually moose. Wings of males and females are lost once on moose. Adults feed on blood and interstitial fluid, mating and overwintering on the host.

The developing larva is retained in the uterus of the adult female. Females extrude white mature larva, the prepupa, one at a time, from autumn until the next summer (Härkönen et al. 2010). The skin of prepupa fattens and hardens into a seed-like dark case as the prepupa transforms to the pupa and drops to the ground on vegetation or snow. Pupae remain on the ground until autumn (for details see Bequaert 1953, Haarløv 1964, and a life cycle diagram in Samuel and Madslien 2010).

STATUS IN SCANDINAVIA

Expanding distribution and consequences for hosts

Lipoptena cervi has expanded its distribution west- and northward in Scandinavia in recent decades (see distribution maps in Kaunisto et al. 2011 and Välimäki et al. 2010). Summarizing this expansion, Välimäki et al. (2010) state that *L. cervi* "has been resident in Sweden for more than two centuries, whereas in Finland (~50 years) and Norway (~30 years) it has established itself relatively recently." There are two fronts of ked expansion: one that began in 1960 in southernmost Finland (59-60^{o} N) with source keds from Russia, and one that began on or perhaps slightly before 1983 in southeastern Norway (~59^{o} N) with source keds from Sweden. By the end of 2008, deer keds in Norway had spread from the first known source south and east of Oslo and the Oslo Fiord (~59 ^{o} N), west and north at ~7 km/yr. Northward expansion along the border of Sweden and Norway reached ~62^{o} N by end of 2008. Northern expansion in Sweden is less well documented, but has been relatively slow. In the early 1960s keds were as far north as 59^{o}, ~420 km from the southern tip of Sweden, and by 2008 keds were found as far north as ~62.5^{o}. Northern expansion in Finland has been more rapid, spreading at a rate of 11 km/yr, and now is close to the Arctic Circle (~66^{o} N) where it overlaps with the southern edge of reindeer herding areas (Kaitala et al. 2009). Thus, deer keds currently occupy a small part of Norway near and north of Oslo, the southern half of Sweden, and approximately the southern 75% of Finland.

There has been progress in identifying factors involved in the expansion of *L. cervi* distribution. Changes in moose numbers and climate are likely key factors. Numbers of moose began to increase rapidly in Norway, Sweden, and Finland in the 1960s, owing to increased clear-cutting practices by the forest industries and changes in management strategies to sex and age-specific harvests (Lavsund et al. 2003). Lavsund et al. (2003) documented that harvest of moose, which likely reflects population density, was highest in the early 1980s (Sweden and Finland), again in Finland in the late 1990s and early 2000s (also see Selby et al. 2005), and in the 1990s in Norway (also see Lykke 2005). In 2003, moose densities in all 3 countries "were lower in the north than in the south and higher in Norway and Sweden than in Finland" (Lavsund et al. 2003). The 2008 moose population in Finland stabilized at 90,000 (Pusenius et al. 2008, in Kaitala et al. 2009). Kaitala et al. (2009) suggested that increase in moose densities in Finland has been the main reason why deer keds have been able to expand their range and increase in numbers. Välimäki et al. (2010) point out that there was little or no range expansion of *L. cervi* in Fennoscandia when densities of moose were relatively low.

Northern range expansion of *L. cervi* should be limited by colder temperatures and shorter growth season that would most affect off-host life stages, because it is the pupae on the ground and recently emerged young winged adults, not adult keds on moose, that are exposed to changing and potentially adverse northern environmental conditions (Härkönen et al. 2010, Välimäki et al. 2010). Härkönen n et al. (2010) studied development of pupae and timing of adult emergence along a latitudinal gradient from boreal taiga in central Finland to Arctic tundra in northern

Finland, and found success of pupae emerging to young adults was higher (19% emerged at the southernmost site at 62° N) and earlier in the south and much lower (<2% emerged at the high Arctic site at 70° N) and later in the far north. However, a few pupae emerged in the high Arctic, nearly 500 km north of its current northern range. Thus, at 70° N, fewer young winged adults had less time before winter to find a host, but the results from 5 sites at different latitudes suggest that "spread of deer keds to cervids in the southern parts of the reindeer herding area seems inevitable." This indicates that *L. cervi* has broad ecological tolerances (Kaunisto et al. 2011) and suggests that the colder and shorter growing season in the north may slow, but not stop the northern spread of deer keds.

Moose are numerous in southern parts of Finnish Lapland (Pusenius et al. 2008, in Kaitala et al. 2009) and are considered the main host for deer keds (Kaitala et al. 2009). Thus, it is likely that reindeer will be attacked by adult flies; in addition, they are a suitable host. Kynkäänniemi et al. (2010) experimentally infested reindeer with *L. cervi*, and a few keds survived and reproduced. Kaunisto et al. (2009) found that deer keds occasionally infest semi-domesticated reindeer and wild Finnish forest reindeer, *R. t. fennicus*. Bequaert (1957) reported that reindeer introduced to Scotland from Lapland became "heavily infested with *L. cervi*" shortly after their arrival.

Keds can be numerous on moose and they might be associated with mortality of moose. Madslien et al. (2011) found up to 16,500 keds on moose during an outbreak of ked-caused hairloss in moose in eastern Norway and mid-western Sweden, 2006-2007. These numbers were considered conservative because keds prefer hair-covered skin and many moose had severe alopecia. During the outbreak over 100 moose were observed; most with severe loss of hair and varying degrees of emaciation, and some with atypical behaviour (e.g., in farm buildings, unresponsive to humans). Some were found dead and others in obvious severe distress were humanely killed. Madslien et al. (2011) felt the main cause of the outbreak, high numbers of deer keds, was in response to extremely high summer and autumn temperatures in 2006, providing good development and survival of pupae. In Finland, numbers of keds averaged 10,616, 3,549, and 1,730 on bulls, cows and calves, respectively, with full coats of hair (n = 23) (Paakkonen et al. 2010).

Public Health Issues

Newly emerging young adult keds attack humans as well as ruminants, especially in Finland. Keds do not reproduce on humans, but infestation is a nuisance for rural people such as hunters, berry pickers, and forestry workers (Härkönen et al. 2009, Kortet et al. 2009). Apparently it is not the ked bite that is the problem, but rather the inconvenience of removing "dozens of keds from hair and clothes." More serious health issues have emerged and increasing numbers of people in Finland suffer from chronic dermatitis and occupational allergic rhinoconjunctivitis following bites by deer keds. It is estimated that several thousand people have ked-caused dermatitis and growing numbers of forest workers have become sensitized to ked bite.

A recent twist has been added to this subject. Several of the many newly-described species in the bacterial genus *Bartonella* cause diseases in humans (Jacomo et al. 2002, Chomel et al. 2009). *Bartonella henselae*, for example, was identified in 1990 and is now known to cause several clinical diseases including cat scratch disease. It is transmitted from cats to humans by the bite of an infected cat flea or by a cat bite or scratch. Dehio et al. (2004) found that *L. cervi* collected from roe and red deer in Germany were infected with *Bartonella schoenbuchensi*. The twist is that Dehio et al. (2004) noticed that clinical signs and other aspects of cat scratch disease were similar to that of dermatitis in humans caused by the bite of *L. cervi* and suggested that bartonellae are "pathogens that should be considered possible etiological agents of deer ked dermatitis."

STATUS IN NORTHEASTERN UNITED STATES

Apparently in the late 1800s *L. cervi* was introduced to northeastern United States on an unknown deer transported from Europe, and later established on white-tailed deer (Bequaert 1953[1]). Summarizing records from Bequaert (1937, 1942, and 1957), *L. cervi* was collected from white-tailed deer in New Hampshire (Grafton County in 1907, Sullivan County in 1950) and a captive wapiti (*Cervus canadensis*) in Sullivan County in 1942. It was collected from white-tailed deer in New York (Albany, Cattaraugus, and Hamilton Counties in 1938, 1949 and 1954, respectively), Massachusetts (Dukes County in 1924), and Pennsylvania (Pike and Clinton Counties, no date; McKean and Cameron Counties in 1953). Keds also were reported as being common on wapiti in Cameron County, Pennsylvania. Other reports of *L. cervi* in the United States are from white-tailed deer in New York (Bump 1941), West Virginia (Kellogg et al. 1971), and Worcester County, Massachusetts (Matsumoto et al. 2008).

Given the above, *L. cervi* is probably more prevalent on white-tailed deer and moose of the northeastern United States than currently known or assumed. If *L. cervi* survived on wapiti sympatric with white-tailed deer in central Pennsylvania (Bequaert 1957), it should presumably occur on moose sympatric with white-tailed deer. Exact numbers of keds on these hosts are unknown. Anecdotally, Bequaert (1957) mentioned a heavily infested white-tailed deer from Sullivan County, New Hampshire in 1950, and one of us (Samuel)[2] saw many keds on an old male white-tailed deer killed in McKean County, Pennsylvania by his father around 1950 (Samuel and Madslien 2010). Matsumoto et al. (2008) found only 6 keds on 4 of 27 white-tailed deer in Worcester County, Massachusetts.

More recently, keds were collected opportunistically from several moose and white-tailed deer at hunter check stations by one of us (Gonynor-McGuire) in 2007 and 2008. In October 2007, Gonynor-McGuire thoroughly examined harvested moose for ticks and keds in New Hampshire; examinations were 5-10 minutes in length. Several dozen keds were collected and tentatively identified as *L. cervi*, but were subsequently lost. In October 2008 in cooperation with New Hampshire Fish and Game Department personnel (K. Rines and K. Gustafson), Gonynor-McGuire supplied kits for collecting keds at harvest check stations. Fourteen keds were collected from 11 white-tailed deer at stations in Cheshire, Coos, Grafton, and Sullivan Counties, and 1 ked from each of 2 moose from stations in Coos and Grafton Counties. Keds from both species of host were identified by Samuel using keys and descriptions of Bequaert (1937, 1957), and were subsequently compared with *L. cervi* from moose in Norway. The keds from the 2 moose from New Hampshire were deposited in the University of Alberta Parasite Collection;

[1]In what we think is the only discussion of this introduction, Bequaert (1953) states "This parasite was, in my opinion, brought from the Old World by Man with European Deer. From this host it strayed to the native Virginia deer, *Odocoileus virginianus*, on which it now breeds at several localities in the northeastern United States......The exact date of the introduction is unknown; it was first recognized in the United States in 1907, when it was described as a new species by Coquillet (*L. subulata*) [later changed to *L. cervi*]. If it were truly native, or autochthonous, it would be found over a much wider territory and be more abundant; while its presence on native deer could scarcely have escaped the early American entomologists."

[2]Hunters in northeastern United States must occasionally see keds on their killed deer, maybe their moose. Obviously my father did, but he thought they were ticks. Hunters mistaking keds for ticks is mentioned on fact sheets for this parasite on the internet (e.g., http://ento.psu.edu/extension/factsheets/deer-keds). In 2007, many hunters at a New Hampshire deer check station near Berlin, NH said they thought keds were ticks (Gonynor-McGuire, personal observation).

accession numbers UAPC #11566 and #11572. Several keds from each of 2 moose from the Madslien et al. (2011) study in Norway were also deposited: UAPC #11563 and #11564. Keds from 6 white-tailed deer were deposited in the UAPC (#11565, #11567-11571), and from 4 white-tailed deer in the University of Alberta E. H. Strickland Entomological Museum (UASM213577-213580). This is the first report of this parasite from moose in North America.

Keds are observed annually on harvested moose and white-tailed deer in New Hampshire, with keds more common in recent years, but prevalence and numbers have not been monitored (K. Rines, pers. comm.). While studying winter ticks (*Dermacentor albipictus)* at the University of New Hampshire, D. Bergeron (pers. comm.) observed small numbers of keds on a few of the many moose he surveyed at 3 regional harvest check stations in northern New Hampshire, 2008-2010.

Surveys of moose and white-tailed deer for deer keds in various jurisdictions in the northeastern United States would be worthwhile, particularly if potential public health problems associated with *Bartonella* species and deer keds become a reality. Matsumoto et al. (2008) found DNA of *B. schoenbuchensis* in 5 of 6 keds from 4 white-tailed deer at 3 different locations in Worcester County, Massachusetts[3].

If check stations for deer and moose are part of surveys, the following information might be relevant. Madslien et al. (2011) examined fresh carcasses of moose in Sweden and Norway and found keds aggregated in neck, axillae, groin, and perineal regions. Keds were located on the skin surface, their head oriented towards the skin. As the carcass cooled, they crawled away from the skin and onto protective hairs. Samuel and Trainer (1972) examined a standardized area (medial surface of the hind leg and inguinal region) of white-tailed deer in southern Texas for *Lipoptena mazamae*. They found no significant migration of keds to or from the area during the 2 hours following death of deer. Dead deer were hung by the back legs, which were spread using a gambrel. After 2 hours, keds began moving to extremities such as the nose, ears, and lower legs. Given time constraints at hunter check stations, the technique used by Sine et al. (2009) for detecting winter ticks on moose might be useful for detecting deer keds.

[3]These authors raise the possibility that *B. schoenbuchensis* was possibly introduced to the Northeast with the original importation of ked-infested cervid(s).

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