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Ear Mange Mites (*Notoedres muris*) in Black and Norway Rats (*Rattus rattus* and *Rattus norvegicus*) from Inner-City Vancouver, Canada

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ABSTRACT: The ear mange mite, *Notoedres muris* (Astigmata: Sarcoptidae), is a parasitic burrowing mite of black and Norway rats (*Rattus rattus* and *Rattus norvegicus*), which causes a proliferative dermatitis primarily affecting the ears. We characterize the ecology of *N. muris* in a group of black and Norway rats trapped in an inner-city area of Vancouver, Canada. Rats ($n=725$) were trapped for 1 yr (September 2011–August 2012) in 43 city blocks (0.82 km^2) and one property (0.03 km^2) within an international shipping port at the northern border of the study area. Mite infestation was diagnosed in 15 of 32 rats (47%, 95% confidence interval [CI]=30.9–53.6%) trapped in a large indoor facility at the port property. No affected animals were identified outside this facility, either within the port property or in any of the blocks under study. There was a positive relationship between infestation and both weight and nose-to-rump length (proxies for age), suggesting transmission through intraspecific social contact within colonies. This is the first report of *N. muris* in Canada. The focal distribution of *N. muris* at the port may reflect an importation event.

Key words: Ecology, ear mange, *Notoedres muris*, *Rattus*, urban.

The ear mange mite, *Notoedres muris* (Megnin; Astigmata: Sarcoptidae), is a parasitic burrowing mite that infests a wide range of mammals, predominantly rodents (Baker 2007). The mite, which is transmitted primarily by direct contact between hosts, burrows into the superficial layers of the skin, inciting a pruritic and proliferative dermatitis. Areas most commonly affected are the sparsely-haired regions of the pinnae, face, tail, and legs (Baker 2007). The typical macroscopic lesions are crusting papilloma-like carbuncles on the ears, sometimes associated with pinnal deformity (Lavoipierre 1964; Baker 2007).

Infestation can occur in laboratory settings (Baker 2007), but ear mange is more often found in wild black and Norway rats (*Rattus rattus* and *Rattus norvegicus*; Lavopierre 1964). *N. muris* has been recovered from these species in several countries, including Australia (Domrow 1992), the US (Degiusti and Hartley 1965), South Africa (Zumpt 1961), Brazil (Lopes et al. 1992), and Belgium (Fain 1965). Within North America, the only published record of ear mange in rats is from Detroit, Michigan (Degiusti and Hartley 1965), although *N. muris* has also been found in California voles (*Microtus californicus*) in San Francisco (Lavoipierre 1964). We describe the presence and distribution of *N. muris* ear mange in an inner-city area of Vancouver, Canada. Rats were trapped in an inner-city area of Vancouver, Canada (49°15′0″N, 123°8′0″W) over 1 yr (September 2011–August 2012). The roughly rectangular study area included 43 city blocks (0.82 km^2) and one property (0.03 km^2) within an international shipping port, forming the northern border of the study area. Pairs of blocks were randomly allocated to 2-wk trapping periods over the year. For each block, 15–20 Tomahawk live rat traps (Tomahawk Live $Trap_{llc}$, Hazlelhurst, Wisconsin, USA) were placed in alleyways. At the port site, 56 traps were placed in eight locations, including indoor and outdoor areas where site employees had seen rats. Trapped rats underwent isoflurane anesthesia and intracardiac pentobarbital euthanasia. At the port site,

rats trapped by a private pest control professional (PCP) within a facility not accessible to researchers were also collected. These rats were trapped with the use of snap-type kill traps. Information regarding species, length, weight, sex, and sexual maturity was collected. This study was approved by the University of British Columbia's Animal Care Committee (A11-0087).

Each rat underwent complete necropsy. For rats with grossly identifiable dermatologic abnormalities, skin samples were fixed in 10% neutral buffered formalin and examined microscopically. Skin with microscopic evidence of mite infestation was sent to the Proctor Laboratory, University of Alberta, for identification. There, ear nodules were dissected beneath a stereomicroscope to extract mites, which were cleared in 85% lactic acid and mounted in PVA medium (BioQuip, Rancho Dominguez, California, USA) on glass slides for microscopic examination.

Mites were identified as *N. muris* based on the presence of setae *gp*, perianal setae with simple rather than furcate tips, and a completely striated dorsum (Fig. 1; Fain 1965; Klompen et al. 1983). Exemplars are deposited in the E.H. Strickland Entomological Museum, University of Alberta.

Gross lesions were characterized by proliferative and crusting dermatitis affecting the pinnae and, in more severely affected rats, the skin of the face, legs, and tail (Fig. 2A, B). Microscopically, affected areas exhibited epidermal hyperplasia and hyperkeratosis with intracorneal pustules and mild lymphoplasmacytic dermatitis. Adult mites were observed tunneling through the superficial keratinized layers of the epidermis, leaving deposits of eggs in their wake. There were varying degrees of gross pinnal deformity, which corresponded to auricular cartilage resorption and remodeling on microscopic examination (Fig. 3).

Descriptive statistics and bivariate comparisons (using simple logistic regression) were used to identify associations between *N. muris* infestation and demographic characteristics, including species (based on external morphology, Nagorsen 2002), sex, sexual maturity (open vaginal orifice in females and scrotal testes in males), weight (per 10 g), nose-to-rump length (cm), and volume of internal fat (fat score on a scale of 0–3). Fisher's exact test was used to examine the relationship between *N. muris* prevalence and location, and Wilson score interval was used to calculate 95% confidence intervals for prevalence data. All statistics were conducted with the use of R (R Foundation for Statistical Computing, Vienna, Austria).

Thirteen of 725 rats collected were definitively diagnosed with *N. muris* ear mange based on the presence of typical gross and microscopic lesions in combination with intralesional mites on histopathology. An additional 2 rats were considered positive based on the presence of gross and microscopic lesions consistent with mite infestation, although mites were not identified on histopathology.

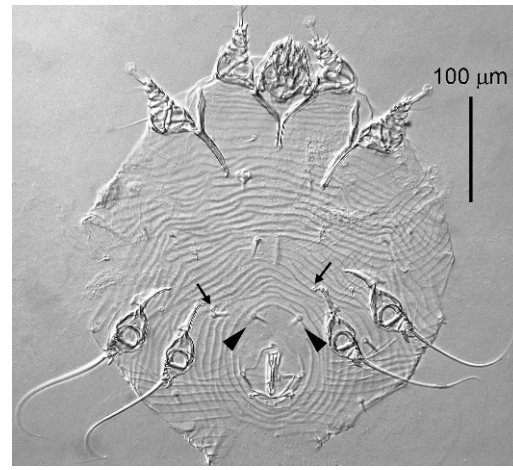

FIGURE 1. Light microscopic image of a female *Notoedres muris* mange mite from the ear of a black rat (*Rattus rattus*) from a port facility in Vancouver, Canada. Arrows indicate locations of setae *gp* and arrowheads indicate anterior pair of perianal setae. Presence of setae *gp*, perianal setae with simple rather than furcate tips, and completely striated dorsum are together diagnostic for *N. muris* (Fain 1965; Klompen et al. 1983).

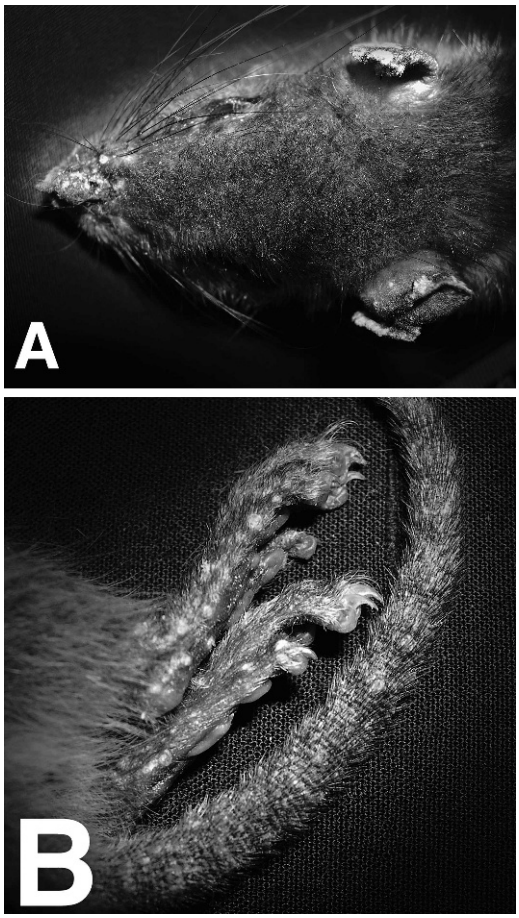

FIGURE 2. *Notoedres muris* ear mange (gross pathology) in black and Norway rats (*Rattus rattus* and *Rattus norvegicus*) from a port facility in Vancouver, Canada. (A) Proliferative dermatitis of the nose and pinnae of a black rat, with pinnal deformation; (B) proliferative dermatitis affecting the hind legs and tail of a Norway rat.

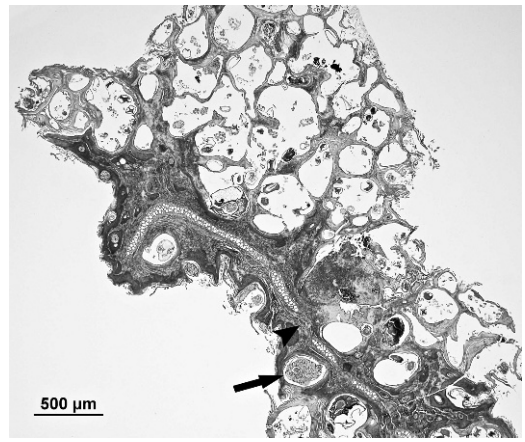

FIGURE 3. *Notoedres muris* ear mange (microscopic pathology) in black and Norway rats (*Rattus rattus* and *Rattus norvegicus*) from a port facility in Vancouver, Canada. There is epithelial hyperplasia and hyperkeratosis with intralesional mites (arrow) and auricular cartilage resorption (arrowhead). H&E stain.

Only rats trapped by the PCP in the indoor port facility showed evidence of ear mange. Forty-three rats were trapped at the port, including 11 trapped by researchers and 32 trapped by the PCP. The prevalence of ear mange was 15/725 (2.1%, 95% confidence interval [CI]=1.3–3.4%) for the sample as a whole, 15/43 (34.9%, 95% CI=22.4–49.8%) for all rats trapped at the port, and 15/32 (46.9%, 95% CI=30.9–53.6%) for rats collected by the PCP. There was no evidence of ear mange in any of the rats collected from the blocks surrounding the port and ear mange was significantly associated with geographic location ($P<0.001$).

Given the clustered distribution of *N. muris* ear mange, statistical analyses were conducted among the rats trapped by the PCP only ($n=32$). Among this group, 68.4% (19/32) rats were female and 71.4% (20/28) were mature (sexual maturity could not be determined for four rats). Eighty-one percent (26/32) were black rats, and the remainder were Norway rats. Mean weight, length, and fat score were 106.2 g, 14.41 cm, and 0.3, respectively.

Among *N. muris*–infested rats ($n=15$), 6/15 (40.0%) were male, 12/14 (85.7%) were sexually mature, 13/15 (86.7%) were black rats, and mean weight, length, and fat score were 135.9 g, 16.3 cm, and 0.2, respectively. Among *N. muris*–negative rats, 7/17 (41.2%) were male; 8/14 (57.1%) were sexually mature; 13/17 (76.5%) were black rats; and mean weight, length, and fat score were 80.0 g, 12.8 cm, and 0.4, respectively. Infestation was not significantly associated with sex, sexual maturity, species, or fat score ($P>0.05$).

For some comparisons, null findings could be a result of the small size of the analytic sample. For example, the distribution of mature animals and fat scores seems to suggest a direct and inverse association with *N. muris* infestation. Probability of *N. muris* infestation was significantly associated with weight (OR = 1.17, 95% CI=1.03−1.34) and nose-to-rump length (odds ratio=1.49, 1.15−2.08).

Little is known regarding the health impact of ear mange in wild rats. Infestation is reported to be pruritic (Baker 2007), and we suspect that the pinnal deformity was a result of scratching. Others have reported that *N. muris* mites can penetrate the dermis and directly damage the auricular cartilage (Lavoipierre 1964). However, in our sample of rats, mites were not observed to burrow beyond the epidermis. *Notoedres muris*–associated inflammation and pruritis may result in biologic and behavioral changes that increase the energy demands of the animal, as is the case with other burrowing mites such as *Sarcoptes scabei* (Samuel et al. 2001). Further study is needed to investigate this hypothesis.

The positive association between ear mange, nose-to-rump length, and weight suggests that probability of infestation increases with age (Feng and Himsworth 2013). Given that *N. muris* is transmitted by direct contact between individuals (Baker 2007), this may be a function of older rats having had more opportunity to come into contact with other *N. muris*–infested rats. Alternatively, it could suggest that mite transmission within a colony occurs through social interactions among adults (i.e., mating or dominance behaviors; Feng and Himsworth 2013).

Strikingly, *N. muris* infestation was limited to black and Norway rats trapped by a PCP inside a facility at the port. No affected rats were trapped in the inner-city neighborhood adjacent to the port, or in other locations within the port. This focal distribution may indicate that affected colonies are sufficiently isolated to preclude mite transmission.

The concept of numerous discrete rat colonies existing within small geographic areas is consistent with what is known about the ecology of rats in urban centers. Rat colonies exist within small distinct home ranges defined by availability of food and harborage, the presence of physical barriers to rat movement, and social pressures from other conspecific colonies or other rat species. When the environment is stable and resources are plentiful, there is little movement of rats among colonies (Feng and Himsworth 2013). These factors can lead to heterogeneous distribution of pathogens over small geographic areas (Himsworth et al. 2013), as was seen in this study.

Given that no affected rats were trapped elsewhere in the study area, and the port property under study regularly receives ships and cargo from overseas, we propose that the presence of *N. muris* ear mange may reflect an importation event. Unfortunately, there is insufficient data regarding *N. muris* and its genotypes to confirm the origin of the parasites in this study definitively. The possibility of importation deserves consideration, as ship traffic is recognized to be a source of foreign rats and their diseases in other parts of the world (Morelli et al. 2010). Although *N. muris* is not significant from a public health perspective, the potential of importation raises the possibility of more noxious rat-borne pathogens gaining access to new locations via ports.

This is the first report of *Notoedres muris* ear mange in Canada, and one of few reports in North America. The clustered nature of mite infestation reinforces the importance of accounting for rat ecology when studying disease, as prevalence may vary drastically between colonies. The specific port location suggests an importation event, which will require further study of port rat populations and their pathogens for confirmation. Researchers studying rats should be vigilant

for this mite, to better characterize its ecology and distribution.

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