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Canine Distemper Outbreak in a Population of Eastern Spotted Skunks

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Abstract - Canine distemper is an epizootic disease that can cause high mortality rates in carnivores, such as mustelids, and can have important deleterious effects on vulnerable, often small, carnivore populations due to its highly transmissible nature. In April and May 2020, we recovered 5 *Spilogale putorius* (Eastern Spotted Skunk) carcasses over a 15-day period that showed no visible signs of trauma. Clinical examination of the carcasses indicated that the skunks died due to canine distemper. Four of these skunks were radio-collared as part of our research at the time of their deaths, meaning that 50% of our study sample succumbed to distemper. Additionally, 2 other skunks we had radio-collared went missing during this time and might have contracted and died of distemper as well. To our knowledge, this is the first documented outbreak of distemper in Eastern Spotted Skunks. Our observation underscores the need to further study the effects of disease on the declining Eastern Spotted Skunk across its range.

Introduction

Spilogale putorius (L.) (Eastern Spotted Skunk) is believed to have undergone a range-wide decline since at least the 1940s (Gompper and Hackett 2005). Although the cause of this decline is still unknown, viral diseases are hypothesized to have contributed to declines in Eastern Spotted Skunk populations (Gompper and Hackett 2005, Eastern Spotted Skunk Cooperative Study Group 2020). Spotted skunks (*Spilogale* spp.) have tested positive for rabies (Aranda and López-de Buen 1999, Heidt et al. 1982, Hendricks and Seaton 1969, Parker 1975, Suzán and Ceballos 2005), canine parvovirus (Bakker et al. 2006, Suzán and Ceballos 2005), and Powassan virus (Johnson 1987). Evidence of other viral diseases in Eastern Spotted Skunks in the published literature is scant, and there has been no comprehensive examination of the occurrence of viruses or their effects on populations of Eastern Spotted Skunks (Eastern Spotted Skunk Cooperative Study Group 2020).

Canine distemper (hereafter, distemper) is a disease caused by a morbillivirus in the family Paramyxoviridae (Tavernier et al. 2012) that is primarily transmitted through aerosols (Harder and Osterhaus 1997) or direct contact between individuals and is present in infected individuals' nasal and ocular discharges, feces, and urine (Appel et al. 1981). Clinical signs of distemper in carnivores are varied and can include fever, encephalitis, ataxia, myoclonus, seizures, coma, anorexia, vomiting, coughing, ocular or nasal discharge, pneumonia, gastroenteritis, diarrhea, pruritus, hyperkeratosis, and death, among others (Appel et al. 1994, Deem et al. 2000,

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Gemma et al. 1996, Lan et al. 2006, Williams et al. 1988). Distemper has been documented in many terrestrial carnivore families globally (Deem et al. 2000). Mustelids are known to be highly susceptible to distemper (Budd 1981, Pearson and Gorham 1987), with close to a 100% mortality rate reported for *Mustela putorius puro* L. (Domestic Ferret) (Davidson 1986), and distemper poses a significant threat to endangered species like *Mustela lutreola* (L.) (European Mink) (Philippa et al. 2008), and *Mustela nigripes* (Audubon and Bachman) (Black-footed Ferret) (Carpenter et al. 1976, Thorne and Williams 1988). Distemper has also been reported in *Mephitis mephitis* (Schreber) (Striped Skunk) on multiple occasions (Diters and Nielsen 1978, Gehrt 2005, Goss 1948, Helmboldt and Jungherr 1955, Møller and Nielsen 1964, Woolf et al. 1986). While distemper has not previously been documented in the Eastern Spotted Skunk, Gompper and Hackett (2005) suggested that viruses such as distemper might have played a role in the range-wide decline of the species.

Methods

Here, we report the mortalities of 5 Eastern Spotted Skunks due to distemper during a radio-tracking study in DuPont State Recreational Forest (DSRF) in Henderson and Transylvania counties, NC (35.189983°N, 82.603433°W), over a 15-day span in April and May 2020. From February to April 2020, we captured and fitted very high frequency (VHF) radio-tracking collars (Model M1740; Advanced Telemetry Systems, Inc., Isanti, MN) on 8 male spotted skunks within the study area. Each VHF collar was equipped with a motion-activated mortality sensor that increased the frequency of an audible signal to alert the user when the collar had been stationary for 6 or more hours. On a daily basis, we attempted to determine the general location of the signal of each collared skunk and if mortality sensors on each collar had been activated. We also attempted to track the skunks to their diurnal den sites at least 2–3 times per week.

Observations and Discussion

On 21 April 2020, we opportunistically discovered a deceased, uncollared adult female spotted skunk curled up on the ground ~1.5 m from the side of a recreational trail within our study area. The study area was closed to the public at the time, and therefore, it was unlikely that the skunk's mortality was human-caused. There were no signs of visual trauma, and the skunk appeared to have died sometime within the past 24 hours, as the body was not in rigor mortis and there were no flies present or signs of decomposition. The skunk weighed ~280 g, did not appear malnourished, and had a healthy-looking coat. The only notable observation was that the skunk's chin was wet (a possible indication of nasal discharge or vomiting pre-mortem).

The following day (22 April 2020), the collars of 2 adult male skunks were emitting mortality signals. We tracked the first male (study-specific ID: S3) to a ground burrow it had frequently been tracked to and found the skunk curled up dead inside. The skunk had a wet chin similar to the female we found the previous day. After recovering the carcass of S3, we weighed the skunk and determined that

it had lost ~27 g since we last captured it 5 days earlier (final weight of 447 g). During this previous capture, S3 appeared to be healthy, with no apparent injuries or odd behaviors. We deployed a motion-triggered game camera (Bushnell Outdoor Products, Overland Park, KS) facing the burrow entrance where S3 was found dead, and video footage of the skunk at this burrow from the night before the carcass was found showed S3 to be active around the burrow entrance. Additionally, the day prior to our discovery of the carcass, S3 was observed on the camera outside of the burrow around midday, which is atypical, though not unprecedented, behavior for this primarily nocturnal species (Kinlaw 1995). We found the second skunk (ID: S6) deceased at the base of a tree in an area with a relatively open canopy and ~60 m away from the burrow location we tracked it to the prior day. As with the uncollared female and S3, the only visible abnormality on S6 was a wet chin. Feces from S6 were also present at the mortality location and were dark and runny, contrasting with the lighter color and chalky appearance of typical Eastern Spotted Skunk scat. Additionally, S6 had lost 117 g since we captured it 14 days prior (final weight of 407 g). In the days and weeks preceding their mortalities, both of these male skunks had exhibited typical nightly movements, and their den-site selection was normal. We tracked both skunks to den sites the day prior to mortality, and their collars were not emitting mortality signals at the time. Although we did not observe either skunk at the den sites on these occasions, we assumed that they died within 24 hours of our discovering their deceased bodies.

On 2 May 2020, we located the fourth dead spotted skunk, an adult male (ID: S7). We last heard a normal signal from S7 on 29 April 2020. We first heard the mortality signal for this skunk on 1 May 2020. However, S7 was located on a private property adjacent to our study area, and we did not receive permission to access the property until 2 May 2020. On that day we located S7 deceased and lying out in the open on the ground. The carcass had ants covering the chin area and flies appeared to be laying eggs on the skunk. We observed no external signs of injury or that decomposition had yet occurred, although the left hindquarters of S7 appeared wet and looked to have some fur loss, potentially indicating pruritus. This skunk had lost 92 g grams since we last captured it 44 days prior (final weight of 453 g).

On 6 May 2020, we tracked an adult male spotted skunk (ID: S10) and found it curled up on the ground at 1005 EDT in a relatively open area 37 m away from the den site we had tracked it to the previous day. At this time, S10 was still alive, but non-reactive and taking shallow breaths. We stayed and observed S10, and it did not appear to die until ~1330 EDT. Like the previous skunk mortalities, this skunk's chin appeared wet, and dark and runny feces were also present near the skunk. This skunk had lost a total of 170 g in body weight since it was last captured 33 days prior (final weight 430 g). Similar to the previous 3 deceased radio-collared skunks, our tracking efforts did not reveal any abnormal movements or behaviors. However, 2 days prior to the death of S10, we had tracked the skunk to a tree with a large cavity, in which the skunk was visible and could be heard sneezing.

We were unable to verify potential mortalities of 2 additional radio-collared spotted skunks that might have succumbed to distemper. On 6 April 2020, we heard

the mortality signal for an adult male (ID: S8). However, we were denied access to the private property the signal appeared to be coming from and were unable to determine whether S8 had slipped its collar or died. Although we could not confirm if S8 died from distemper, it might have represented the first mortality from the disease at our study site. Similarly, for another adult male (ID: S2), we were only able to locate the skunk's undamaged collar (i.e., no signs of predation or other mortality) on 28 April 2020, and therefore have no indication of whether S2 died or had simply slipped its collar. Thus, at least 5, but perhaps as many as 7, spotted skunks died within a 30-day period in an area of ~7.4 km^2 (Fig. 1), which is particularly noteworthy because despite intensive trapping efforts, we only collared 8 spotted skunks at DSRF in 2020 (such small sample sizes are typical for studies

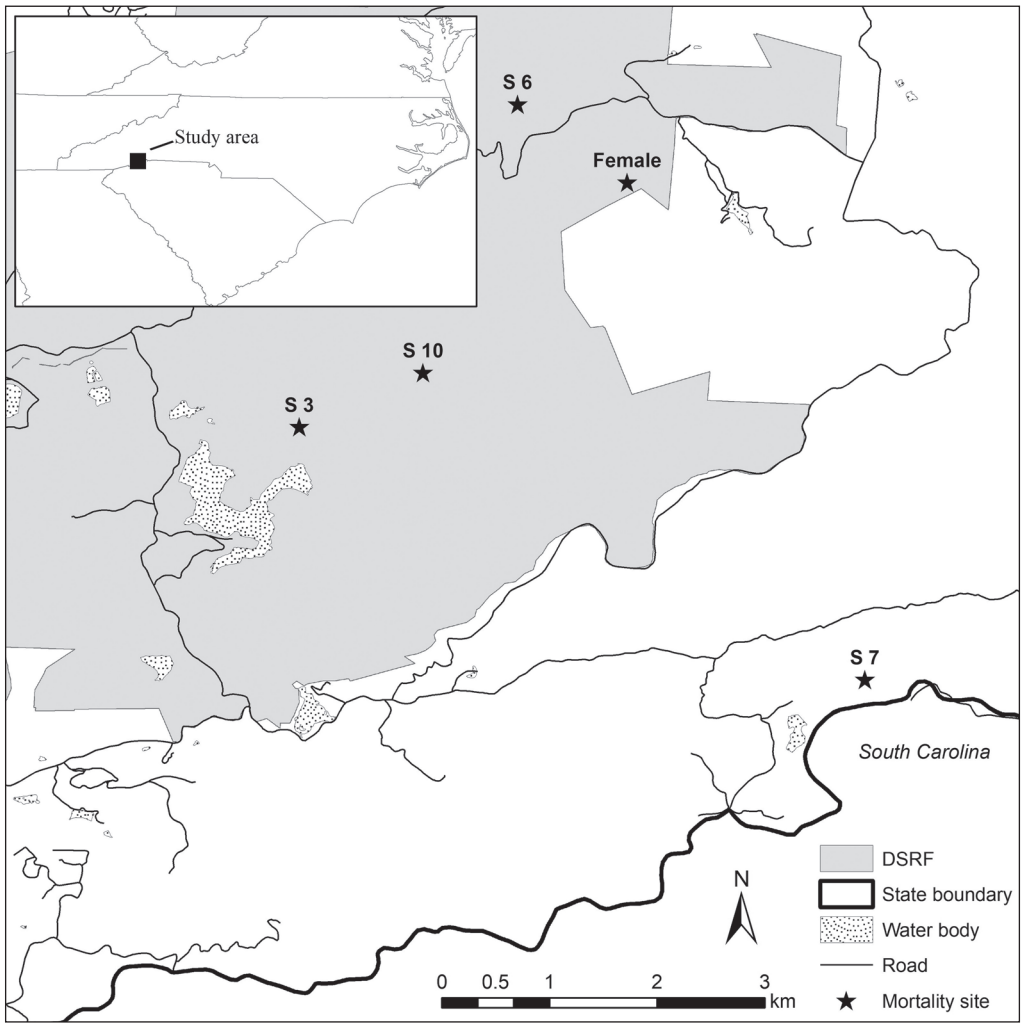

Figure 1. Locations of *Spilogale putorius* (Eastern Spotted Skunk) mortalities from canine distemper at DuPont State Recreational Forest (DSRF), NC, and adjacent private lands during a canine distemper outbreak, April–May 2020. The mortality site of an uncollared female skunk is indicated by a "Female" label.

of this species in this region; Eng and Jachowski 2019, Sprayberry and Edelman 2018, Thorne 2020). Thus, a loss of 4 of our collared spotted skunks represents a 50% mortality rate of our sampled population. Further, although the fate of 3 collared skunks remains unknown (an additional collared skunk had slipped its collar in February), by 10 May 2020, we were unable to successfully relocate the last of the 8 radio-collared spotted skunks in our study area.

We sent all 5 recovered spotted skunk carcasses to the Southeastern Cooperative Wildlife Disease Study, Athens, GA, for necropsy, where distemper was clinically determined to be the cause of death for each skunk. A fluorescent antigen test was used on samples of brain tissue from each carcass to test for distemper (Tipold et al. 1992), with positive results from all 5 skunks, indicating that they each had an active infection of distemper at the time of death. Histological examination of tissues from the skunks further revealed mild brain or lung lesions that are symptomatic of distemper infection. Brain tissues from the skunks were also tested for rabies using a fluorescent antigen test, with all skunks testing negative for rabies infection. Additionally, polymerase chain reaction (PCR) tests were conducted on tissues from each skunk (i.e. a combination of pooled spleen, mesenteric lymph node, and intestine samples), with all skunks testing negative for canine parvovirus DNA. Two skunks (S7 and S10) had comorbidities including emaciation and multisystemic parasitism (lungworms, intestinal worms, etc.) that might have contributed to their overall poor conditions, and ultimately their deaths. Mild endoparasitism identified in the other 3 skunks was determined to be incidental (i.e., not expected to affect health). Of note, all 4 radio-collared skunks appeared to be healthy and did not appear emaciated during their last captures before they were found deceased. The amount of time between these skunks' last captures and the discovery of their carcasses varied tremendously (5–44 days) and the average weight lost during this time period was 18.3% (± 9.6 *SD*) of their body weight at last capture.

To our knowledge, this is the first documentation of a distemper outbreak in any spotted skunk species, and this occurrence raises further questions. For one, the reservoir or host species from which distemper was transmitted into our study population of Eastern Spotted Skunks is unknown because distemper can affect a wide variety of hosts (Beineke et al. 2015). In eastern North America, *Procyon lotor* (L.) (Raccoon) is known to have periodic epidemics of distemper (Deem et al. 2000, Roscoe 1993), and distemper is an important mortality factor for *Urocyon cinereoargenteus* (Schreber) (Gray Fox; Davidson et al. 1992, Hoff et al. 1974). Based on motion-activated camera surveys (S.N. Harris, unpubl. data), Raccoons were fairly common at our study site prior to and during the distemper outbreak, and Striped Skunks, *Canis latrans* Say (Coyote), and *Vulpes vulpes* (L.) (Red Fox) occurred at DRSF as well, suggesting a distemper outbreak in these species could have spilled over into the Eastern Spotted Skunk population. Additionally, *Canis lupus familiaris* L. (Domestic Dog; both feral individuals and free-roaming pets) have been observed at DSRF. Domestic Dogs are known hosts of distemper (Appel and Gillespie 1972) and have been implicated as the reservoir species for distemper epidemics previously observed in wildlife species (Alexander and Appel 1994,

Cleaveland et al. 2000, Gowtage-Sequeira et al. 2009). Therefore, the distemper outbreak in spotted skunks at our site could have originated in Domestic Dogs.

We are also unsure of the geographical extent and timing of the distemper outbreak in spotted skunks or other wildlife outside of the distemper-positive skunks we observed at our study site. The only non-target species we captured during our trapping efforts were Striped Skunks and *Didelphis virginiana* (Kerr) (Virginia Opossum), but none of these individuals exhibited symptoms of distemper. Additionally, we never captured non-target species at the same trap locations as Eastern Spotted Skunks and did not capture more than 1 unique spotted skunk at an individual trap site within 16 days, limiting the likelihood that these trapping efforts could have contributed to transmission of distemper. However, on 2 occasions we captured 2 spotted skunks on the same day and were not able to disinfect processing equipment between skunk captures, so it is possible that there could have been disease transmission from our equipment. We encourage Eastern Spotted Skunk researchers to adopt equipment-disinfection protocols in future research to reduce the potential transfer of pathogens between captured animals.

In a similar and simultaneously conducted radio-tracking study of spotted skunks at a study site in Burke County, NC (~100 km from DSRF), we did not observe any confirmed or likely distemper mortalities in collared skunks. However, the North Carolina Wildlife Resources Commission confirmed a distemper-positive Gray Fox in Burke County on 7 April 2020 and 2 distemper-positive Raccoons in Caldwell County, which is adjacent to Burke County, on 2 June 2020 and 5 June 2020 (C. Olfenbuttel, unpubl. data). The US Department of Agriculture Animal and Plant Health Inspection Service's (USDA APHIS) Wildlife Services observed suspected distemper-positive Raccoons euthanized within their oral rabies vaccination zone in Buncombe County (n = 314), Haywood County (n = 62), and Jackson County (n = 4) from January through July 2020 (S. Brown, USDA APHIS Wildlife Services, Fletcher, NC, pers. comm.), which are adjacent to Henderson and Transylvania counties, where DSRF is located.

The outbreak we observed in spotted skunks could have been exacerbated by the timing of the event, as it occurred toward the end of the breeding season of Eastern Spotted Skunks (late March–April; Kinlaw 1995). Male Eastern Spotted Skunks are known to increase their home ranges as they search for females for mating, likely increasing potential contact between individuals, and the 7.4-km^2 area in which the distemper mortalities occurred is less than the average home-range size of male Eastern Spotted Skunks in the spring (Lesmeister et al. 2009). Since all radio-collared skunks tracked during the distemper outbreak were males, we have little information on how the outbreak affected females in the population, outside of the opportunistic discovery of the dead female spotted skunk that had distemper. Our tracking data were not refined enough to detect male–male spotted skunk interactions, and little is currently known about this type of interaction. The timing of this event also coincided with the breeding season of Raccoons, when males are known to expand their home ranges (Byrne and Chamberlain 2011).

We are unsure when the distemper outbreak at our study site began and ended, but our observations of distemper-positive spotted skunks in April and May are

similar to distemper epidemics in Raccoons in New Jersey that peaked near the end of their breeding season in March and April (Roscoe 1993). Likewise, cases of distemper in Gray Foxes between 1972 and 1989 in the southeastern United States peaked in March and April (Davidson et al. 1992). Although the animal was not tested, the Virginia Department of Wildlife Resources (VDWR) received a video taken on 13 May 2020 from Highland County, VA, of an Eastern Spotted Skunk exhibiting symptoms consistent with distemper (M. Fies, VDWR, Verona, VA, pers. comm.). Previous to that video, VDWR had no records of confirmed or suspected distemper in Eastern Spotted Skunks in Virginia.

Our observations suggest that distemper can have important localized impacts on Eastern Spotted Skunk populations. While some imperiled populations of carnivores have been known to recover to pre-outbreak levels within a few years after a distemper epizootic, such as *Canis simensis* Rüppell (Ethiopian Wolf; Gordon et al. 2015), other species, like the Black-footed Ferret, have exhibited severely depressed populations after distemper outbreaks (Thorne and Williams 1988). For Eastern Spotted Skunks, the relatively high mortality rates we observed (50%) combined with low connectivity among isolated populations (Eng and Jachowski 2019, Thorne 2020) and low survival rates of some populations (35% annual survival; Lesmeister et al. 2010) could lead to localized extirpation. At a broader scale, future research is needed to identify if distemper could be contributing to landscape-scale declines for the Eastern Spotted Skunk throughout its range.

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Literature Cited

Alexander, K.A., and M.J.G. Appel. 1994. African Wild Dogs (*Lycaon pictus*) endangered by a canine distemper epizootic among Domestic Dogs near the Masai Mara National Reserve, Kenya. Journal of Wildlife Diseases 30:481–485.

Appel, M.J.G., and J.H. Gillespie. 1972. Canine distemper virus. Virology Monographs 11:1–96.

Appel, M.J.G., E.P.J. Gibbs, S.J. Martin, V. ter Meulen, B.K Rima, J.R. Stephenson, and W.P. Taylor. 1981. Morbillivirus diseases of animals and man. Pp. 259–273, *In* E. Kurstak and C. Kurstak (Eds.). Comparative Diagnosis of Viral Diseases. Vol. 4. Academic Press, New York, NY. 694 pp.

Appel, M.J.G., R.A. Yates, G.L. Foley, J.J. Bernstein, S. Santinelli, L.H. Spelman, L.D. Miller, L.H. Arp, M. Anderson, M. Barr, S. Pearce-Kelling, and B.A. Summers. 1994.

Canine distemper epizootic in Lions, Tigers, and Leopards in North America. Journal of Veterinary Diagnostic Investigation 6:277–288.

Aranda, M., and L. López-de Buen. 1999. Rabies in skunks in Mexico. Journal of Wildlife Diseases 35:574–577.

Bakker, V.J., D.H. Van Vuren, K.R. Crooks, C.A. Scott, J.T. Wilcox, and D.K. Garcelon. 2006. Serologic survey of the Island Spotted Skunk on Santa Cruz Island. Western North American Naturalist 66:456–461.

Beineke, A., W. Baumgärtner, and P. Wohlsein. 2015. Cross-species transmission of canine distemper virus: An update. One Health 1:49–59.

Budd, J. 1981. Distemper. Pp. 31–44, *In* J.W. Davis, L.H. Karstad, and D.O. Trainer (Eds.). Infectious Diseases of Wild Mammals. Second Edition. Iowa State University Press, Ames, IA. 446 pp.

Byrne, M.E., and M.J. Chamberlain. 2011. Seasonal space use and habitat selection of adult Raccoons (*Procyon lotor*) in a Louisiana bottomland hardwood forest. American Midland Naturalist 166:426–434.

Carpenter, J.W., M.J.G. Appel, R.C. Erickson, and M.N. Novilla. 1976. Fatal vaccine-induced canine distemper virus infection in Black-footed Ferrets. Journal of the American Veterinary Medical Association 169:961–964.

Cleaveland, S., M.G.J. Appel, W.S.K. Chalmers, C. Chillingworth, M. Kaare, and C. Dye. 2000. Serological and demographic evidence for Domestic Dogs as a source of canine distemper virus infection for Serengeti wildlife. Veterinary Microbiology 72:217–227.

Davidson, M. 1986. Canine distemper, virus infection in the Domestic Ferret. Compendium on Continuing Education for the Practicing Veterinarian 8:448–453.

Davidson, W.R., V.F. Nettles, L.E. Hayes, E.W. Howerth, and C.E. Couvillion. 1992. Diseases diagnosed in Gray Foxes (*Urocyon cinereoargenteus*) from the southeastern United States. Journal of Wildlife Diseases 28:28–33.

Deem, S.L., L.H. Spelman, R.A. Yates, and R.J. Montali. 2000. Canine distemper in terrestrial carnivores: A review. Journal of Zoo and Wildlife Medicine 31:441–451.

Diters, R.W., and S.W. Nielsen. 1978. Toxoplasmosis, distemper, and herpesvirus infection in a skunk (*Mephitis mephitis*). Journal of Wildlife Diseases 14:132–136.

Eastern Spotted Skunk Cooperative Study Group. 2020. Eastern Spotted Skunk Conservation Plan. 43 pp. Available online at https://easternspottedskunk.weebly.com/uploads/3/9/7/0/39709790/ess_conservation_plan_dec92020.pdf. Accessed 20 January 2021.

Eng, R.Y.Y., and D.S. Jachowski. 2019. Evaluating detection and occupancy probabilities of Eastern Spotted Skunks. Journal of Wildlife Management 83:1244–1253.

Gehrt, S.D. 2005. Seasonal survival and cause-specific mortality of urban and rural Striped Skunks in the absence of rabies. Journal of Mammalogy 86:1164–1170.

Gemma, T., T. Watari, K. Akiyama, N. Miyashita, Y.S. Shin, K. Iwatsuki, C. Kai, and T. Mikami. 1996. Epidemiological observations on recent outbreaks of canine distemper in Tokyo area. Journal of Veterinary Medical Science 58:547–550.

Gompper, M.E., and H.M. Hackett. 2005. The long-term, range-wide decline of a once common carnivore: The Eastern Spotted Skunk (*Spilogale putorius*). Animal Conservation 8:195–201.

Gordon, C.H., A.C. Banyard, A. Hussein, M.K. Laurenson, J.R. Malcolm, J. Marino, F. Regassa, A.M.E. Stewart, A.R. Fooks, and C. Sillero-Zubiri. 2015. Canine distemper in endangered Ethiopian Wolves. Emerging Infectious Diseases 21:824–832.

Goss, L.J. 1948. Species susceptibility to the viruses of Carré and feline enteritis. American Journal of Veterinary Research 9:65–68.

Gowtage-Sequeira, S., A.C. Banyard, T. Barrett, H. Buczkowski, S.M. Funk, and S. Cleaveland. 2009. Epidemiology, pathology, and genetic analysis of a canine distemper epidemic in Namibia. Journal of Wildlife Diseases 45:1008–1020.

Harder, T.C., and A.D.M.E. Osterhaus. 1997. Canine distemper virus: A morbillivirus in search of new hosts?. Trends in Microbiology 5:120–124.

Heidt, G.A., D.V. Ferguson, and J. Lammers. 1982. A profile of reported skunk rabies in Arkansas: 1977–1979. Journal of Wildlife Diseases 18:269–277.

Helmboldt, C.F., and E.L. Jungherr. 1955. Distemper complex in wild carnivores simulating rabies. American Journal of Veterinary Research 16:463–469.

Hendricks, S.L., and V.A. Seaton. 1969. Rabies in wild animals trapped for pelts. Bulletin of the Wildlife Disease Association 5:231–234.

Hoff, G.L., W.J. Bigler, S.J. Proctor, and L.P. Stallings. 1974. Epizootic of canine distemper virus infection among urban Raccoons and Gray Foxes. Journal of Wildlife Diseases 10:423–428.

Johnson, H.N. 1987. Isolation of Powassan virus from a spotted skunk in California. Journal of Wildlife Diseases 23:152–153.

Kinlaw, A. 1995. *Spilogale putorius*. Mammalian Species 511:1–7.

Lan, N.T., R. Yamaguchi, A. Inomata, Y. Furuya, K. Uchida, S. Sugano, and S. Tateyama. 2006. Comparative analyses of canine distemper viral isolates from clinical cases of canine distemper in vaccinated dogs. Veterinary Microbiology 115:32–42.

Lesmeister, D.B., M.E. Gompper, and J.J. Millspaugh. 2009. Habitat selection and home-range dynamics of Eastern Spotted Skunks in the Ouachita Mountains, Arkansas, USA. Journal of Wildlife Management 73:18–25.

Lesmeister, D.B., J.J. Millspaugh, M.E. Gompper, and T.W. Mong. 2010. Eastern Spotted Skunk (*Spilogale putorius*) survival and cause-specific mortality in the Ouachita Mountains, Arkansas. American Midland Naturalist 164:52–60.

Møller, T., and S.W. Nielsen. 1964. Toxoplasmosis in distemper-susceptible Carnivora. Pathologia Veterinaria 1:189–203.

Parker, R.L. 1975. Rabies in skunks. Pp. 41–51, *In* G.M. Baer (Ed.). The Natural History of Rabies. Vol. 2. Academic Press, New York, NY. 640 pp.

Pearson, R.C., and J.R. Gorham Jr. 1987. Canine distemper virus. Pp. 371–378, *In* M.J. Appel (Ed.). Virus Infections of Carnivores. Elsevier, Amsterdam, The Netherlands, 500 pp.

Philippa, J., C. Fournier-Chambrillon, P. Fournier, W. Schaftenaar, M. van de Bildt, R. van Herweijnen, T. Kuiken, M. Liabeuf, S. Ditcharry, L. Joubert, M. Bégnier, and A. Osterhaus. 2008. Serologic survey for selected viral pathogens in free-ranging endangered European Mink (*Mustela lutreola*) and other mustelids from southwestern France. Journal of Wildlife Diseases 44:791–801.

Roscoe, D.E. 1993. Epizootiology of canine distemper in New Jersey Raccoons. Journal of Wildlife Diseases 29:390–395.

Sprayberry, T.R., and A.J. Edelman. 2018. Den-site selection of Eastern Spotted Skunks in the southern Appalachian Mountains. Journal of Mammalogy 99:242–251.

Suzán, G., and G. Ceballos. 2005. The role of feral mammals on wildlife infectious disease prevalence in two nature reserves within Mexico City limits. Journal of Zoo and Wildlife Medicine 36:479–484.

Tavernier, P., K. Baert, M. van de Bildt, T. Kuiken, A. Cay, S. Maes, S. Roels, J. Gouwy, and K. Van Den Berge. 2012. A distemper outbreak in Beech Martens (*Martes foina*) in Flanders. Vlaams Diergeneeskundig Tijdschrift 81:81–87.

Thorne, E.D. 2020. Spatial ecology of a vulnerable species: Home-range dynamics, resource use, and genetic differentiation of Eastern Spotted Skunks in central Appalachia. Ph.D. Dissertation. Virginia Polytechnic Institute and State University, Blacksburg, VA. 212 pp.

Thorne, E.T., and E.S. Williams. 1988. Disease and endangered species: The Black-footed Ferret as a recent example. Conservation Biology 2:66–74.

Tipold. A, M. Vandevelde, and A. Jaggy. 1992. Neurological manifestations of canine distemper virus infection. Journal of Small Animal Practice 33:466–470.

Williams, E.S., E.T. Thorne, M.J.G. Appel, and D.W. Belitsky. 1988. Canine distemper in Black-footed Ferrets (*Mustela nigripes*) from Wyoming. Journal of Wildlife Diseases 24:385–396.

Woolf, A., C. Gremillion-Smith, and R.H. Evans. 1986. Evidence of canine distemper virus infection in skunks negative for antibody against rabies virus. Journal of the American Veterinary Medical Association 189:1086–1088.