Mortality due to Tyzzer's Disease of Muskrats (*Ondatra zibethicus*) in Northern Ohio, USA

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ABSTRACT: In 2017, we investigated a mortality event of muskrat (*Ondatra zibethicus*) in northwest Ohio, US, and determined the causes of death to be from Tyzzer's disease due to *Clostridium piliforme* and *Klebsiella pneumoniae* septicemia. The gross presentation resembled tularemia, which highlighted the importance of a complete diagnostic investigation.

Muskrats (*Ondatra zibethicus*) are common wetland mammals that play ecologic, wetland management, and economic roles. Over the last several decades, North American muskrat populations have been in decline, possibly due to several causes (Ahlers and Heske 2017). Disease does not appear to be the ultimate factor in these declines, but diseases are ever-present and could compound primary stressors (Pacioni et al. 2015).

Between 10 November and 22 November 2017, 18 dead muskrats were found at a managed wetland near Port Clinton, Ohio, US (41°31′N, 82°59′W). The surrounding landscape consisted of managed wetlands in public and private holdings that were characterized by emergent marshes and flooded row crops (approximately 250 ha), with some commercial development, and bounded by Lake Erie and the Portage River. Daytime high temperatures ranged from −1 C to 11 C and low temperatures were −5 C to 3 C at night. No major precipitation events occurred prior to or during the mortality; however, there was an 11 C temperature drop within a 24-h period when the carcasses were initially observed. No other neighboring property owners reported muskrat mortality; however, some mortality may have gone undetected.

We performed cause-of-death examinations on five muskrats including gross necropsy, histopathology, bacterial culture, and parasi-tology. For histopathology, tissue samples (brain, heart, lung, liver, kidney, spleen, lymph node, adrenal gland, salivary gland, testis, adipose tissue, skeletal muscle, trachea, pancreas, urinary bladder, esophagus, stomach, and intestinal tract) were fixed in 10% neutral buffered formalin, dehydrated, embedded in paraffin, sectioned at 5 μm, and stained with H&E for light microscopy (Luna 1968). Liver sections were also stained with Brown and Hopps Gram stain or modified Steiner's stain.

Body condition of the five muskrats varied from poor, with depletion of all fat reserves, to good, with abundant subcutaneous and visceral fat. All five animals had from pinpoint to 1-mm diameter white or red foci throughout the liver (Fig. 1a). One animal (no. 001) also had a moderately enlarged right cervical lymph node and a mildly enlarged spleen.

Microscopically, the livers of all animals contained similar areas of random to massive coagulative necrosis. In 4/5 animals (002–005), adjacent hepatocytes multifocally contained packets of long, silver-positive bacterial rods (Fig. 1b). These bacteria were non-staining on both H&E and Gram stain. In one animal (001), short Gram-negative bacterial rods were within subcapsular hepatocellular necrosis in one section and no silver-positive rods were seen in any section. This animal also exhibited characteristics of septicemia: bacterial meningoencephalitis with malacia and neuronal necrosis, necrotizing bacterial lymphadenitis with abscessation, and splenic necrosis with bacteria. Additional microscopic findings in the remaining four animals included fat necrosis on the epicardium, renal capsule, pancreas, or mesentery and fibrinoid vascular necrosis in the liver (Table
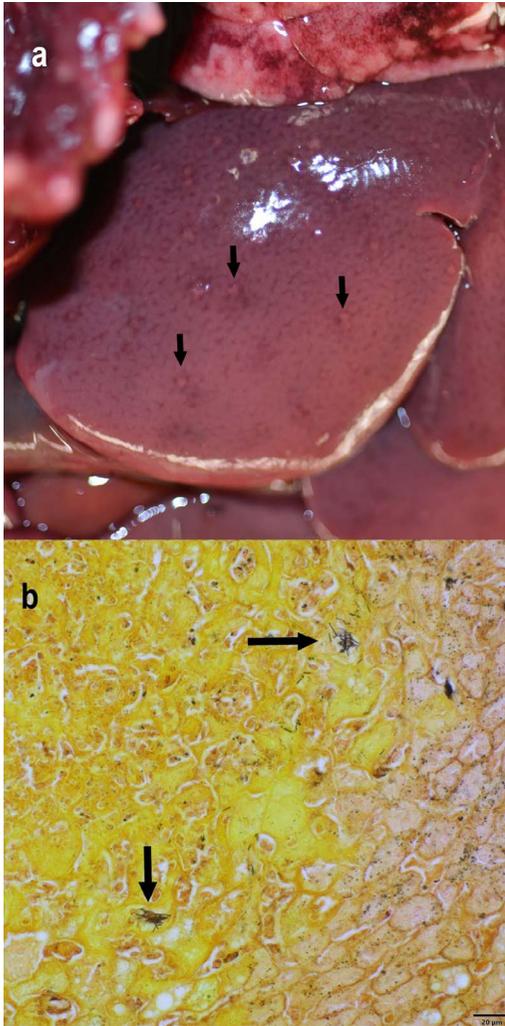
FIGURE 1. Liver from one of five muskrats (*Ondatra zibethicus*) necropsied following a mortality event that occurred between 10 November and 22 November 2017 in Ottawa County, Ohio, USA. (a) All necropsied animals had from pinpoint to 1-mm diameter white or red foci disseminated throughout the liver (arrows). (b) White foci noted grossly corresponded with areas of coagulative necrosis. Hepatocytes at the periphery of necrotic areas multifocally contained bundles of silver-positive bacterial rods (arrows). Modified Steiner's stain.

1). Autolysis interfered with the microscopic examination of the intestinal tract of all animals.

Liver from all five muskrats, lungs from three muskrats, and lymph node from one muskrat were surface-sterilized by flaming and cultured on tryptic soy agar with 5%

TABLE 1. Relevant gross, microscopic, molecular, and microbiologic findings in muskrat (*Ondatra zibethicus*) carcasses examined.

Specimen	Liver pinpoint foci	Liver pathology	Other pathology	Silver-positive rods	Gram-negative rods	*Klebsiella pneumoniae* culture growth	*Clostridium piliforme* nested PCR detection	*Francisella tularensis* PCR detection
001	Yes	Coagulative necrosis	Septicemia; bacterial meningoencephalitis; bacterial lymphadenitis; splenic necrosis	No	Yes	Yes	No	No
002	Yes	Coagulative necrosis	Fat necrosis	Yes	No	No	Yes	Not tested
003	Yes	Coagulative necrosis	Fat necrosis	Yes	No	No	Yes	Not tested
004	Yes	Coagulative necrosis; vascular necrosis	Fat necrosis	Yes	No	Yes	Yes	No
005	Yes	Coagulative necrosis	Fat necrosis	Yes	No	No	Yes	Not tested

sheep blood at 37 C. Isolated bacteria were identified by sequencing a portion of the 16S rRNA gene (Shearn-Bochsler et al. 2018).

Most bacteria recovered in culture were inconsistent between animals and likely represented postmortem colonizers (i.e., *Arthrobacter* sp. [n=1], *Buttiauxella* sp. [n=1], *Carnobacterium* sp. [n=1], *Serratia* sp. [n=1], *Streptococcus* sp. [n=2]). *Klebsiella pneumoniae* was grown from the lung, liver, and lymph node of the muskrat diagnosed with a Gram-negative bacterial septicemia. Several colonies of *K. pneumoniae* were also recovered from the liver of a second muskrat (Table 1).

Based on the characteristic bacterial silver-positive rods on histopathology, we screened liver from all five muskrats for the presence of *Clostridium piliforme* using a nested PCR, with 4/5 being PCR-positive (Niepceron and Licois 2010). Sequencing of the amplicons confirmed the presence of *C. piliforme*. The sequences were 100% identical to one another and 98–99% identical to sequences for *C. piliforme* in GenBank across the approximately 700-nucleotide region examined (GenBank accession nos. MH357836–MH357839). Portions of livers with lesions from two animals tested PCR negative for *Francisella tularensis*, and we did not pursue additional molecular testing for tularemia because the diagnostic findings consistently indicated *C. piliforme* and *Klebsiella* etiologies (Versage et al. 2003; Table 1).

Tyzzer's disease is rarely reported in muskrats or other wildlife (Wobeser 2001; Wobeser et al. 2009), and infectious diseases have not emerged as a significant threat to muskrats during a multi-decade population decline in the US (Ahlers and Heske 2017). Tyzzer's disease is sporadically reported in domestic animals and farmed wildlife but does not appear to have human health impacts (Wobeser 2001). However, the initial presentation of the disease and epizootic nature of the muskrat mortality event stresses the importance of screening for Tyzzer's disease, as well as to rule out zoonotic diseases with similar gross pathology and epidemiology, such as tularemia (caused by *F. tularensis*; Mörner and Addison 2001). We did not see other lesions commonly reported in Tyzzer's disease, such as myocardial necrosis and necrotizing typhlitis (Wobeser et al. 1978), although autolysis interfered with full evaluation of the intestinal tract.

Tyzzer's disease mortality has been documented in North American muskrats since at least 1947 (Wobeser et al. 1979), and the disease may be underreported as the pathogen is thought to be common in the environment (Wobeser 2001; Wobeser et al. 2009). However, the few reports are not sufficient to make inference about epidemiology or the impact of Tyzzer's disease in muskrats. Ahlers and Heske (2017) presented hypotheses to explain long-term muskrat declines, several of which included mechanisms likely to result in physiologic stress. Such stress may predispose muskrats to developing Tyzzer's disease (Wobeser 2001) and, thus, *C. piliforme* may be a secondary disease risk in muskrat populations already in decline due to other stressors. In the current case report, one out of the five muskrats lacked evidence of *C. piliforme* infection but had septicemia caused by *K. pneumoniae*, another opportunistic pathogen. We therefore encourage furbearer management to consider the potential impact of both primary and secondary infectious diseases, especially where muskrat populations are under nondisease stress.

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