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A retrospective study of mortality in Pennsylvania captive white-tailed deer (*Odocoileus virginianus*): 2000–2003

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Abstract. The postmortem records of 160 white-tailed deer (*Odocoileus virginianus*) submitted for necropsy examination from 59 separate Pennsylvania captive deer farms over a 3.5-year period were reviewed to determine the primary cause of death of each animal. The most common causes of death were bronchopneumonia (39 cases), enterocolitis (30 cases), malnutrition (13 cases), and trauma (11 cases). Other causes of mortality included severe gastrointestinal parasitism (6 cases), cellulitis with septicemia (5 cases), degenerative myopathy (4 cases), ruminal acidosis (4 cases), and nephritis (4 cases). The cause of death was undetermined in 13 of the 160 animals. *Arcanobacterium pyogenes* (19 cases), *Fusobacterium necrophorum* (10 cases), *Escherichia coli* (7 cases), and *Mannheimia haemolytica* (4 cases) were the most commonly isolated bacteria from the pneumonic lungs. Bacterial agents associated with enterocolitis included *Clostridium perfringens* (15 cases), *E. coli* (12 cases), and *Mycobacterium avium* subsp. *paratuberculosis* (2 cases). The majority (52.2%) of the death loss in white-tailed deer of known ages occurred in animals 1 year of age or less, with 46.2% of the bronchopneumonia cases and 50.0% of the enterocolitis cases occurring during this time period. Cases of degenerative myopathy, myocardial degeneration, hepatic necrosis, meningoencephalitis, peritonitis, and urolithiasis considered severe enough to be the primary cause of death appeared early in life, affecting deer 6 months of age or less in all cases. In conclusion, bronchopneumonia, enterocolitis, malnutrition, and trauma were considered the most common causes of death in confined white-tailed deer in this study.

Introduction

Although a significant amount of information has been published regarding causes of mortality in free-ranging deer and other cervids, reports regarding mortality of captive white-tailed deer are much less prevalent in the literature.[2,4,6–9,11–13] In contrast to Europe and New Zealand, which have well-established deer farming operations, this industry is still in a relatively early stage of development in the United States.[1,3]

Farming of white-tailed deer (*Odocoileus virginianus*) is a growing industry in Pennsylvania and is becoming an important component of the agricultural business sector. Maximizing the health of the deer within each operation is of utmost importance and concern to attending veterinarians and the owners and managers of these facilities.

In an attempt to more fully describe the causes of mortality in deer farming operations in Pennsylvania, postmortem records of farmed white-tailed deer submitted to the Pennsylvania Animal Diagnostic Laboratory at the Pennsylvania State University, Pennsylvania Animal Diagnostic Laboratory System (PADLS-PSU), over a 3.5-year period were examined.

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Materials and methods

The postmortem records of 160 captive white-tailed deer (*O. virginianus*) submitted to the PADLS-PSU from January 1, 2000, through June 30, 2003 were reviewed to determine the primary cause of death of each animal. The deer were received from 59 separate Pennsylvania captive deer operations. With the exception of 2 deer obtained from 1 captive white-tailed deer farm located in eastern Pennsylvania, the remaining deer operations (58) were found within the central and western areas of the state. In-state interfarm transport of captive white-tailed deer to breeding operations and the transport of white-tailed bucks from breeding farms to hunting preserves via auctions and private sales was a relatively common practice by deer farm owners providing deer for this study. The majority of the deer were captive born. A minority of more mature animals were previously purchased by the deer farm owners primarily from the Midwestern states and states adjacent to Pennsylvania.

Postmortem procedures included gross and microscopic examination of lung, heart, rumen, abomasum, small intestine, large intestine, mesenteric lymph nodes, liver, kidney, spleen, skeletal muscle (semimembranosus), and brain. The tissues were fixed in 10% buffered formalin, routinely processed, paraffin embedded, sectioned at 3 μm, and stained with hemotoxylin and eosin.

Bacteriology (aerobic, anaerobic, *Mycoplasma* spp., and *Mycobacterium* spp. cultures) procedures were performed on

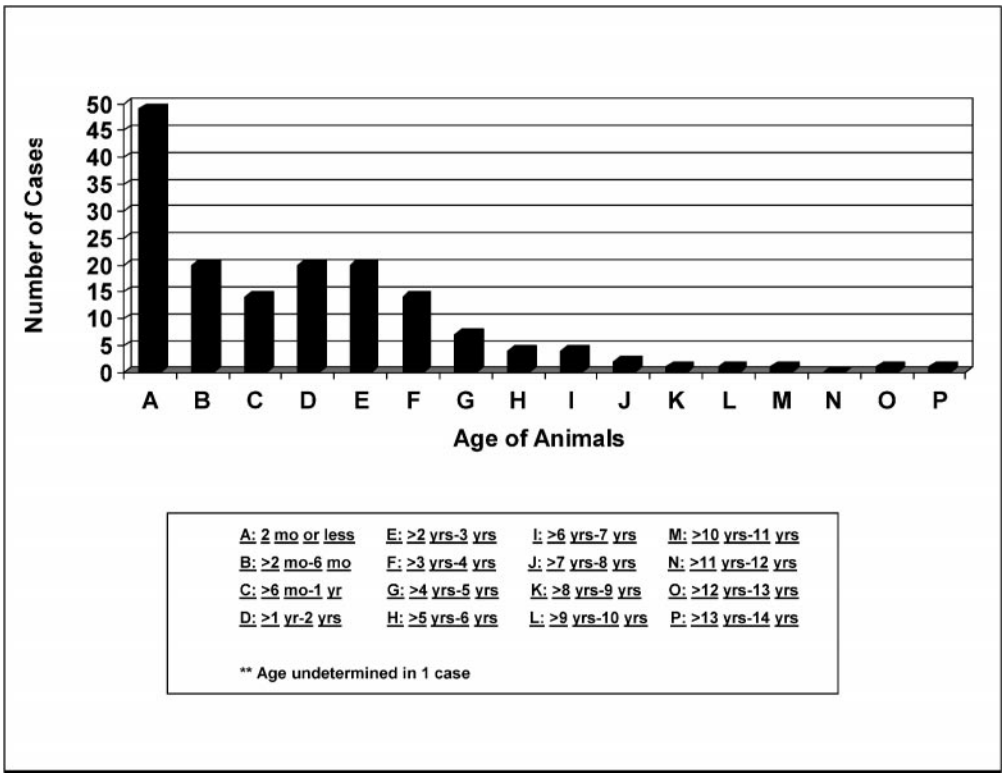

Figure 1. Mortality in Pennsylvania captive white-tailed deer from 2000 to 2003 by age groups.

selected cases. Tissues (other than intestinal) processed for aerobic culture were inoculated onto tryptic soy agar with 5% sheep blood,[a] Columbia CNA agar with blood,[a] and MacConkey agar plates[a] and incubated overnight at 37 C; for anaerobic culture, tissues were inoculated onto CDC anaerobic blood agar,[a] kanamycin–vancomycin (KV),[a] KV with laked blood (LKV),[a] phenylethyl alcohol agar (PEA),[a] McClung egg yolk agar[a] and B. frag isolation agar[a] and incubated at 37 C using the Mitsubishi AnaeroPack system[b]; for *Mycoplasma* culture, tissues were inoculated onto Myco agar plates,[c] PPLO agar plates,[d] and into PPLO broth[d] and incubated at 37 C in 10% CO_2. Broth was subcultured twice at 48-hr intervals onto both plate types, and plates were examined microscopically for growth consistent with *Mycoplasma* spp. at 48-hr intervals up to 10 days postinoculation. Intestinal tissues processed for aerobic culture were inoculated onto tryptic soy agar with 5% sheep blood[a] and MacConkey agar plates[a] and incubated at 37 C overnight; for anaerobic culture (for *Clostridium* spp. only), tissues were inoculated onto anaerobic PEA[a] and McClung egg yolk agar plates[a] and incubated at 37 C using the Mitsubishi AnaeroPack system.[b] All plates were examined after overnight incubation for colonies typical of *Escherichia coli* and *Clostridium perfringens*. Culture for *Mycobacterium avium* subsp. *paratuberculosis* (MAP) was performed at the Pennsylvania Veterinary Laboratory, Harrisburg, Pennsylvania, using a single-centrifugation/decontamination procedure in Hexadecylpyridinium chloride prepared in brain-heart infusion broth (HPC/BHI), followed by inoculation onto 4 slants of Herrold egg yolk agar[e] and incubation at 37 C for 12 wk. Slants were examined at 6 and 12 wk for evidence of MAP.

Fecal parasitology procedures, using the McMaster fecal flotation technique, were also performed on selected cases.

In those deer in which multiple diagnoses were made, only the lesion considered the actual cause of death or the primary lesion responsible for euthanasia was included in this study.

Results

The deer examined ranged in age from 1 day to 14 years and were categorized into specific age groups (Fig. 1; Table 1). Information regarding the exact age of 1 animal could not be obtained from the owner.

The primary causes of mortality of the 160 white-tailed deer included bronchopneumonia (39 cases), enterocolitis (30 cases), malnutrition (13 cases), and trauma (11 cases). Other causes of mortality included gastrointestinal parasitism (6 cases), cellulitis with septicemia (5 cases), degenerative myopathy (4 cases), ruminal acidosis (4 cases), nephritis (4 cases), asphyxia (3 cases), abomasitis (2 cases), hepatic necrosis (2 cases), pericarditis (2 cases), pleuritis (2 cases), vertebral body/spinal cord abscessation (2 cases), brain abscessation (2 cases), multiple system abscessation (2 cases), and 1 case of each of the following conditions: myocardial degeneration, renal abscessation, systemic granulomas, polioencephalomalacia, peritonitis, ruptured cecum, acute pulmonary hemorrhage, urolithiasis, arthritis with septicemia, anesthesia, abdominal abscessation, meningoencephalitis, torsion of the small

Table 1. Total number of cases and age distribution of specific causes of mortality in Pennsylvania captive white-tailed deer from 2000 to 2003.

Cause of mortality	Age of deer																
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	†
Bronchopneumonia (39)	12	4	2	7	5	3	2	1	1	1	1						
Enterocolitis (30)	12		3	4	4	5	1	1									
Malnutrition (13)	6	3	1		2			1									
Trauma (11)	2	1	1		2	2			1				1		1		
Gastrointestinal parasitism (6)	1	3	1														1
Cellulitis with septicemia (5)	1	1		1	1	1											
Degenerative myopathy (4)	4																
Ruminal acidosis (4)		2		1	1												
Nephritis (4)	3						1										
Asphyxia (3)	1			1						1							
Abomasitis (2)				1					1								
Hepatic necrosis (2)		2															
Pericarditis (2)	1		1														
Pleuritis (2)		1			1												
Vertebral body/spinal cord abscessation (2)			1													1	
Brain abscessation (2)			1	1													
Systemic abscessation (2)				1		1											
Myocardial degeneration (1)	1																
Renal abscessation (1)			1														
Systemic granulomas (1)							1										
Polioencephalomalacia (1)					1												
Peritonitis (1)		1															
Ruptured cecum (1)							1										
Pulmonary hemorrhage (1)						1											
Urolithiasis (1)	1																
Arthritis with septicemia (1)								1									
Anesthesia (1)				1													
Abdominal abscessation (1)									1								
Meningoencephalitis (1)	1																
Torsion of small intestine (1)			1														
Nephrosis (1)				1													
Undetermined (13)	3	2	1	1	3	1	1					1					

* A = 2 mo or less; B = >2 mo to 6 mo; C = >6 mo to 1 yr; D = >1 yr to 2 yr; E = >2 yr to 3 yr; F = >3 yr to 4 yr; G = >4 yr to 5 yr; H = >5 yr to 6 yr; I = >6 yr to 7 yr; J = >7 yr to 8 yr; K = >8 yr to 9 yr; L = >9 yr to 10 yr; M = >10 yr to 11 yr; N = >11 yr to 12 yr; O = >12 yr to 13 yr; P = >13 yr to 14 yr.

† Unknown age.

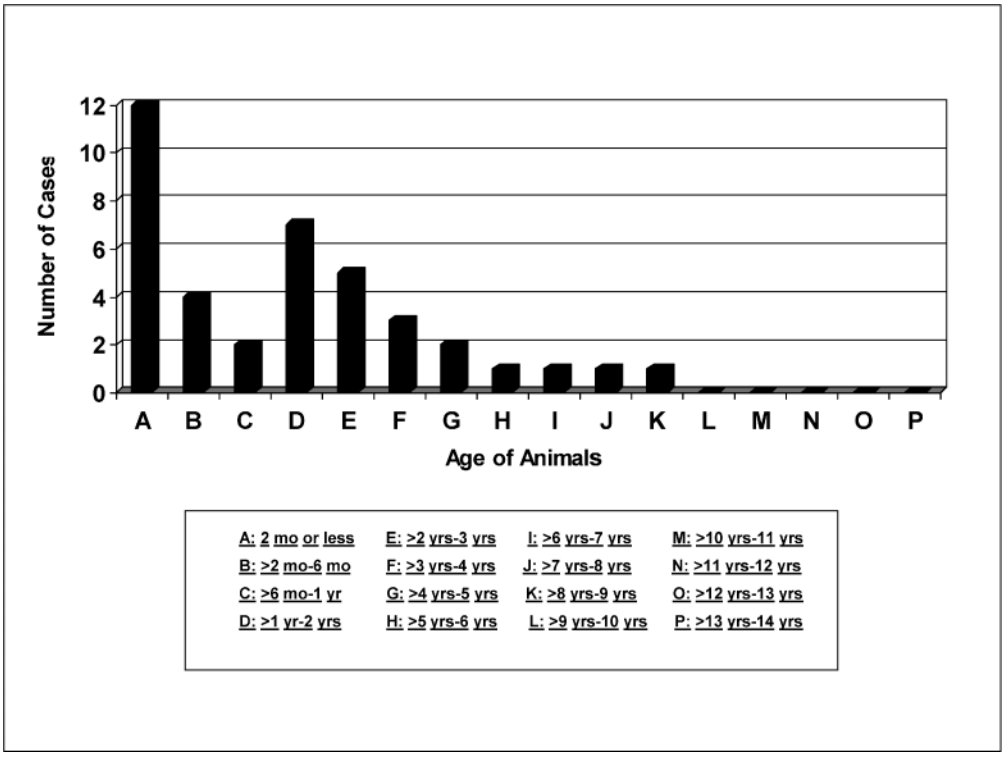

Figure 2. Age and number of Pennsylvania captive white-tailed deer with bronchopneumonia from 2000 to 2003.

intestine, and nephrosis. The cause of death could not be determined in 13 cases (Table 1).

The majority (52.2%) of the death loss in white-tailed deer of known ages submitted for necropsy in this study occurred in animals 1 year of age or less. Deer 2 months of age or less represented the majority (59.0%) of the mortality within this age group (1 year of age or less) and accounted for 30.8% of the mortality of all deer of known age in this study. In addition, deer 6 months of age or less represented 43.4% of the mortality in all deer in which the age was known. Animals greater than 3 years of age accounted for 22.6% of the cases, with deer greater than 4 years of age representing only 13.8% of all deer submissions.

Table 2. Microbial isolates obtained from Pennsylvania captive white-tailed deer with bronchopneumonia from 2000 to 2003.

Isolate	Number of cases
Arcanobacterium pyogenes	19
Fusobacterium necrophorum	10
Escherichia coli	7
Mannheimia haemolytica	4
Pasteurella spp. (other than *P. multocida*)	3
Mycoplasma sp.	3
Pasteurella multocida	2
Pseudomonas aeruginosa	2
No significant bacterial growth	5
Culture not attempted	3

Bronchopneumonia was diagnosed in 39 deer ranging in age from 10 days to 8.2 years (Fig. 2; Table 1). On gross examination of the majority of the lungs, there was marked anteroventral reddening and consolidation, with the overlying pleura covered with a thick layer of fibrin. Pneumonic lungs from 36 of the 39 deer were submitted for bacterial culture procedures. Bacterial procedures performed included aerobic (36/36), anaerobic (23/36), and *Mycoplasma* (36/36) culture. *Arcanobacterium pyogenes* (19/36), *Fusobacterium necrophorum* (10/23), *E. coli* (7/36), *Mannheimia haemolytica* (4/36), *Pasteurella* spp. other than *Pasteurella multocida* (3/36), *Mycoplasma* spp. (3/36), *P. multocida* (2/36), and *Pseudomonas aeruginosa* (2/36) were recovered. *Arcanobacterium pyogenes* and *F. necrophorum* were isolated together in 5 of the cases. No significant bacterial growth was obtained from 5 of the affected lungs (Table 2).

Enterocolitis was diagnosed in 30 deer ranging in age from 3 days to 6 years (Fig. 3; Table 1). Using both aerobic and anaerobic bacterial culture procedures, *C. perfringens* was recovered in 15 of the affected deer and *E. coli* in 12 cases. *Mycobacterium avium* subsp. *paratuberculosis* was isolated in 2 cases. Bacterial culture of the intestine was not performed in 1 case. Eleven of the 15 deer with enterocolitis asso-

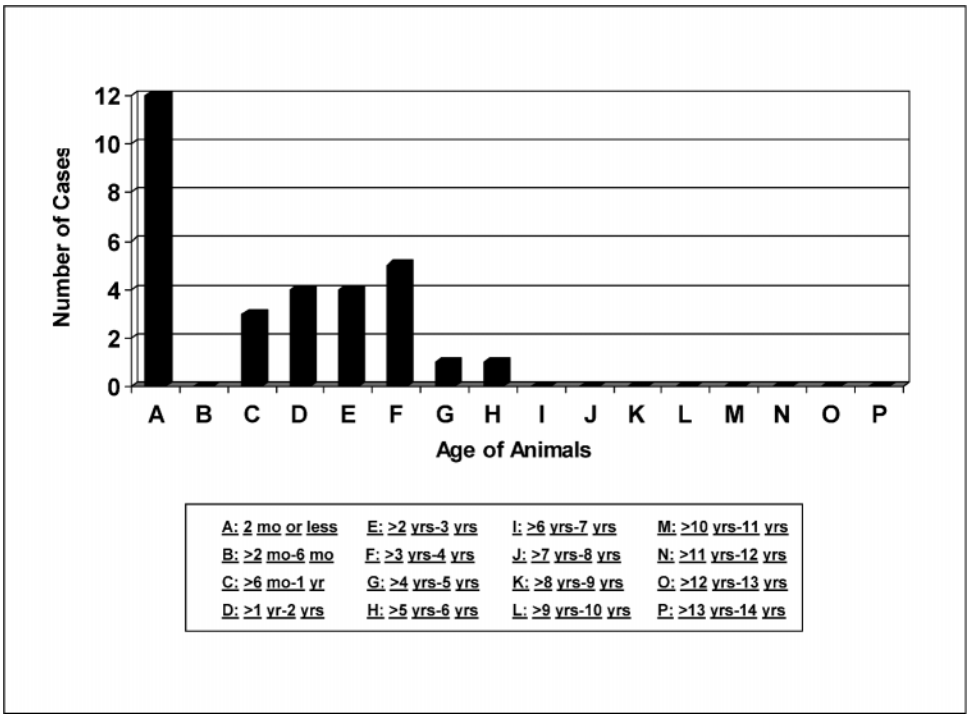

Figure 3. Age and number of Pennsylvania captive white-tailed deer with enterocolitis from 2000 to 2003.

ciated with *C. perfringens* displayed varying degrees of mural or luminal hemorrhage (or both) of the intestinal tract grossly. Microscopically, many of these cases were characterized by mucosal epithelial cell necrosis, acute hemorrhage within the lamina propria, and variable accumulations of fibrin, neutrophils, and bacteria consistent with *C. perfringens* within the mucosal epithelium and lamina propria. *Mycobacterium avium* subsp. *paratuberculosis* was isolated in 2 cases of enterocolitis. Accumulations of macrophages, epithelioid cells, lymphocytes, and occasional multinucleated giant cells were present microscopically within the lamina propria and tunica submucosa of the small intestine and colon in both cases.

Malnutrition was found in 13 deer that ranged in age from 1 day to 6 years. Cases were characterized by minimal body fat and small amounts of ingesta within the gastrointestinal tract on gross postmortem examination, with no significant lesions evident microscopically.

Trauma was the cause of death in 11 deer ranging in age from 31 days to 13 years (Table 1). Types of trauma varied and included multiple contusions with severe subcutaneous and skeletal muscle hemorrhage, subdural hemorrhage of the brain, abdominal puncture, stifle injury, and fractures of the neck, femur, and ribs. The time of year in which the trauma occurred also varied (Table 3).

Discussion

Hunting, animal predation, and starvation have been considered major causes of death in free-ranging

Table 3. Cases of trauma in captive Pennsylvania white-tailed deer from 2000 to 2003.

Age of deer	Type of trauma	Month of trauma
31 days	bilateral stifle trauma	July
2 mo	subdural hemorrhage—brain	July
6 mo	fractured femur	December
7 mo	fractured neck	December
2 yr, 4 mo	abdominal puncture; fractured ribs	September
2 yr, 9 mo	multiple contusions with severe hemorrhage (hip, shoulder)	February
3 yr, 6 mo	multiple contusions with severe hemorrhage (dorsum of back)	November
4 yr	multiple contusions with severe hemorrhage (thorax); fractured ribs	April
7 yr	multiple contusions with severe hemorrhage (dorsum of back)	June
10 yr, 6 mo	multiple contusions with severe hemorrhage (ventral abdomen)	October
13 yr	multiple contusions with severe hemorrhage (thorax); fractured ribs	April

white-tailed deer.[4,7,9,12,13] Bronchopneumonia (39 cases) and enterocolitis (30 cases) were the most common causes of mortality in this study, collectively representing 43.1% of all cases. In recent studies involving mortality in captive cervids, respiratory and enteric diseases due to infectious agents were also considered relatively common causes of death.[3,5,10]

The majority of the cases of bronchopneumonia (64.1%) occurred in deer 2 years of age or less, with 46.2% of the cases seen in animals 1 year of age or less. *Arcanobacterium pyogenes* and *F. necrophorum* were the most commonly isolated bacterial respiratory pathogens from affected lungs, accounting for 52.8% and 27.8%, respectively, of the cases of bronchopneumonia in which bacterial cultures were attempted. The occurrence of *F. necrophorum* in pneumonic lungs may have been underrepresented in this study because of the fact that anaerobic culturing procedures were performed on lung tissue in only 23 of the 36 deer with bronchopneumonia. Of these 23 deer, 43.5% (10/23) were positive for *F. necrophorum.* The use of antibiotics before the death of the animal, severe autolysis of the tissues at the time of necropsy, and performance of the necropsy too late in the disease process may be contributing factors for the lack of isolation of significant bacterial etiologic agents in 5 of the cases of bronchopneumonia cultured.

One-half of the cases of enterocolitis (50.0%) occurred in deer 1 year of age or less. Of the cases in which bacterial cultures were performed (29/30), *C. perfringens* was the most frequently isolated organism from the intestinal tract of deer with fatal enterocolitis (51.7%). The rapid introduction of high carbohydrate rations to deer unaccustomed to this diet and the subsequent proliferation of intestinal *C. perfringens* are often associated with acute enterotoxemia in both domestic and nondomestic ruminants. Although specific data regarding feeding practices were not obtained from the captive deer operations, ration mismanagement may have been an important factor in many of the cases of enterocolitis associated with *C. perfringens* in this study.

Other major causes of mortality in this study, in decreasing order of frequency, included malnutrition (13 cases), trauma (11 cases), severe gastrointestinal parasitism (6 cases), and cellulitis with septicemia (5 cases). Malnutrition, the third leading cause of death of deer in this study, is again indicative of the importance of adequate maternal care of the neonate including good milk production by the doe and effective ration management including the use of feedstuffs appropriate for the cervid. Although trauma was found to be the fourth leading cause of death in the present study, this condition was considered the leading cause of mortality in captive cervids in previous publications.[3,5] Multiple contusions with severe hemorrhage (6/13) were the most common type of trauma evident in this study. Rib fractures were also noted in 3 of 13 deer. Traumatic injury may have been inflicted by herdmates due to change of social status within the herd, overcrowding, fighting of bucks during the rut, competition over limited feeder space, and addition of animals into the herd from an outside source or from a different herd on the farm. In this study, 5 cases of trauma did occur during the time period usually associated with the rut season (Sep–Dec). Dogs or other animals on the farm may also overly excite deer in the herd. Inappropriate animal handling procedures or equipment may also be an important factor contributing to traumatic injuries. Fawns are at much greater risk of injury than mature animals when being moved from one pen to another or through a handling facility.

Degenerative myopathy (4 cases), nephritis (4 cases), and ruminal acidosis (4 cases) were also present in this study. Rumenitis and associated ruminal acidosis have been previously described as important causes of mortality in captive white-tailed deer.[5,14] The authors of one study suggested that a high carbohydrate supplemental diet used in many captive deer operations may have been responsible for the rumenitis present.[14]

Cases of degenerative myopathy, myocardial degeneration, hepatic necrosis, meningoencephalitis, peritonitis, and urolithiasis considered severe enough to be the primary cause of death appeared early in life, affecting deer 6 months of age or less in all cases.

The findings in this study indicate that the first year of life for captive deer is especially critical, representing the majority (52.2%) of the total death loss for all known age groups. Almost one-half (46.2%) of the bronchopneumonia cases and 50.0% of the enterocolitis cases occurred during this age period. Possible contributing factors for the relatively high death rate seen in animals during the first year of life in this study include poor-quality colostrum or inadequate colostrum ingestion and absorption by the fawn, leading to poor passive immunity and subsequent increased susceptibility to disease. Other factors also include poor maternal care, immaturity of the immune system of the fawn, and inadequate milk production by the doe. High deer population density on the farms, inappropriate postweaning nutrition, inadequate shelter including lack of appropriate protection from temperature extremes, dirty or excessively soiled fawning areas, and lack of adequate vaccination programs for the does and fawns may also be important factors. Inadequate or inappropriate transitional diet immediately after weaning, which occurred in the fawns in this study at 2–4 months of age, may also have had a contributing effect on the mortality of deer in this age group.

Veterinarians, deer confinement operation owners, and managers must be vigilant and provide appropriate care and management for these animals during this extremely critical period. By determining the major causes of death and specific age groups most vulnerable to mortality, a variety of effective preventative measures can be instituted, including implementation of vaccination programs, ensuring that newborns receive adequate amounts of good-quality colostrum, and using appropriate nutritional programs. Avoiding animal overcrowding, periodic moving of feeders to clean areas, conducting herd health checks throughout the day, especially during the fawning season, paddock rotation, and providing clean and adequate shelter for protection from temperature extremes should be instituted. Additional management techniques such as allowing animals to become accustomed to handling areas, fence lines, and gates before they are handled; removal of antlers of aggressive animals and members of the bachelor herd; and protection of deer that are chemically immobilized from herdmates should also be instituted to maximize the health of these animals.

Sources and manufacturers

a. Remel, Lenexa, KS.
b. Mitsubishi Gas Chemical Co., Inc., Tokyo, Japan.
c. University of California at Davis Biological Media Services, Davis, CA.
d. Hardy Diagnostics, San Diego, CA.
e. Pennsylvania Veterinary Laboratory, Harrisburg, PA.

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