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# Health Assessment of White-Tailed Deer of the Cuyahoga Valley National Recreation Area, Ohio
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**Creekmore, T. E. and L. H. Creekmore. Health Assessment of White-tailed Deer of the Cuyahoga Valley National Recreation Area, Ohio, February 23, 2000.**

*Abstract:* Data from 10 white-tailed deer (*Odocoileus virginianus*) collected on the Cuyahoga Valley National Recreation Area (CVNRA), Ohio, on February 23, 2000, were analyzed and compared to data from 10 deer collected on February 17, 1999, March 3rd and 4th, 1998, and February 3, 1997, respectively, by the National Wildlife Health Center as part of a deer herd health assessment program. Results from 2000 show decreases in fat indices, fetal rate, and the twinning rate and reveal that the physical condition of the deer herd has declined from 1999 but remains above 1997 levels. As in previous years, physiological indices such as the fetal/doe ratio, fawn pregnancy rates, twinning rates, and T3 and T4 values remain below reference values for deer with adequate nutrition. The deer are presently causing damage to urban gardens and landscapes, to agricultural crops, and to motor vehicles as a result of collisions on roads and highways. The deer herd is considered potentially vulnerable to adverse environmental factors in years when they are nutritionally stressed and in the future may experience population declines due to malnutrition and density dependent disease.

## INTRODUCTION

The Cuyahoga Valley National Recreation Area (CVNRA), located near Brecksville, Ohio, is managed by the National Park Service (NPS). Resource managers of the CVNRA have become concerned in recent years about the increase in number and density of white-tailed deer (WTD) (*Odocoileus virginianus*) on the area. During 1990-1994, deer-vehicle collisions within Summit and Cuyahoga Counties, in and near the CVNRA, increased at an annual rate of 16 percent. Private landowners in the same general area have experienced increasing damage to gardens, landscaping, and agricultural crops due to deer feeding. In February and March of 1996, excessive fawn deer mortality occurred on the CVNRA. Because of concern for a catastrophic crash in the population and the direct and indirect effect of high deer densities on other natural resources, as well as on park visitors, the CVNRA developed a Resource Management Plan in 1993 which proposed to monitor white-tailed deer herd health and mortality in addition to other environmental parameters potentially impacted by WTD. This health assessment is the fourth year of data collection and analysis for that plan.

The objectives of the deer herd health assessment are to: (1) provide information on the health of the deer herd by assessing body condition through external and internal gross examination and through physiological indicators obtained through testing of blood, tissue, and feces, (2) provide information on the deer herd's exposure to infectious disease by assessing serum antibody titers to selected disease pathogens, (3) provide baseline data that will be used to monitor changes in herd health over time and to measure the response of the deer herd to resource adaptive management, (4) provide information on some zoonotic diseases carried by the deer herd, and (5) store serum and tissues that may be used for later analysis.

## METHODS

To accomplish these objectives, 40 deer on the CVNRA have been killed, 10 deer each in 1997, 1998, and 1999, and 2000 using a .243 caliber rifle aiming for the neck region. Blood was immediately collected from the heart and placed in tubes containing EDTA anticoagulant or into tubes to allow clotting to occur. Clotted blood was centrifuged and serum harvested within two hours of collection. Refrigerated serums were sent the morning following collection by overnight service to Columbus, OH, Veterinary Diagnostics Laboratory for serum chemistries and T3/T4 measurements. The remaining serum was frozen and later sent to the Wisconsin Animal Health Laboratory for serology for bluetongue virus (BTV), epizootic hemorrhagic disease virus (EHDV), bovine virus diarrhea (BVD), parainfluenza 3 virus (PI3), bovine respiratory syncytial virus (BRSV), and leptospirosis, as well as to Michigan State University Animal Diagnostic Laboratory for analysis for Vitamin E and trace minerals. In addition, whole blood preserved in EDTA was sent to Michigan State University for selenium whole blood analysis. Additional frozen serum from each deer was banked. Blood smears were made from the EDTA blood within 2-4 hours of collection, air-dried and fixed for later parasitologic examination. The EDTA blood was then refrigerated and shipped by overnight service the next morning to the Columbus, OH Veterinary Diagnostics Laboratory for a complete blood count (CBC). Deer were transported to a facility at the CVNRA where they were necropsied. In 1997 and 1998 deer weights were estimated by chest girth. In 1999 and 2000, animals were weighed using a hanging spring scale. Rectal swabs were collected from each deer to culture for *Salmonella* sp. and *Escherichia coli*, specifically *E. coli* O157: H7. Various tissues were collected by standard procedures for assessment by histology, microbiology, and parasitology as indicated by necropsy findings. Feces were collected for measurement of fecal diaminopimelic acid (DAPA) and nitrogen. These samples were refrigerated for 48 hours, then frozen and later submitted by overnight service to the Washington State University Wildlife Habitat Laboratory for analysis. Fecal samples were collected for parasitologic assessment in 2000. Samples were chilled and submitted to Marshfield Laboratories in Marshfield, Wisconsin for Baermann's sedimentation procedure to examine for lungworm or other nematode larvae. In addition, obex, tonsil and retropharyngeal lymph nodes were collected from all 10 animals sampled in 2000 and tested for chronic wasting disease, and lung, tonsil, and mandibular, parotid, and retropharyngeal lymph nodes were collected for bovine tuberculosis testing.

## RESULTS

### *General Body Condition*

General body condition was assessed and the animals were sexed, aged, and weighed as part of the necropsy examination (Table 1). Mean BW of 2.5 year-old and older females (n=6) was 111.0 lbs. (50.5 kg.) (range, 95-135 lbs.). Mean body fat % (BF%) and visual kidney fat index (VKFI) (Kistner, 1980) for all deer were 37.9 % and 2.4, respectively. The mean % body fat in females (n=8) was 39.9 compared to a mean in males (n=2) of 30.0. The mean visual kidney fat for females versus males was 2.6 and 1.5 respectively. The mean kidney fat index (KFI) was for female (range 6.35-39.75) and male (range 3.45-14.75) deer were 80.2 and 9.1

respectively. Bone marrow fat (BMF) (Cheatum, 1949) results ranged from a rating of II (85%) to V (50%) with a mean for all deer of 3.5 (62.5%). The mean BMF for both females and males was 3.5 (62.5%), and mean BMF for females 2.75 years or older was 3.6 (65.8%).

Table 1. Body condition, sex, age, weight, and location of white-tailed deer collected on Cuyahoga Valley National Recreation Area, Ohio, February 23, 2000.

| ID # | Sex | Age (yrs) | Body Fat (%)[1] | KFI[2/3] | Weight (lbs) | Bone Marrow Fat [4] | Pregnant |
|---|---|---|---|---|---|---|---|
| 001 | F | 2.75 | 69 | IV / 39.75 | 116 | II | Yes |
| 002 | F | 4.75 | 35 | II / 10.95 | 95 | V | Yes |
| 003 | F | 2.75 | 55 | III /36.96 | 111 | III | Yes |
| 004 | F | 2.75 | 35 | II / 9.45 | 97 | III | Yes |
| 005 | F | 0.75 | 25 | II / 6.35 | 67 | IV | No |
| 006 | M | 1.75 | 25 | I / 3.45 | 95 | IV | - |
| 007 | F | 0.75 | 25 | II / 8.15 | 72 | V | No |
| 008 | F | 2.75 | 40 | III / 17.4 | 112 | V | Yes |
| 009 | M | 0.75 | 35 | II / 14.75 | 89 | III | - |
| 010 | F | 5.75 | 35 | III /16.6 | 135 | III | Yes |

[1]Techniques developed by T.P. Kistner (Oregon State University, Corvallis), 1980, A Field Guide Technique for Evaluating Physical Condition in Deer, based on visual estimation of the relative amounts of fat in six body locations and the condition of the body musculature.
[2]KFI=Kidney Fat Index (Kistner, 1980) based on visual observation and estimation of the surface area of the kidney covered by fat I(<25%), II (25-50%), III (50-75%), IV (>75%).
[3]KFI= Kidney Fat Index (Riney, 1955) based on mean weights of perirenal fat divided by mean kidney weight x 100. [4]Bone Marrow Fat (Cheatum, 1949), I (90%)White Solid, II (85%) Spotted Pink Solid, III (70%) Dark Pink Solid, IV (55%) Yellow Solid, V (50%) Red Solid, VI (1.5%) Red Gelatinous, VII (1.5%) Yellow Gelatinous.

*Sex, Age, and Reproduction*

Mean age of adult females examined in 2000 (n=6) was 3.58 years (range 2.75-5.75). Sex ratio of fetuses (n=9) at near mid-gestation was 78% male and 22% female. Table 2 depicts the reproductive performance of deer on the CVNRA. All of the 6 does of breeding age (2.75-5.75 years old) examined were pregnant. The two female fawns examined were not pregnant. Crown to rump lengths for fetuses ranged from 12.5 to 24.0 cm. The twinning rate for those does that were pregnant was 50.0%.

Table 2. Reproductive performance of white-tailed deer on the Cuyahoga Valley National Recreation Area, Ohio, February 23, 2000.

| ID # | Age (yr) | Fetuses per Doe | Fetal Sex/Size[1] (cm) |
|---|---|---|---|
| 001 | 2.75 | 2 | M/24.0, M/24.0 |
| 002 | 4.75 | 1 | M/21.0 |
| 003 | 2.75 | 2 | M/20.75, M/20.75 |
| 004 | 2.75 | 1 | M/12.5 |
| 008 | 2.75 | 1 | M/13.0 |
| 010 | 5.75 | 2 | F/20.5, F/20.5 |

[1]Crown to rump length

*Pathology*

Observations of pathology from gross and microscopic examination of 10 deer were predominantly unremarkable. Minor lesions on the surface of the liver of one deer indicated larval parasite migration. Meningeal nematodes (*Parelaphostrongylus tenuis*) were found in six of the 10 deer examined. No liver flukes (*Fascioloides magna*) were observed on gross examination of the liver. One adult female (001) had mild abomasal lesions suggestive of medium stomach worm infection. Swab cultures for *Salmonella* and *E. coli* 0157:H7 were negative for all 10 deer. No evidence of chronic wasting disease or bovine TB were seen in the 10 animals tested.

*Parasitology*

No significant external parasites were observed. Second and third instars of nasal bots (*Cephenemyia spp.*) were found in four deer, and meningeal worms were found in six deer. *Parelaphostrongylus sp.* larvae and eggs were seen in eight of 10 deer during histologic examination of lung sections. No *Haemonchus contortus* was seen on close gross examination of abomasal content. Fecal Baermann sedimentation revealed that six of the nine deer tested had nematode larvae present in the feces. No *Dictyocaulus viviparus* lungworms were found on lung wash examination of airways and no parasites were seen on the blood smears examined. Neither the parasite prevalences nor species found are unusual or considered a health issue.

*Serology*

Serum from each of the 10 deer was analyzed for antibody titers to six disease pathogens; bluetongue virus (BTV), epizootic hemorrhagic disease (EHD), bovine viral diarrhea types I and II (BVD), parainfluenza virus type 3 (PI-3), *Leptospira interogans* (6 serotypes), and respiratory syncytial virus (RSV). No antibodies were reported in any of the 10 deer tested.

*Clinical Pathology*

Basic statistical descriptions of hematological and biochemical variables for 10 animals, 6 adult females, 1 adult male, 1 nine month old male, and 1 nine month old female are presented in Tables 3 and 4. Data were compared with reference values provided by Seal et al. (1981), Bubenik and Brownlee (1987) and Tumbleson et al. (1968), for white-tailed deer when possible, otherwise reference values for domestic animals were used (Smith, 1996).

*Hematology*

Packed cell volumes were all within the range of the reference values; however, the hemoglobin concentrations were low in nine of the 10 deer when compared to reference values from killed white-tailed deer (Table 3). The leukocyte values are within the reference range for all of the deer examined. Lymphopenia was observed in 71% of the deer and monocytosis was observed in 17%. Of the deer sampled, 67% had eosinophilia; in three animals the increase was marked.

Table 3. Mean (S.D.), minimum and maximum values for hematologic parameters of 10 free-ranging white-tailed deer from Cuyahoga Valley National Recreation Area, Ohio, February 23, 2000.

| Parameter | Mean (S.D) | Min.-Max. | Reference Values[1] |
|---|---|---|---|
| PCV (%) | 46.41 (4.0) | 40.0-52.0 | 39 - 58 |
| Hemoglobin (g/dl) | 16.56 (1.3) | 14.4-18.4 | 18.3 -19.3 |
| MCHC (g/dl) | 35.6 (1.1) | 34.1-39.3 | 34.7 - 36.1 |
| MCV (fl) | 35.1 (1.7) | 33.9-39.3 | 23.8 - 33.0 |
| Nucleated RBC (/100 WBC) | 0.0 | - | - |
| Leucocytes (x10³/μl) | 1.68 | 0.6-3.1 | 1 - 4.2 |
| Seg. Neutrophils (%) | 36.7 | 21-60 | 57 - 72[2] |
| Seg. Neutr. (x 10³/μl) | 0.75 | 0.37-1.86 | 0.6 - 2.8 |
| Neutrophilic Bands (%) | 0.0 | - | - |
| Neutr. Bands (x10³/μl) | 0.0 | - | - |
| Lymphocytes (%) | 51.1 | 28-71 | 24 - 35[2] |
| Lymphocytes (x10³/μl) | 1.05 | 0.75-1.50 | 0.6-1.8 |
| Monocytes (%) | 2.67 | 2-4 | 1 - 3[2] |
| Monocytes (x10³/μl) | 0.05 | 0.03-0.09 | < 0.010 |
| Eosinophils (%) | 9.86 | 5-17 | 2 - 7[2] |
| Eosinophils (x10³/μl) | 0.19 | 0.09-0.37 | < 0.10 |
| Platelet Estimate | Adequate | Adequate | < 0.10 |

[1]Reference values were adopted from Seal et al., 1981 except when other source is indicated.
[2]Bubenik and Brownlee, 1987.

*Biochemistry*

All 10 deer sampled had elevated levels of potassium. Chloride values were slightly below the reference vales for six deer and phosphorus levels were elevated in eight deer. AST was slightly elevated in two deer and CPK was above the reference range for five of the 10 deer tested. Creatinine values were above the reference value for nine deer.

Slightly depressed chloride levels were apparent in 60% of the animals examined. The calcium / phosphorus ratio is well balanced and one deer had a slightly elevated magnesium value. Five deer had glucose values greater than the reference range. Creatinine levels were elevated in nine animals. Hypoalbuminemia (<2.5 g/dl) was detected in five of the deer sampled. However, two of the deer with hypoalbuminemia had values that were only slightly below the reference value, and comparison of albumin values with body fat results indicates that only two deer (005,006) had depressed albumin results as well as reduced fat stores. Two deer had slightly elevated AST values and eight animals had depressed GGT results. The T3 values were below the reference range for eight of the 10 animals tested and T4 levels for all of the deer collected in 2000 were below the normal reference values.

Table 4. Mean (S.D.), minimum and maximum values for serum biochemical values for 10 free-ranging white-tailed deer from Cuyahoga Valley National Recreation Area, Ohio, February 23, 2000.

| Parameter | Mean (S.D.) | Min.-Max. | Reference Value[1] |
|---|---|---|---|
| Sodium (mmol/L) | 144.8 (3.1) | 141-152 | 132 - 156 |
| Potassium (mmol/L) | 8.9 (1.5) | 6.3-11.1 | 3.4 - 5.0 |
| Chloride (mmol/L) | 99.1 (1.92) | 97-102 | 100 - 110 |
| Calcium (mg/dl) | 9.3 (0.5) | 8.4-10.3 | 8.1 - 10.8 |
| Phosphorus (mg/dl) | 9.6 (1.5) | 7.8-12.5 | 4.5 - 8.5 |
| Magnesium (mg/dl) | 2.5 (0.1) | 2.2-2.7 | 2.2-2.6[2] |
| Glucose (mg/dl) | 272.2 (106.2) | 87-419 | 60 - 320 |
| BUN (mg/dl) | 19.5 (2.4) | 17-23 | 15 - 45 |
| Creatinine (mg/dl) | 2.4 (0.4) | 1.7-3.4 | 0.4 - 2 |
| Total Protein (g/dl) | 5.9 (0.6) | 5.1-6.8 | 5.0 - 7.8 |
| Albumin (g/dl) | 2.4 (0.3) | 1.9-2.6 | 2.5 - 4.2 |
| ALKP (U/L) | 55.5 (34.7) | 22-136 | 27 - 107[3] |
| CPK (U/L) | 443.5 (246.8) | 145-851 | 20 - 400 |
| AST (U/L) | 115.1 (28.6) | 83-164 | 40 - 150 |
| | | | |

| | | | |
|---|---|---|---|
| GGT (U/L) | 35.3 (6.8) | 27-51 | 40 - 100 |
| Total Bilirubin (mg/dl) | 0.3 (0.1) | 0.2-0.4 | 0.1- 1 |
| T3 (ng/ml) | 0.69 (0.4) | 0.26-1.39 | 1.25 - 3.05 |
| T4 (ng/ml) | 69.0 (20.0) | 44.9-112.8 | 150 - 300 |

[1]Reference values were adopted from Seal et al., 1981 except where indicated.
[2]Smith, 1996 (bovine values).
[3]Tumbleson et al., 1968.

*Nutrition*

*Trace minerals and vitamin E*

Basic statistical descriptions for serum copper, zinc and iron, and whole blood selenium and serum vitamin E concentrations are presented in Table 5. Serum copper values (range 0.367-0.654) were below the reference value for all 10 deer tested, based on data from domestic animals (Smith, 1996). Serum zinc results were below the reference value for nine of the 10 deer tested.

Whole blood analysis for selenium (ng/ml) was below the reference range of 100-180 (Puls, 1994) for nine deer. Six deer had vitamin E values that were depressed and one animal had a value slightly above the reference range; the remaining 4 deer had vitamin E levels within the normal reference range.

Fecal samples from 10 deer were pooled into one composite sample for analysis of fecal 2,6 diaminopimelic acid (FDAPA) and fecal nitrogen (FN). The composite results from 2000 for FDAPA and FN were 0.700 mg/gm and 1.87% respectively.

Table 5. Mean (S.D.), minimum and maximum values for selected trace minerals and vitamin A for 10 free-ranging combined adult female (n=8), adult male (n=1), and young of the year (n=1) white-tailed deer from Cuyahoga Valley National Recreation Area, Ohio, February 23, 2000.

| Parameter | n | Mean (S.D.) | Min.-Max. | Reference Values[1] |
|---|---|---|---|---|
| Copper (ppm) | 10 | 0.48 (0.11) | 0.367-0.654 | 0.7 - 1.2 |
| Zinc (ppm) | 10 | 0.49 (0.12) | 0.315-0.717 | 0.7 - 1.0 |
| Iron (ppm) | 10 | 1.7 (0.27) | 1.14-1.98 | 0.7 - 2.3 |
| Selenium (ng/ml) | 10 | 88.5 (38.68) | 59-181 | 100 - 180[2] |
| Vitamin E (µg/ml) | 10 | 2.05 (0.69) | 1.12-3.31 | 2.09 - 3.05[3] |

[1]Smith, 1996.
[2]Puls, 1994
[3]Ullrey, 1981

## DISCUSSION

The small sample size precludes meaningful statistical analysis. However useful comparisons can be made between years and among other deer populations, and over time assumptions can be made about the general trend of the population.

The deer collected during February 2000 were tested for chronic wasting disease and bovine TB to provide control negative samples for studies being conducted in the western U.S. However, these negative data are important considering the ongoing bovine TB problem in Michigan and the continued movement of game farm cervids throughout the U.S..

The general body condition for deer examined in 2000, while improved from 1997 levels, shows a decrease from1999 results (Table 6). Decreases in mean % body fat (37.9%) and mean KFI (2.4) were seen in 2000 when compared to 1999 BF% and KFI results of 49.0% and 3.2, respectively. In addition, the mean body weight for adult does (111.0) was the lowest reported during this study. However, the average age of the six adult does collected in 2000 was 3.6 years, compared to average ages for adult does of 4.5, 5.4, and 4.6 years for 1997, 1998, and 1999, respectively. The apparent decrease in mean weight of adult does in 2000 is probably a result of the younger age structure of the sample population. The age structure of the population is difficult to determine due to the small sample size. However, based on this limited sample, no abnormalities were noted in the sex ratio and age structure.

Body fat, KF, and bone marrow fat indices were higher for adult does than for the 1.75 year old male. In general, adult does enter the winter in better body condition than adult bucks, and fawns of both sexes. Adult bucks feed little and are very active during the late fall breeding season and consequently enter the winter in poor physical condition. Fawns initially invest the majority of their energy in body growth, but photoperiod changes cause a physiologic shift to fat deposition in the fall. Consequently, the fat reserves available to deer in the late winter are a crucial factor in survival during periods of stressful weather conditions. Winter mortality usually involves fawns and adult males, with adult doe mortality restricted to extreme conditions of weather and/or habitat quality.

In general, reproductive performance of the deer herd of the CVNRA appears to have decreased from 1999 levels, and is considered low based on the number of fetuses per doe (1.5:1). The mean number of fetuses per doe in 1999 and 2000 (1.5:1) increased from 1997 levels (1.28:1), and was about the same as 1998 results (1.63:1). These results are below the mean number of fetuses per doe (1.8:1) for deer in the same age group recorded for northern Ohio (Gladfelter, 1984). Reproduction among fawns and yearlings is more variable than among adult does as a result of sensitivity to nutritional factors (Verme, 1969). Normally, 97% of the female population breeds at 1.5 years of age, and pregnancy rates in fawns from Ohio range up to 60% (Gladfelter, 1984). However, none of the fawns (n=6) collected during the four years of this study have been pregnant. The twinning rate increased steadily from 1997 through 1999 but decreased in 2000. The twinning rate in 2000 was 50.0% compared to 1999 was 71.4% as 62.5% in 1998 and 28.0% in 1997. The decrease in the number of adult does with twins is probably a reflection of the lower average age of the does sampled in 2000. Fetal sex ratios in 2000 were 71% male and 29% female. The fetal sex ratio in 1999 was 54% male and 46%

female while 1998 results were reversed at 46% male and 54% female. The fetal sex ratio for 1997 was 43% male and 57% female. Theoretically, the sex ratio of fetuses should be even, but wide variations have been reported, with males usually predominating. Verme (1969) observed that adult does on a low nutritional plane prior to breeding produced 72% males, compared to well fed does that produced 43% males.

The fetal size for pregnant does necropsied in 2000 ranged from 12.5 to 24.0 cm. This range of fetal lengths indicates a breeding season from November 2 to December 9. Deer 004 collected in 2000 had a breeding date of December 9 based on the fetal size of 12.5 cm, and animal 008 had a single fetus that measured 13.0 cm indicating a breeding date of December 6. These breeding dates are later than those found in CVNRA deer in 1998 and 1999. Several factors may account for these late breeding dates. Poorly nourished does begin breeding several weeks later than animals in good physical condition (Verme, 1965), and does that fail to breed during the normal rut cycle in mid November will ovulate again 25 to 30 days later (Plotka et al., 1977). In addition, malnutrition can cause retarded growth of fetuses and thus preclude any accurate determination of their age by measurement (Short, 1970). CVNRA has an unhunted population and as such should have an adequate adult sex ratio to facilitate breeding. Both does with late breeding dates were 2.5 years of age during the breeding season but had only single fetuses. Therefore, the small fetal sizes encountered in these two deer are probably a result of nutritional stress, either during the breeding season, or more likely during the late winter gestation period. The fetal size (crown-rump length) varied significantly from 1.0-19.0 cm in 1997, and this fetal length indicates a breeding season from about November 1 to January 1. Again, accurate determination of the breeding dates was probably affected by malnutrition and these results are not a reflection of an extended breeding season. The fetal size in 1998 was tightly clumped, ranging from 22-28 cm indicating a breeding season ranging from October 25 to November 16, 1997 and fetal size in 1999 ranged from 15.5-23.0 cm which places the breeding season between October 30 and November 22. The fetal size results from 1998 and 1999 are an indication of improved physical condition when compared to 1997 values, but fetal sizes in 2000 indicate a reduced nutritional state in individual animals.

Parainfluenza virus type 3 titers were found in four deer tested in 1999, one animal in 1998, and five deer in 1997. However, no PI-3 titers were found in animals tested in 2000. PI-3 is primarily a viral disease of cattle, and limited studies of this agent in deer suggest that only nonfatal clinical manifestations occur (Richards, 1981).

None of the animals sampled were anemic; however, anemia induced by undernutrition during winter may be concealed by the hemoconcentration that accompanies seasonal dehydration and decreased plasma volume (DelGiudice et al., 1992). In addition, deer species have a large muscular spleen that undergoes splenic contraction secondary to acute stressful events causing transitory increases in packed cell volume. As a result, antemortem stress may mask any anemic states in the animals sampled. The hemoglobin concentrations were below the reference range for killed white-tailed deer in eight of the 10 animals tested. Seal et al. (1981) found variations in hemoglobin results of gunshot deer that were attributed to differences in the elapsed time of death of the animal.

Lymphocytosis was observed in five deer and an elevated monocyte count was seen in 1 animal. Elevated lymphocyte and monocyte counts occur most commonly due to chronic infections or as a physiologic response to fear, excitement, or handling (Kirk and Bristner, 1985).

The absence of any discernable chronic infections in these animals implicates stress as the cause of these elevated white blood cells. However, it is unclear from the literature exactly how quickly this adrenal related response occurs, or if gunshot stress is a factor. As a result, the exact cause of the elevated lymphocyte and monocyte levels is undetermined. High eosinophil counts, seen in four of these deer, are rare in ruminants but may be caused by parasitic infection. However, the parasite burden was low in the animals examined making parasite infection less likely as the cause for the eosinophilia.

Potassium values were elevated in all 10 deer, creatinine values were above the reference range for nine deer, and CPK results were elevated in five animals. The high levels of potassium and CPK found may in part be caused by postmortem collection of blood from the heart (Seal et al., 1981; White and Cook, 1974). High potassium levels may also result from in vitro hemolysis (Smith, 1996). Prolonged storage can similarly cause an increase in potassium but the serum was separated within 3 hours of collection. High concentrations of CPK may also be attributed to general trauma and tissue damage caused by shooting. Elevated potassium and creatinine levels were observed in a study by DelGiudice et al. (1992) in early and late winter as a result of decreased plasma volume and glomerular filtration rate due to reduce water intake. The slightly low chloride levels seen in six of the deer from this study are a change likely due to dehydration. The validity of serum glucose for evaluating nutritional status is questionable as excessive depletion of gluconeogenic precursors can be masked by abnormally high glucose levels caused by handling stress (DelGiudice et al., 1987). The glucose values do not fall below the normal limits and the six deer with high values may be explained by capture stress indicating that glucose is likely within normal range in a non-stressed state.

In 1997, low protein concentrations and BUN values in the normal range suggested energy deprivation and catabolism of body protein for energy (DelGiudice and Seal, 1988). In 1998 and 1999, and 2000 the total protein and BUN values are within the normal range indicating a better plane of nutrition and energy balance.

Hypoalbuminemia was seen in six of the animals tested. However, only two animals had albumin levels that were significantly out of the normal range. The primary cause of hypoalbuminemia is inadequate intake of dietary protein (Smith, 1996).

A hypothyroid state in the winter is normal for white-tailed deer, but can be intensified by decreased food intake (Seal et al., 1972). The adaptive significance of diminished thyroid function in malnourished deer may be to reduce energy requirements when caloric intake is inadequate; a vital consideration in over winter survival and neonatal mortality. The mean T4 values for 2000 (69.0) are lower than those found in 1999 (77.7 ng/ml) and 1998 (72.7 ng/ml) and are well below the 1997 values (85.6 ng/ml). The T3 values in 2000 (0.69) are lower than both 1999 (0.81 ng/ml) and 1998 (0.93 ng/ml) results but are similar to 1997 values (0.6 ng/ml). The T4 and T3 levels in CVNRA deer from all years remain consistently below the reference values, these decreased concentrations may reflect the diminished dietary energy available. The mean serum T4 concentration in these deer was lower than values for undernourished female white-tailed deer (T4=97 ng/ml) (DelGiudice et al., 1987) suggesting a compromised nutritional situation.

Fecal DAPA and Fecal nitrogen results provide an indication of the quality of forage ingested within the previous 48 hours. Fecal DAPA increases in the rumen as a function of increased bacterial mass, and FN tends to increase as dietary protein and nitrogen increases

(Leslie et al., 1989). These methodologies were developed for western deer species (Hodgman et al., 1996), but because the results indicate changes in forage quality these techniques are applicable to Ohio deer. Fecal DAPA and FN results for deer collected at CVNRA should provide an indication of forage quality changes when compared between years. Fecal DAPA and FN results show a slight decline in winter nutritional quality between 1997 and 1998 and a slight increase in 1999, but results are greatly influenced by differences in collection dates and short-term changes in weather patterns. The Fecal DAPA result (0.700 mg/gm) for 2000 was the highest reported during the four years of this study. In contrast, the 2000 FN value (1.87 gm/100gm)) was by far the lowest reported. Both results are within the DAPA and FN normal ranges of .25-1.3 mg/gm and 1-3 gm/100gm respectively (B. Davitt, personal communication). The DAPA and FN results from 2000 indicate that 24-48 hours prior to being euthanized the animals ingested forage with relatively high digestibility but low protein content. This short term aspect of DAPA and FN analysis provide an indication of forage quality at the time of sampling and can be compared to longer term indices such as fetal rates and fat indices.

Mean serum copper values (ppm) in 2000 (0.48) are lower than those noted in 1999 (0.61) and 1997 (0.50) and similar to1998 (0.45) results (Table 7). Serum copper values continue to be below the reference range of 0.7-1.2. Copper deficiencies in wild ruminants have occurred worldwide with symptoms including pale, faded, brittle hair, osteoporosis, abnormal hoof and antler growth, weight loss and reduced reproduction (Robbins, 1993). Absorption of copper tends to be low and is affected by the copper status of the animal, chemical form, and levels of other metal ions which may interfere with absorption such as calcium, cadmium, zinc, iron, lead, silver, molybdenum and sulfur (Robbins, 1993). The 1999 results reverse somewhat the trend of lower copper values between 1998 and 1997 and no clinical signs or lesions were seen that can be directly attributed to copper deficiency. In sheep, cattle and red deer, copper concentrations below 0.5ppm are considered diagnostic for copper deficiency (Mertz, 1986; MacKintosh et al., 1986). In cattle, no clinical signs are observed until levels are <0.2ppm, but animals with serum copper levels < 0.4ppm show positive growth response to supplementation (Wikse et al., 1992).

Zinc results were below the normal range for nine of the 10 deer sampled (Table 7). Mean zinc values dropped from 1.1ppm in 1997 to 0.45ppm in 1999 and increased slightly in 2000 (0.49). Slightly depressed levels of zinc were noted in 90% of the animals tested in 1998 as compared to data from 1997 where none of the animals examined had low levels of zinc. Zinc deficiency is characterized in calves by poor growth, rough scaly skin and dull listless appearance (Swenson, 1982), and deficiencies have been reported in grazing cattle (Dynna and Havre, 1963). The zinc content of liver and bone samples varies seasonally in free-ranging wild herbivores (Anke et al., 1980), but zinc deficiency has not been reported in wild animals (Robbins, 1993). No clinical signs of zinc deficiency were noted in the deer examined in 1999.

Seven of 10 deer sampled in 2000 had selenium values below the normal range (Table 7). In 1999, all 10 deer had selenium values below the reference range. Selenium deficiency primarily affects juveniles, resulting in increased mortality during neonatal and pre-weaning periods (Keen and Graham, 1989) and may also cause low fertility (Robbins, 1993). Ohio is included in the area where the selenium concentration in plants is low (80% of all forage and grain contain <0.05ppm of selenium) relative to domestic animal needs (Robbins, 1993). No clinical signs of selenium deficiency were apparent likely because the vitamin E levels were only slightly below normal values. Adequate dietary levels of vitamin E can reduce the selenium requirement (Ullrey, 1981).

*Conclusions*

Decreases in fat indices, fetal rate, and the twinning rate reveal that the physical condition of the deer herd has declined from 1999 but remains above 1997 levels. As in previous years, physiological indices such as the fetal/doe ratio, fawn pregnancy rates, twinning rates, and T3 and T4 values remain below reference values for deer with adequate nutrition. However, these studies are timed to evaluate the deer herd during the time of year when they are expected to be in their worst physical condition and no animals were seen that were totally devoid of fat reserves. During years without adverse weather conditions or food source failures the only population impact of this lower nutritional plane will be a reduced rate of productivity. Results from all four years of this study indicate that the deer population on the CVNRA is in excess of the carrying capacity of the habitat. If habitat quality and deer populations remain at current levels, fawn mortality can be expected during periods of extreme winter stress.

Table 6. Comparison of mean body condition and reproductive results 1997-2000.

| **Parameter** | **1997** | **1998** | **1999** | **2000** | **Ref. Value**[1] |
|---|---|---|---|---|---|
| Body Weight[1] | 134.6 | 131.3 | 121.7 | 111.0 | |
| Body Fat | 33.0 | 35.6 | 49.0 | 37.9 | |
| KFI (visual) | 3.0 | 2.8 | 3.2 | 2.4 | |
| Fetuses/Doe | 1.3 | 1.6 | 1.5 | 1.5 | 1.8 [2] |
| Twinning Rate | 28.0 | 62.5 | 71.4 | 50.0 | |

[1]Body weight was estimated in 1997-98 using chest girth measurements.
Deer were weighed with a hanging scale in 1999.

[2] Gladfelter, 1984

Table 7. Comparison of mean Vitamin E and trace mineral results 1997-2000.

| **Parameter** | **1997** | **1998** | **1999** | **2000** | **Ref. Value**[1] |
|---|---|---|---|---|---|
| Copper (ppm) | 0.50 | 0.45 | 0.61 | 0.48 | 0.7-1.2 |
| Zinc (ppm) | 1.1 | 0.54 | 0.45 | 0.49 | 0.7-1.0 |
| Iron (ppm) | 1.70 | 1.83 | 1.90 | 1.67 | 0.7-2.3 |
| Vitamin E (ug/ml | NT | 1.96 | 2.18 | 2.05 | 2.09-3.05[2] |
| Selenium (ng/ml) | 92.7 | 112.0 | 44.1 | 88.45 | 100-180[3] |

[1]Smith, 1996.
[2]Ullrey, 1981
[3]Puls, 1994
NT=Not Tested

*Recommendations for Research*

Baseline data on deer herd health is essential in understanding current herd status and trends. With such information, predictions on population dynamics and responses to resource management actions can be made. It is recommended that (1) an annual herd health assessment, similar to the ones conducted from 1997 to 2000, be continued in 2001. After completion of this 5-year database, assessments at three-year intervals should be sufficient, (2) if large scale habitat or population changes are initiated, annual herd health assessments should be implemented for a period time to measure the effects of management changes.

Armed with this information resource management personnel of the Cuyahoga Valley national Recreation Area should be able to make scientifically based and sound decisions to properly manage the white-tailed deer herd and associated natural resources.

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