LONG TERM MONITORING PROTOCOLS

FOR

WHITE-TAILED DEER

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INTRODUCTION

The protection offered by national parks is beneficial to wildlife. Many national parks which maintain cultural landscapes using agricultural management practices are particularly beneficial to white-tailed deer (Odocoileus virginianus). In fact, numerous eastern parks that maintain cultural landscapes have reported significant increases in deer populations. Although high deer populations provide unique public viewing opportunities, many eastern parks are severely overpopulated and experiencing significant impacts on their natural and cultural resources.

White-tailed deer are native to Great Smoky Mountains National Park (GRSM or Park), and inhabit all of the Park. However, the highest density of deer is located in the Cades Cove area. Cades Cove is a cultural zone which uses agricultural management (haying and cattle grazing) to maintain open vistas and a cultural landscape.

The white-tailed deer herd in Cades Cove have undergone significant changes. Historically, very few deer existed in the Cades Cove area. However, with the establishment of the park, prohibition of hunting, a lack of natural predators, and agricultural practices that are beneficial to deer, the deer herd in Cades Cove steadily increased. Deer became extremely abundant until a die off in the early 1970's due to hemorrhagic disease (Fox and Pelton 1973).

By the early 1980's, the deer population in Cades Cove increased to pre-die off levels. In 1981, the Tennessee Wildlife Resources Agency (TWRA) was involved in a deer restoration program. The Park honored TWRA's request for deer, and from 1981 to 1984, 281 deer (242 females and 39 males) were captured in Cades Cove and relocated to other areas of east Tennessee.

In the late 1980's, the Cades Cove deer herd experienced another, although minor, die off due to hemorrhagic disease. Since that time the deer herd has not increased significantly. Recent nighttime roadside spotlight counts and other anecdotal observations suggest that the Cades Cove deer herd is relatively stable or slightly decreasing.

The deer herd in Cades Cove is an important component of the Parks ecosystem. Deer can be an important prey base for large carnivores, including black bears (Ursus americanus), bobcats (Lynx rufus), coyotes (Canis latrans), and the red wolf (Canis rufus). The deer herd also provides unique viewing and photographic opportunities to Park visitors and, therefore, has significant intrinsic value (Hastings 1986).

Because cultural management practices in Cades Cove are beneficial to deer, there is concern that the deer herd has not been in balance with the carrying capacity of the environment. The possibility of disease outbreaks and possible parasite transfer to and from domestic stock could result in significant die-off's. Habitat degradation including browse damage to native plants, shifts in tree species composition, and alteration of

community structure of a number of unique plants has also been a concern (Bratton 1979). Public heath concerns regarding disease transmission and deer/vehicle collision also are concerns at higher deer densities.

Deer populations that exceed the carrying capacity of their environment require herd control measures to alleviate negative impacts to the ecosystem. Determining if the Cades Cove deer herd is in balance with its environment, therefore, requires a comprehensive monitoring program that measures the density and health status of the population. By monitoring these population parameters, and conducting intensive monitoring programs when necessary, we can properly initiate corrective measures to rectify any herd health problems.

Objectives:

1) monitor the relative density of the white-tailed deer population in Cades Cove; and

2) determine and monitor the health status of the white-tailed deer population in Cades Cove.

A. NIGHTTIME ROADSIDE SPOTLIGHT COUNTS

Several methods (e.g., pellet counts, mark-recapture, daytime drive counts, roadside night counts, etc.) have been used in Cades Cove to estimate deer densities (Kiningham 1980, Wathen and New 1989). Although, absolute density estimates would provide the best information, the techniques are labor intensive

and expensive. However, population indices, such as nighttime roadside spotlight counts are inexpensive and useful in determining relative changes in the density of deer (i.e. whether the deer herd is increasing or decreasing). Nighttime roadside spotlight counts are preferable over daytime counts because they have less variability (Burst and Pelton 1978).

Materials

-map of Cades Cove with areas outlined (Fig. 1)
-data form (Fig. 2)
-2 spotlights (1 million candle power)
-cable that connects to the vehicle battery
-pickup truck

Personnel Requirements & Responsibility

Only three people are needed to conduct the survey; one person to drive and record data, and two people to spotlight and count deer (one for each side of the vehicle). The wildlife biologists coordinate the spotlight counts. The wildlife biologists are responsible for obtaining supplies, training personnel, determining responsibilities and schedules, data analysis, and preparation of an annual report.

Training of new field personnel can usually be conducted prior to the count. Training includes an overview of the spotlight count survey, field demonstration, and a review of data forms (Fig. 2), maps (Fig. 1) and data collection.

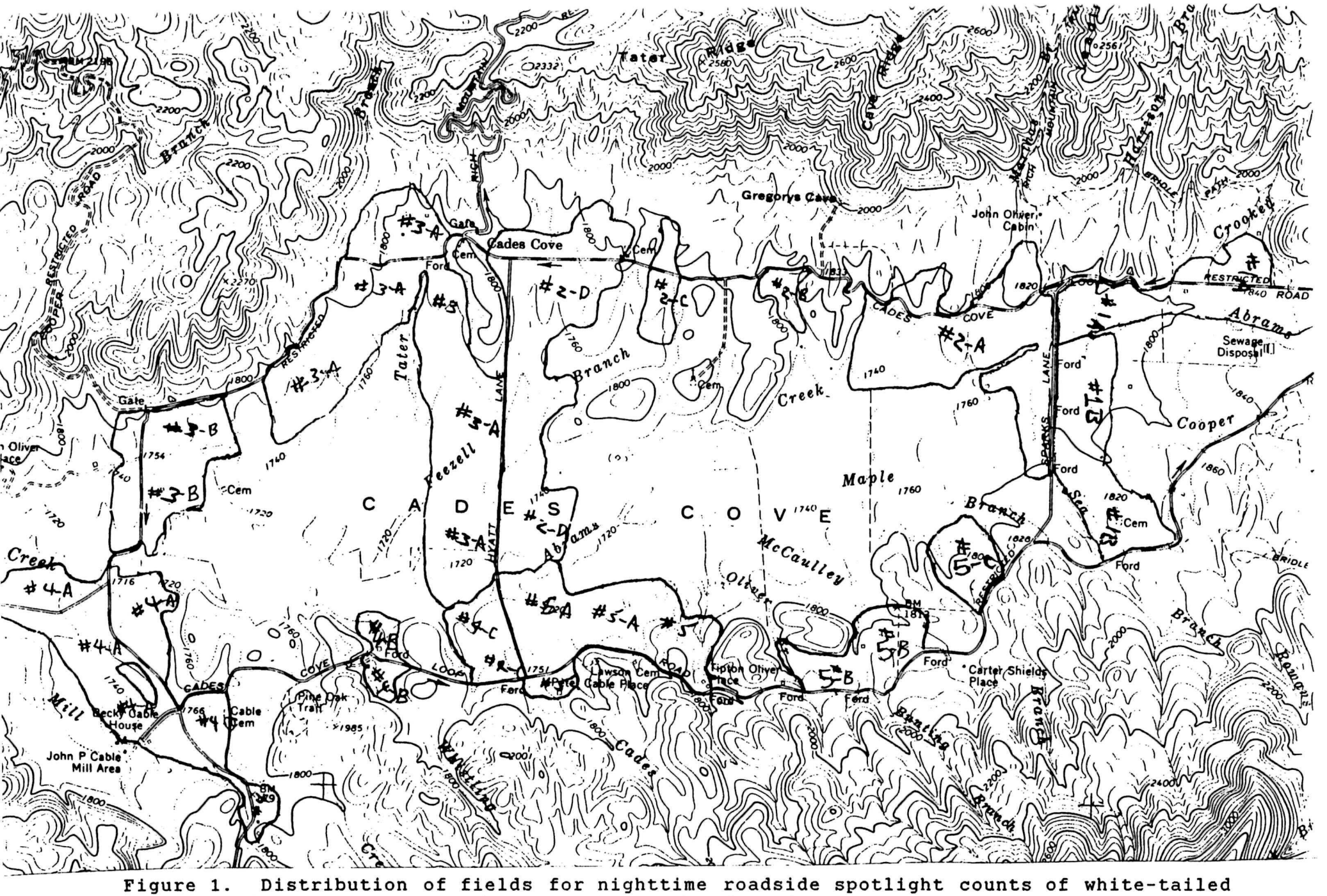

Figure 1. Distribution of fields for nighttime roadside spotlight counts of white-tailed deer in Cades Cove, Great Smoky Mountains National Park.

Figure 2. White-tailed deer roadside night count data sheet.

Date:_____ Observers:_____

Starting Time:_____ _____

Ending Time:_____ Moon Phase: FQ FM LQ NM

Official Sunset:_____ Spotlight (Candle Power)_____

Weather Data:

Temperature_____ Windy_____ Calm_____

Clear_____ Partly Cloudy_____ Cloudy_____

Rain_____ Snow_____ Fog_____

Comments:_____

_____

Number Observed In Area

Species	1	2	3	4	5	Total
DEER						
RACCOON						
BEAR						
COYOTE						
OPOSSUM						
SKUNK						

Comments:_____

_____

AMOUNT OF AREA SURVEYED:_____ (hectares)

ESTIMATED DEER DENSITY:_____ (deer/hectare)

Sampling Design

Roadside night counts are conducted on alternate weeks throughout the year. The survey begins approximately 0.5 hours after official sunset. The technique, which is a modification of the drive count method (Overton 1971), involves driving the 17.7 km Cades Cove Loop road and selected side roads and recording all deer observed (Wathen and New 1989). Using hand held spotlights (1 million candle power), an imaginary drive line is projected perpendicular to both sides of the road. As this line sweeps through fields, all deer that pass through are counted. Areas in which visibility is impaired by fog or other obstacles are deleted from a particular count. Observation of other wildlife also are recorded.

For simplicity of counting, the following five areas within Cades Cove have been defined (Fig. 1 and Fig. 2); 1) area 1 - fields east of sparks lane; 2) area 2 - fields west of sparks lane, east of hyatt lane and north of abrams creek; 3) area 3 - fields west of hyatt lane and north of abrams creek; 4) area 4 - field west of hyatt lane and south of abrams creek; and 5) area 5 - fields east of hyatt lane, west of sparks lane and south of abrams creek. Each primary area contain several fields that can be deleted from a count if visibility is impaired by fog or other obstacles.

Utilization of fields by deer in Cades Cove varies throughout the year (Wathen and New 1989). To account for seasonal variation among nighttime roadside counts, the following

seasons were defined: 1) Fall - September, October, November; 2) Winter - December, January, February; 3) Spring - March, April, May; 4) Summer - June, July, August (Kiningham 1980, Wathen and New 1989).

Data Management

Computerized databases, managed by the wildlife biologists, will be used for data entry and data analysis. Deer density estimates are derived by dividing the total number of deer observed by the total area surveyed (deer/hectare). Mean yearly density estimates can be compared to determine relative changes. Statistical analysis to compare densities between years and among seasons will be conducted using General Linear Models (GLM) (SAS 1985).

Quality control

Data will be collected by either NPS wildlife biologists, NPS wildlife biological technicians, or NPS volunteers. Field personnel will participate in a brief training seminar. Training is conducted by the wildlife biologists or wildlife biological technicians that are knowledgeable and have experience conducting nighttime spotlight counts. For each nighttime spotlight count, at least one participant will have previous experience conducting a survey and data collection. All spotlight count data will be compiled, stored and analyzed by the wildlife biologists.

B. DEER HEALTH CHECKS

Significant levels of disease are generally associated with a deer herd that is approaching or exceeding its carrying capacity (Eve 1981). However, nutritional deficiencies and infectious diseases may not be evident until the population has exceeded carrying capacity for several years and habitat degradation has occurred. Therefore, monitoring the physical condition and presence of infectious and parasitic diseases in white-tailed deer is an important component in determining the status of deer density relative to the habitat carrying capacity.

Materials

- first aid/emergency kit
- park radio with extra battery
- flashlights (C-cell and mini-mag)
- headlamps
- spotlights (1 million candlepower)
- portable 12 volt battery
- clipboard
- data sheet (Fig. 3)
- binoculars
- pneu dart rifle (model 193) with scope
- 1cc type C pneu darts
- green powder charges
- water
- bandanna
- Coveralls
- rubber boots
- rubber gloves
- knives
- cutting boards
- tree pruning shears
- sheet metal snips
- Centrifuge
- Cooler with ice or gallon jugs with pure Formalin
- String
- Ziplock bags (both quart and gallon sizes)
- deer aging chart
- Platform or spring scale
- small mailing scale (5 pound maximum)

- Alcohol/Glycerin (tick preservative)
- drug kit
    - drugs
        -Xylazine hydrochloride (450 mg/ml)
        -Telazol (416 mg/ml)
        -potassium chloride
    -sterile water
    - syringes (luer lock tips)
        -3 ml to load darts
        -20 ml used to administer potassium chloride
    - needles
        - 3 inch 18 ga (to administer potassium chloride)
        - 2 inch 20 ga (to load pneu darts)
        - 1.5 inch 20 ga Vacutainer
    - Vacutainer blood collection tube holder
    - Vacutainer blood collection tubes (100 X 16 mm)
    - cloth measuring tape (metric)
    - tweezers
    - scalpel
    - pencils/pens
    - emergency medical information (in case of accidental human injection)

Personnel Requirements & Responsibility

Deer health checks are conducted in cooperation with The University of Tennessee (UTK) wildlife diseases class. Guidance will also be provided by the Southeastern Cooperative Wildlife Disease Study (SCWDS). GRSM field personnel will consist of the wildlife biologists, wildlife biological technicians, student conservation association assistants, and NPS volunteers.

The wildlife biologists will coordinate the deer health checks. The wildlife biologists are responsible for training personnel, determining responsibilities, obtaining supplies, data analysis, and preparation of an annual report.

Individuals responsible for deer immobilization will be certified in wildlife immobilization (see NPS-77 for requirements). Field necropsy training and guidance is provided

by Dr. John New, instructor of the UTK wildlife disease class, as well as an individual from the SCWDS. Field necropsy training includes, determining physical condition ratings, collecting abomasum for abomasum parasites counts, collecting blood and tissue samples for hematological and serological profiles, collecting parasitic data, and pathologic assessments.

Sampling Design

Deer health checks are a technique which involves collecting deer and assessing their overall condition based several components including: mean abomasum parasite counts; overall physical condition; body weights; hematologic values; serologic profiles; parasitic data; and pathological assessment (W. R. Davidson person. commun).

Deer health checks are conducted biennially in late August or early September, usually within 1 or 2 days. Approximately 5-10 adult deer (i.e. $\geq$1 year of age) are collected, using free range capture. No more than two deer are selected from a particular field. Deer are free range darted using a combination of Telazol and Xylazine. Dosage recommendations are: Xylazine 2.5 mg/kg and Telazol 3 mg/kg (Nielsen and Beheler-Amass 1995). Immobilization drugs are superconcentrated (i.e. Telazol @ 416 mg/ml and Xylazine @ 450 mg/ml) to reduce the volume of drug and subsequent size of dart. Immobilized deer are humanely euthanized by injecting potassium chloride into the heart (Smith et al. 1986).

Anatomical measurements

Anatomic measurements (recorded in centimeters) are taken from each animal and include: total length (tip of snout to base of tail along curve of spine), head length (tip of snout to crown of head), jaw length, head circumference (over zygomatic arches), head circumference (over zygomatic arches), chest circumference (posterior to forelegs), height at shoulder (perpendicular distance from top of scapula to hooftip of extended forelimb), front foot length (carpus to hooftip), and rear foot length (fibular tarsal to hooftip). Antler measurements include number of points, antler beam circumference (2.5 cm above the pedicel), and antler beam length. Weights (recorded in pounds) are determined with either a platform or spring scale. Ages of deer are determined by tooth eruption and attrition (Severinghaus 1949).

Blood and Serum

Blood is extracted from the jugular vein of immobilized deer into 100 x 16 mm Vacutainer red top blood collection tubes using 20-gauge one-inch needles. Blood samples are refrigerated and allowed to clot. Samples are centrifuged within 24 hours after collection. Serum samples are separated, frozen and later banked at the University of Tennessee College of Veterinarian Medicine (UTCVM) for future disease monitoring. Deer serum samples will be available for determination of selected viral, bacterial, and rickettsial diseases such as Leptospirosis, Brucellosis,

Infectious bovine rhinotracheitis (IBR), Bovine virus diarrhea (BVD), Parainfluenza (PI_3), Epizootic hemorrhagic disease (EHD), Bluetongue (BT), and Lyme Disease.

Ectoparasites

Deer are surveyed for the presence of various arthropods that are common to white-tailed deer in the southeastern United States (Davidson and Nettles 1988). Ticks are commonly found around the ears, head, neck, inguinal, and perianal areas. Louse flies and lice are usually located in the axillary and inguinal areas. The number of arthropods are rated on a scale ranging from light (i.e. very few are located) to heavy (i.e. most of the body is covered with the parasite). Ectoparasites are collected and preserved in Alcohol/Glycerin, and later identified by and stored at the UTCVM.

Necropsy Examination

A detailed necropsy examination (Nettles 1981), including parasite recovery and abomasal parasite counts (APC's) (Eve and Kellogg 1977) is performed on each deer within 12 hours after collection (Appendix A and Appendix B). All major organs are examined for abnormalities that would indicate any previous or current health problems. Major organs are surveyed for endoparasites that are common to white-tailed deer in the southeastern United States (Davidson and Nettles 1988).

Endoparasites are collected and preserved in Alcohol/Glycerin, and later identified by and stored at the UTCVM.

During the course of the necropsy, the abomasum is removed, stored in a ziplock bag, and frozen. The abomasum is collected by gently pulling the viscera to the outside of the body. Using cord, the abomasum is tied just below its entrance into the small intestine. A second cord is tied around the small intestine approximately one inch below the first cord. The small intestine is cut between the two cords so that the abomasal contents will not be lost and the small intestine will not leak and contaminate the necropsy. Locate the juncture of the omasum and abomasum. The abomasum is tied off slightly above this juncture. Make sure you have all of the abomasum as this juncture is somewhat angular. A second cord is tied approximately one inch above the first. Again, cut between the two cords so that the contents of the abomasum will not be lost and the contents of the omasum will not leak and contaminate the necropsy. Samples are then placed in ziplock bag, frozen and shipped to the TWRA laboratory in Nashville, Tennessee, for analysis. Laboratory analysis is described in detail by Eve and Kellogg (1977) (Appendix B).

Physical condition ratings

Physical condition ratings are a coding system (none, light, moderate, heavy) based on body fat levels in the kidney, heart, pericardial, and tail (Stockle et al. 1978) (Appendix C) and are determined during the necropsy. The kidney fat index (KFI) is

determined by removing the kidneys and weighing them with the existing fat. Kidney fat is removed and the kidneys are weighed again. The KFI is determined by the following equation:

$$KFI = \frac{(((K1WF + K2WF)/2) - ((K1WOF + K2WOF)/2))}{(K1WOF + K2WOF)/2)}$$

where K1WF = kidney 1 with fat

K2WF = kidney 2 with fat

K1WOF = kidney 1 without fat

K2WOF = kidney 2 without fat

Data Management

Computerized databases, managed by the wildlife biologists, will be used for data entry and basic data analysis. Herd health parameters will be tabulated for each deer. Herd health and risk of mortality due to disease will be determined by collectively analyzing mean APC's, average body weight, physical condition indices, and large lungworm examinations. Other health parameters including parasite loads and gross lesions and abnormalities during necropsy also will be noted. A summary report with a series of tables and interpretive comments will be prepared.

Quality Control

Deer health check will be conducted in cooperation with the UTK wildlife disease class under the supervision of Dr. John New.

An individual(s) from the SCWDS will also assist with deer health checks by providing technical assistance as needed.

The wildlife biologists will be responsible coordinating and conducting the deer health checks. Data will be collected by NPS wildlife biologists, NPS wildlife biological technicians, NPS volunteers and students from the UTK wildlife disease class. The NPS staff and UTK students will have undertaken either college courses in mammalogy, wildlife diseases, etc. or will have previous experience performing field necropsies on white-tailed deer. The wildlife biologists also will be responsible for compiling and interpreting deer health check data and preparing the biennial report.

Literature Cited

Bratton, S. P. 1979. Impacts of white-tailed deer on the vegetation of Cades Cove, Great Smoky Mountains National Park. Proc. Annu. Conf. Southeast Assoc. Fish and Wildl. Agencies 33:305-312.

Burst, T. L. and M. R. Pelton. 1978. Some population parameters of the Cades Cove deer herd, Great Smoky Mountains National Park. Proc. Ann. Conf. Southeast Assoc. Fish and Wildl. Agencies 32:339-347.

Davidson, W. R. and V. F. Nettles. 1988. Field Manual of Wildlife Diseases in the Southeastern United States. Southeast. Coop. Wildl. Disease Study. Athens, Ga. 309pp.

Eve, J. J. 1981. Necropsy procedures. Pages 413-423 in W. R. Davidson, F. A. Hayes, V. F. Nettles, and F. E. Kellogg, eds. Diseases and Parasites of White-tailed Deer. Tall Timbers Research Station, Tallahassee, Florida, Misc. Publ. No. 7.

_____, and F. E. Kellogg. 1977. Management implications of abomasal parasites in southern white-tailed deer. J. Wildl. Manage. 41 (2):169-177.

Fox, J. R. and M. R. Pelton. 1973. Observations of a white-tailed deer die off in the Great Smoky Mountains National Park. Proc. Ann. Conf. Southeast. Assoc. Fish and Wildl. Agencies. 27:297-301.

Hastings, B. C. 1986. Wildlife-related perceptions of visitors in Cades Cove, Great Smoky Mountains National Park. Ph.D. Dissertation, Univ. of Tennessee, Knoxville. 259pp.

Kiningham, M. J. 1980. Density and distribution of white-tailed deer (Odocoileus virginianus) in Cades Cove, Great Smoky Mountains National Park. Unpubl. M.S. Thesis, Univ. of Tennessee, Knoxville. 93pp.

Nettles, V. F. 1981. Necropsy procedures. Pages 6-16 in W. R. Davidson, F. A. Hayes, V. F. Nettles, and F. E. Kellogg, eds. Diseases and Parasites of White-tailed Deer. Tall Timbers Research Station, Tallahassee, Florida, Misc. Publ. No. 7.

Nielsen, L. and K. Beheler-Amass. 1995. Chemical Immobilization of Animals. 4th ed. Safe-Capture International, Inc. Mt. Horeb, Wi. 102pp.

Overton, W.S. 1971. Estimating the numbers of animals in wildlife populations. R.H. Giles, Jr., ed., pp. 403-455. Wildlife management techniques, 3rd ed. The Wildl. Soc., Washington, D.C. 633pp.

Severinghaus, C. W. 1949. Tooth development and wear criteria of age in white-tailed deer. J. Wildl. Manage. 13:195-216.

Smith, A. W., K. A. Houpt, R. L. Kitchell, D. F. Kohn, L. E. McDonald, M. Passaglia, Jr., J. C. Thurmon, E. R. Ames. 1986. Report of the AVMA panel on euthanasia. J. Am. Vet. Med. Assoc. 188:252-268.

Statistical Analysis System Institute, Inc. 1985. SAS User's Guide: Statistics, Version 5 Edition. Cary, N.C. 956 pp.

Stockle, A. W., G. L. Doster, and W. R. Davidson. 1978. Endogenous fat as an indicator of physical condition of southeastern white-tailed deer. Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies 32:269-279.

Wathen, W.G. and J.C. New. 1986. The white-tailed deer of Cades Cove: population status, movements and a survey of infectious disease. NPS Research/Resources Mgt. Report SER-89/01.

APPENDICES

APPENDIX A

Necropsy Procedures (Nettles 1981)

2 *Necropsy Procedures*

VICTOR F. NETTLES
Southeastern Cooperative Wildlife Disease Study

INTRODUCTION

The primary purpose of most necropsy examinations is to determine the cause of sickness or death. Necropsy also is a valuable method of gathering research data or estimating the health of a deer population. The most desirable specimen for diagnostic purposes is a live animal which is displaying clinical signs. Deer recently dead or preserved by refrigeration for up to 48 hours postmortem are adequate in many instances. Unpreserved deer, particularly in hot weather, and frozen deer are less desirable. Gross examination, unfortunately, cannot always provide the diagnosis; therefore, it is important to obtain various samples for further examination by special procedures.

From the onset of the examination, the importance of record keeping cannot be overstated. Case history, clinical signs displayed, and necropsy findings should be recorded in legible, descriptive terms. Each animal should be assigned a number and all material labeled accordingly. Photographs often are desirable, and the investigator should strive for pictures of publishable quality.

Although diseases which are transmissible to humans are rare in white-tailed deer, precautionary measures should be practiced in handling animals and conducting postmortem examinations. Coveralls, vinyl aprons, and rubber gloves and boots should be worn as indicated. The aforementioned apparel, plus necropsy equipment and contaminated surfaces, should be cleansed with a disinfectant when work is completed. Disposal of carcasses and other potentially infective material should be by burning, rendering, or burying with lime. Such sanitation procedures protect not only humans, but susceptible livestock and wildlife as well.

EXAMINATION OF THE LIVE ANIMAL

When the investigator is presented with a live deer, every effort should be made to conduct a detailed clinical examination prior to euthanasia. This examination should include observations of the animal from a distance, a general physical examination, and special tests when feasible. Successful detection of the abnormal white-tailed deer is predicated on the diagnostician's knowledge of the normal. Time spent observing and handling healthy wild or penned deer is well invested when the knowledge gained is applied to a diagnostic situation.

The first step is to simply watch the deer without disturbing it. After a while, it usually is desirable to apply visual and auditory stimuli and to force the deer to move about. During the observation session the investigator should note the following: approximate age, sex, physical condition, skeletal conformation, hair coat, mental alertness, posture, gait, respiratory movements, appetite, consistency of the feces, and appearance of urine. External lesions and abnormal discharges from body orifices should be recorded.

After general observations have been made, it usually is desirable to restrain the deer for closer inspection and specific examinations. Manual restraint by two or three persons or injection of an immobilizing drug may be necessary. Xylazine (Rompun®, Chemagro) at dosages of 0.25 to 1.0 mg/lb is an excellent drug for deer in enclosures. Binding the legs with rope or nylon filament tape is helpful.

Once the deer is secured, the investigator can begin a general physical examination. Body temperature, heart rate, pulse, and respiratory rate are easy to measure in deer but difficult to interpret. All can become elevated by excitement; however, when deer are restrained by an immobilizing drug such as Xylazine these parameters can be depressed.[17] Palpation of the skeletal system and soft tissue should be performed as a preliminary check for injuries. Gross lesions and abnormal discharges can be examined in more detail, and special examinations such as the following can be applied as indicated.

1. Diagnostic therapy—The specific treatment for a suspected disease can be administered to the animal to help confirm cause of illness. The procedure probably is most applicable to toxicoses where antidotes are available;
2. Hematologic—Blood is easily obtained from the jugular vein. Blood cell counts and chemistry values are presented in Chapter 3. Serum for antibody titers can be collected at this time;
3. Microbiologic—Swab cultures for bacteriologic and virologic stud-

ies can be made from body orifices and cutaneous lesions. Crusts and hairs from skin lesions can be obtained to test for dermatophytes and *Dermatophilus congolensis*;

4. Neurologic—Reflexes such as flexor, palpebral, patellar, placing, and righting can be tested in deer. Opthalmologic examination should include pupillary response and visualization of the retina.[9] Electroretinographic examinations have been performed on fawns.[14] Cerebrospinal fluid can be obtained most easily at the atlanto-occipital space;
5. Parasitologic—Blood samples can be examined for parasites, and feces can be obtained from the rectum for direct smear, flotation, and Baermann examinations. Skin scrapings for mange mites or microfilaria may be indicated;
6. Radiographic—Standard veterinary techniques can be employed. A detailed thesis on the osteology of white-tailed deer is available for studies involving the skeletal system;[23] and
7. Stethoscopic—Auscultation of the trachea, thorax, and abdomen can be performed.

EXAMINATION OF THE DEAD ANIMAL

After the investigator has made all necessary observations on the live deer, the animal can be killed humanely. Guidelines have been set for this procedure,[25] but field conditions may dictate the use of a firearm or an overdose of an available immobilizing drug. Once the animal is dead, a second close inspection should be made of the body to detect external lesions, fractures, and abnormal discharges. Ectoparasites should be collected at this time. Ticks commonly frequent the ears, head, neck, inguinal, and perianal regions. Louse flies and lice often are found in the axillary and inguinal areas. Body weight should be obtained. Age of young fawns can be determined by measuring hoof growth since birth.[13] The age of adult deer can be determined by eruption and attrition of the lower premolars and molars.[24]

Skinning and Exposure of the Viscera

The next phase of the examination is to separate the carcass into various components for closer scrutiny. Many times a diagnosis can be reached during this disassembly, but organs first should be examined carefully *in situ*. Except for the skeletal system,[23] arteries of the front limb,[2] and muscles of the hind limb,[3] anatomical descriptions of the white-tailed

deer are lacking and the investigator is forced to rely upon prior experience with deer or other small ruminants. The equipment needed during necropsy may vary with the case and the preferences of the prosector. Important items include sharp boning knives, scapels, general surgery scissors, enterotome scissors, rat-toothed thumb forceps, small plain thumb forceps, bone cutting devices (tree pruning shears and sheet metal snips), large intestinal clamps, a spatula, bowls, trays, a 100 mesh screen, and various containers for samples obtained.

Removal of the skin should be a standard procedure since traumatic injuries often are disclosed by subcutaneous hemorrhages. It is convenient to first remove the head and skin it separately. The head is removed by cutting the throat region between the thyroid and cricoid cartilages of the larynx, with the cut extending to the ventral side of the atlanto-occipital joint. The spinal cord can be exposed, severed, and the atlanto-occipital joint can be disarticulated by dorsal overextension of the neck.

The headless carcass should be placed in lateral recumbancy, and the skin should be cut along the ventral midline from the neck to the rectum. Also, cuts should be made from the hoof to the ventral midline on the medial side of each leg. The skin is then separated from the cannon bone of each leg and cut free distally so that the skin from each leg can be used to pull the remainder of the hide from the limb. An assistant can be stationed across the table to hold the legs while the skin is pulled from the legs and body.

The carcass is then examined externally and placed with the left side down. The right foreleg can be reflected by a cut through the axillary region, and the right hindleg can be disjointed at the hip. The abdominal cavity is opened by cutting through the abdominal muscles of the right side. Caution should be used to avoid perforation of the gastrointestinal tract. The thoracic cavity is exposed with tree-pruning shears by parallel cuts through the right ribcage along the sternum and backbone. The pelvic cavity can be exposed in a similar manner by parallel cuts through the pelvis on each side of the pubic symphysis.

At this point the examiner can rate physical condition by use of parameters such as tail fat, musculature, kidney fat, heart fat, and pericardial fat.[27] Samples for microbiologic studies should be obtained at this time to minimize contamination due to handling. The viscera should be visually inspected *in situ*. The uppermost structures are moved gently to expose underlying organs. Anatomical displacements, inflammatory processes, and fluid accumulations should be noted. The omentum can

be removed for better exposure. Deer abdominal worms, *Setaria yehi*, often are found during examination of the serosal surface of the abdominal cavities.

Removal of the Viscera

The viscera are most easily removed in the following order:

1. Trachea, lungs, and heart—The thoracic viscera are removed by first freeing the trachea and esophagus from the neck region with scissors or knife. The esophagus is separated from the trachea and gently pulled caudad until it is attached only to the diaphragm. The examiner should then lift upward on the trachea and begin cutting the heart and lungs away from the mediastinal blood vessels and pleura. At this time, the thyroid gland and thymus should be examined, and the pericardial sac checked for excessive fluid. The heart, trachea, and lungs should be removed from the chest cavity *en masse*. The heart can be cut from the lungs and these organs can be set aside for later examination;
2. Liver—The liver can be trimmed from the hepatic ligaments, diaphragm, bile duct, and vessels with the aid of scissors or knife. Cuts should be made close to the liver to avoid puncturing the intestinal tract;
3. Omasum and abomasum—These organs should be pulled gently away from the rumen, and clamps or ligatures should be placed at the rumen-omasal junction and the pyloric sphincter of the abomasum. These organs are then removed and placed in a bowl for later processing;
4. Small intestine, pancreas, cecum, and large intestine—These organs can be removed from the abdominal cavity as a group by cutting the mesenteric arteries near the aorta. Ligation of the terminal colon usually is not necessary since the fecal pellets can be pushed away from the section to be severed. The pancreas should be separated from the duodenum;
5. Esophagus, rumen, reticulum, and spleen—The esophagus and rumen can be freed from the diaphragm and lifted from the body. The spleen should be bluntly separated from the rumen;
6. Kidneys, ureters, urinary bladder, and urethra—Each kidney can be removed from the sublumbar connective tissue and gently pulled caudad. The ureter can be seen as a thin tubule connecting the kidney to the urinary bladder. Removal of the urinary bladder and urethra can be accomplished with scissors. The penis in male deer should be examined; and

7. Female reproductive tract—The ovaries, uterus, and vagina can be removed by blunt and sharp dissection. More connective tissue can be left attached to one ovary than the other to distinguish right from left during later examination.

Examination of Individual Body Parts

At this time the animal has been subdivided into the following components: head, skin, lungs/trachea, heart, liver, abomasum/omasum, pancreas, small intestine/cecum/large intestine, spleen, esophagus/rumen/reticulum, kidneys, urinary bladder/urethra, ovaries/uterus/vagina, and carcass. Each component should now be examined in detail. Tissue samples for histopathologic studies can be obtained from each organ during these examinations and fixed in 10% neutral buffered formalin. Impression smears of various organs also can be taken. Materials for microbiologic and toxicologic studies may be collected as indicated. Such sampling can be done as necessary during each of the following special examinations:

1. Skin—The skin should be spread out on a flat surface with the hair side down and examined for hemorrhages, punctures, and subcutaneous nematodes, *Onchocerca cervipedis*. The testicles in the male and mammary gland in the female often are removed with the skin. These organs should be examined by palpation and sliced with a knife;
2. Head—Scrapings of the lacrimal fossae and auditory canals should be examined microscopically for mites.[15] Following this procedure the head is skinned. Examinations of the eyes, nasal turbinates, and cranial vault are augmented by clamping the skull in a special device.[26] The eyes are removed, leaving a tag of tissue on one to distinguish right from left. The cranial vault should be opened and the meninges exposed as described by Prestwood and Smith.[20] Meningeal worms, *Parelaphostrongylus tenuis*, and associated lesions frequently are found in the leptomeninges and venous sinuses. Nasal passages are examined by cutting and reflecting the nasal bones. The head is then removed from the vise, and the tongue and larynx are cut away from the mandibles and hyoid apparatus. Next, the mandibles are disarticulated. These components of the oral cavity should be washed and checked for lesions and pharyngeal bot fly larvae, *Cephenemyia* spp. *Gongylonema pulchrum* can be present beneath the mucosa of the lateral and dorsal surfaces of the tongue;
3. Lungs/trachea—The lung surfaces are rinsed and the color, weight,

and texture of the lungs are noted. Common lesions include hemorrhage, congestion, edema, traumatic damage, areas of consolidation, and emphysema. Next, the lungs are palpated gently to detect abnormally dense areas in the parenchyma. The trachea and bronchial passages are then opened with scissors. This step may reveal material such as froth, blood, rumen contents, or purulent exudate. A direct smear examination of bronchial mucus may reveal larvae and eggs of pulmonary helminths. Large lungworms, *Dictyocaulus viviparus*, can be observed by gross inspection of the airways and recovered by washing the lung over a 100 mesh screen;[21]

4. Heart—The pericardial sac should be removed and the epicardium should be washed of excess blood. After the exterior of the heart is evaluated for lesions, size, and shape, it can be opened by cuts extending from the ventricles into the atria and major vessels. The examiner should note the type of blood clots present (firm, serum, or unclotted) and wash the endocardial surfaces. The heart should be inspected for lesions such as hemorrhage, myocardial necrosis, valvular proliferation, and congenital anomalies. Then, the heart is sliced at 1 cm intervals to reveal deeper lesions;
5. Liver—Excess blood should be wiped from the capsule of the liver. Frequent lesions include fibrin depositions, fibrous scars, encapsulated *Setaria yehi*, cysts of *Fascioloides magna*, abscesses, and recent traumatic injuries. The liver should be sliced at 1 cm intervals to reveal deeper lesions. Total recovery of trematodes can be made through methods described by Foreyt and Todd.[11] The gall bladder is absent in white-tailed deer;
6. Abomasum/omasum—The omasum should be separated from the abomasum. The omasum is then opened, and the mucosa is washed with water. Frequent lesions are congestion, hemorrhage, ulcerations, and scars on the omasal leaves. *Gongylonema verrucosum* can occur in the epithelium.

When the abomasum is examined it often is desirable to recover and enumerate the nematode parasites.[10,18] For this reason excess fat should be trimmed from the greater and lesser curvatures of the abomasum, and the organ should be opened into a bowl. The mucosa is washed gently and searched for lesions. Small ulcers near the pylorus are a common lesion in white-tailed deer and are frequently observed in deer with hemorrhagic disease. Heavy burdens of *Haemonchus contortus* can be seen grossly and are associated with edema and hemorrhage of the abomasal mucosa. Medium stomach worms, *Apteragia* spp. and *Ostertagia* spp., produce indistinct nodules in the

epithelium. Total parasite recovery will require that the abomasal mucosa be scraped and washed thoroughly. Abomasal contents and mucosal scrapings should be preserved in about 4 L of 5% formalin for later examination;[10]

7. Pancreas—This organ should be examined visually, palpated and sliced at 1 cm intervals. Gross lesions of the pancreas are rare, and parasites have not been reported;
8. Small intestine/cecum/large intestine—If feces are needed for Baermann or other examinations, formed pellets can be obtained from the terminal colon. The gut can be most easily separated by first freeing and removing the cecum. The large intestine is then stripped away, leaving the small intestine attached to the mesentery. Each segment of the intestinal tract is split longitudinally and examined. A rack has been designed which augments examination of the small intestine.[8] Intestinal helminths can be recovered by washing the contents in a 100 mesh screen.[22] Gross lesions in the intestinal tract due to parasitism are infrequent;[22]
9. Spleen—Visual inspection, palpation, and slicing at 1 cm intervals are procedures used in examination of the spleen. Extreme engorgement of the spleen is an occasional gross finding in deer. Abscesses and various nodules are rare;
10. Esophagus/rumen/reticulum—The esophagus should be cut free from the rumen and split longitudinally. Few lesions have been observed in the esophagus although gullet worms, *Gongylonema pulchrum* are common.

    The rumen should be opened to note the composition of the ingesta. Area wildlife biologists usually can provide the investigator with information on the normal deer food habits for a given locality and season. Highly fluid or extremely firm rumen contents are abnormal. The next step is to remove the contents and wash the rumen and reticulum with water. Use caution if rumen flukes, *Paramphistomum liorchis*, are sought since these trematodes become detached from the rumen wall and become mixed with the ingesta. Acute rumen lesions include hemorrhage into the rumen, mucosal congestion, and ulcers. Chronic scarring and atrophic papillae are seen with convalescent hemorrhagic disease. *Gongylonema verrucosum* often are found beneath the rumen epithelium;
11. Kidneys—The kidneys should be divided into halves by cutting them longitudinally. The cortical and medullary regions are examined and the capsule is stripped from each half. Lesions which are common include pit-like scars on the capsular surface, infarcted

areas, and white streaks in the cortex. Unusual findings include unilateral renal atrophy, cysts, and calculi;

12. Urinary bladder/urethra—These organs are opened with scissors and visually examined. Lesions in these structures are rare;
13. Ovaries/uterus/vagina—Studies of reproductive organs of white-tailed deer have had considerable value in game management. Details on normal ovaries of white-tailed deer were reported by Cheatum.[5] The vagina and uterus should be opened with scissors to examine the mucosa. Lesions are uncommon in these organs. Fetal development, including a key to age groups, has been described;[1] and
14. Carcass—Major arteries, i.e., carotids, aorta, and ramifications from the aorta, should be opened and searched for arterial worms, *Elaeophora schneideri*. Lymph nodes attached to the carcass should be inspected and incised. Adrenal glands can be examined in a similar manner. Heavy musculature of the loins and thighs are trimmed from the carcass *en masse* and examined for the muscleworm, *Parelaphostrongylus andersoni*, by cutting the muscle into thin slices and searching for small hemorrhages.[19] Joint surfaces of all four limbs are inspected by disarticulation. Bone marrow can be obtained by breaking the femurs. Removal of the spinal cord is accomplished by trimming all muscle tissue from the vertebral column and then cutting the vertebral arches to expose the cord. Sheet metal snips work well on small deer, while tree-pruning shears are required to cut the vertebral arches on larger deer.

FORENSIC EXAMINATIONS

Law enforcement personnel occasionally need certain information obtained at necropsy for evidence. Bullets recovered from fresh wounds may be valuable to enforcement officials if poaching is suspected. Often the conservation officer needs an estimate of the time of death. Several parameters can be measured according to standard methods, i.e., body temperature, pupil diameter and luminosity of the eye, and rigor mortis.[6,12]

Sex determination in a headless carcass which has been skinned and trimmed may be required. Such information can be obtained in adult deer by the presence or absence of suspensory tuberosities where the penis is attached to the pelvis and by the shape of the pubic symphysis in cross-section.[28]

Many times a suspect carcass has been trimmed of all identifying

features or only boneless meat is found. It then becomes a question of what species was killed, i.e., deer, sheep, or goat. Unfortunately, a precipitin reaction is not genera specific.[7,16] Immunoelectrophoresis and immunodiffusion has been used to separate serum, dried blood, and meat of some species, but goat was not included in the study.[16] Other sophisticated techniques such as starch-gel electrophoresis[7] or polyacrylamide gel isoelectric focusing electrophoresis[4] have promise in differentiating deer from domestic meats. The availability of tests for distinguishing meat samples in each state and Canadian province as of 1973 has been compiled.[16]

LITERATURE CITED

1. Armstrong. R.A. 1950. Fetal development of the northern white-tailed deer (*Odocoileus virginianus borealis* Miller). Am. Midl. Nat. 43: 650–666.
2. Bisaillon, A. 1974. The major arteries of the shoulder and arm of the white-tailed deer *Odocoileus virginianus*, Rafinesque, 1832). Anat. Histol. Embryol. 3: 250–261.
3. Bisaillon, A. 1975. The musculature of the hip and thigh of the white-tailed deer (*Odocoileus virginianus*, Rafinesque, 1832). Anat. Anz. Bd. 137: 381–394.
4. Bunch, T.D., R.W. Meadows, W.C. Foote, L.N. Egbert and J.J. Spillett. 1976. Identification of ungulate hemoglobins for law enforcement. J. Wildl. Manage. 40: 517–522.
5. Cheatum, E.L. 1949. The use of corpora lutea for determining ovulation incidence and variations in fertility of white-tailed deer. Cornell Vet. 39: 282–291.
6. Coggin, J.L. and D.F. Mullins. 1976. Estimating time of death in white-tailed deer as an aid to wildlife law enforcement. Virginia Commission of Game and Inland Fisheries. Mimeo. 5 pp.
7. Dilworth, T.G. and J.A. McKenzie. 1970. Attempts to identify meat of animals by starch gel electrophoresis. J. Wildl. Manage. 34: 917–921.
8. Doster, G.L. 1972. A device to aid in examining the small intestine of deer for helminth parasites. J. Wildl. Dis. 8: 163–164.
9. Dukes, T.W. 1969. The ocular fundus of normal white-tailed deer (*Odocoileus virginianus*). Bull. Wildl. Dis. Assoc. 5: 16–17.
10. Eve, J.H. and F.E. Kellogg. 1977. Management implications of abomasal parasites in southeastern white-tailed deer. J. Wildl. Manage. 41: 169–177.
11. Foreyt, W.J. and A.C. Todd. 1976. Effects of six fasciolicides against *Fascioloides magna* in white-tailed deer. J. Wildl. Dis. 12: 361–366.
12. Gill, J.D. and D.C. O'Meara. 1965. Estimating time of death in white-tailed deer. J. Wildl. Manage. 29: 471–486.
13. Haugen, A.O. and D.W. Speake. 1958. Determining age of young fawn white-tailed deer. J. Wildl. Manage. 22: 319–321.
14. Howard, D.R., J.D. Krehbiel, L.D. Fay, J.N. Stuht and D.L. Whitehack. 1976. Visual defects in white-tailed deer from Michigan: six case reports. J. Wildl. Dis. 12: 143–147.
15. Kellogg, F.E., T.P. Kistner, R.K. Strickland and R.R. Gerrish. 1971. Arthropod parasites collected from white-tailed deer. J. Med. Ent. 8: 495–498.
16. Oates, D.W., C.W. Brown and D.L. Weigel. 1974. *Blood and Tissue Identification of Selected Birds and Mammals*. Parts I and II. Nebraska Game and Parks Commission, Lincoln, 105 pp.

17. Presnell, K.R., P.J.A. Presidente and W.A. Rapley. 1973. Combination of etorphine and xylazine in captive white-tailed deer: I. Sedative and immobilization properties. J. Wildl. Dis. 9: 336–341.
18. Prestwood, Annie K., F.A. Hayes, J.H. Eve and J.F. Smith. 1973. Abomasal helminths of white-tailed deer in southeastern United States, Texas, and the Virgin Islands. J. Am. Vet. Med. Assoc. 163: 556–561.
19. Prestwood, Annie K., V.F. Nettles and F.E. Kellogg. 1974. Distribution of muscleworm, *Parelaphostrongylus andersoni*, among white-tailed deer of the southeastern United States. J. Wildl. Dis. 10: 404–409.
20. Prestwood, Annie K. and J.F. Smith. 1969. Distribution of meningeal worm (*Pneumostrongylus tenuis*) in deer in the southeastern United States. J. Parasit. 55: 720–725.
21. Prestwood, Annie K., J.F. Smith and J. Brown. 1971. Lungworms in white-tailed deer of the southeastern United States. J. Wildl. Dis. 7: 149–154.
22. Pursglove, S.R., Annie K. Prestwood, V.F. Nettles and F.A. Hayes. 1976. Intestinal nematodes of white-tailed deer in southeastern United States. J. Am. Vet. Med. Assoc. 169: 896–900.
23. Rumpf, P.F. 1975. An osteology of the white-tailed deer. M.S. Thesis, Auburn University, Auburn, Alabama. 234 pp.
24. Severinghaus, C.W. 1949. Tooth development and wear as criteria of age in white-tailed deer. J. Wildl. Manage. 13: 195–216.
25. Smith, C.R. (Chairman). 1972. Report of the AVMA panel on euthanasia. J. Am. Vet. Med. Assoc. 160: 761–772.
26. Smith, J.F. 1972. A device to aid in examining the brain and meninges of deer for helminth parasites. J. Wildl. Dis. 8: 109–111.
27. Stockle, A.W., G.L. Doster and W.R. Davidson. 1978. Endogenous fat as an indicator of physical condition of southeastern white-tailed deer. Proc. Southeastern Assoc. Fish and Wildl. Agencies. 32: 269–279.
28. Taber, R.D. 1956. Characteristics of the pelvic girdle in relation to sex in black-tailed and white-tailed deer. California Fish and Game 42: 15–21.

APPENDIX B

Management Implications of Abomasal Parasite Counts in Southeastern White-tailed deer (Eve and Kellogg 1977)

MANAGEMENT IMPLICATIONS OF ABOMASAL PARASITES IN SOUTHEASTERN WHITE-TAILED DEER[1]

J. HAMMOND EVE, Southeastern Cooperative Wildlife Disease Study, College of Veterinary Medicine, University of Georgia, Athens 30602[2]

FOREST E. KELLOGG, Southeastern Cooperative Wildlife Disease Study, College of Veterinary Medicine, University of Georgia, Athens 30602

Abstract: Studies on parasites and diseases of white-tailed deer (*Odocoileus virginianus*) in the southeastern United States were conducted from 1961–72. The number of abomasal parasites infecting deer was found to be closely associated with specific herd parameters. Methods were developed and guidelines established for using the intensity of abomasal parasite infections as an index to deer density. The results of this study should augment current procedures employed for appraising deer populations as related to carrying capacity.

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The white-tailed deer is capable of increasing in population density to the point of degrading its habitat. Since sport hunting now is the most widespread and manageable impediment to herd growth, a major management goal is to achieve timely, adequate harvests. It has long been obvious that overpopulation can be a very local phenomenon (Leopold et al. 1947), but now that white-tailed deer virtually blanket the eastern United States, and overpopulated areas are more numerous than ever before, a rapid herd assessment technique is needed.

As herd density progresses toward overpopulation, there are well recognized attendant events. The most palatable food species decrease in frequency, browse lines develop (Leopold et al. 1947:163), reproduction is impaired (Verme 1969), body size declines, antler development is impaired, and spike bucks predominate in the 1½ year age class (French et al. 1955:3–4, 18). This study of southeastern deer concerns the relationship between deer density and intensity of infection by abomasal parasites.

In appraising this paper the reader is requested to bear in mind that the "science" of deer management is imprecise as it is actually practiced. The intensive methodology theoretically at the disposal of the deer biologist usually yields to more subjective evaluations that fall within the financial capabilities of an agency (Murphy 1968:7). Thus it has been necessary to use some "soft" data. The conclusions, in the authors' opinion, are sufficiently modest to be warranted by these data. The technique described in this paper is being employed successfully in many of the southeastern states. Current efforts to explain why it works must be somewhat speculative until further research has been completed.

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[2] Present address: Oklahoma Department of Wildlife Conservation, 1801 N. Lincoln, Oklahoma City 73105.

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MATERIALS AND METHODS

Deer utilized in this study were products of the gamut of habitat types, population levels, hunting methods, and management practices, as evidenced by the varied geography and diverse hunting regulations of the states in which the study was conducted. Several herds were selected to obtain basic parasitologic data on animals considered to be healthy. Other deer were examined in compliance with requests from state wildlife agencies to evaluate the health of particular populations. Varying degrees of competition existed between deer and domestic livestock on some study areas.

From the summer of 1961 through the winter of 1972, 939 white-tailed deer were necropsied. Endoparasites were identified and counted, and pathological lesions were evaluated. These animals were taken during all seasons from 69 localities in 13 southeastern states. Most deer were collected by shooting, although some were trapped and a few had been killed by automobiles. From 1961 through 1966, 10 deer usually constituted a standard sample; but afterwards, sample size was reduced to 5. Efforts were made to select yearling or older deer without regard to sex; however, in a few instances fawns were included in samples. The weight, sex and age (Severinghaus 1949) of these animals were determined by SCWDS personnel.

Deer population levels on each collection site were rated by state biologists using the following scale: (a) suboptimal density-number of deer less than carrying capacity; (b) optimal density-number of deer approximately equals carrying capacity; and (c) overpopulated density-number of deer exceeds carrying capacity. Carrying capacity, as used herein, is defined as the maximum number of deer that can be sustained in a given locality on a long-term basis without deterioration of the range and without impairing the health of the animals. Biologists did not have parasite data available when making their appraisals.

Methods used by biologists to evaluate deer densities in each instance included most or all of the following: amount of browsing on index plants, annual changes in plant frequency and distribution on a single area and comparisons among areas; agricultural crop damage; length of time seasonal food supplies last (e.g., acorns); general observations on deer numbers; history of the area and length of time since deer were introduced; track counts; antler development; fat levels; body size; reproduction; and general biological experience over a period of years of working on game management areas and observing deer and habitat.

Details on deer collection procedures, general necropsy techniques, and the distribution and prevalence of the species of abomasal parasites have been reported elsewhere (Prestwood et al. 1970, 1973).

Abomasal parasites were collected as follows: (1) after the abdominal cavity was opened, the abomasum was isolated from other viscera by ligation or clamping and removed; (2) the abomasum then was placed in a deep, round bottomed 1 gallon pan and opened longitudinally; (3) a metal spatula was used to scrape the abomasal contents and the mucosa into the pan; (4) fresh water was used to wash into the pan all remaining stomach contents from the abomasum, hands, and tools; and (5) the pan contents were poured into a 1 gallon plastic jug and preserved by adding 13 ounces of 100 percent formalin. The jug

then was filled to capacity with water for storage.

Steps leading to evaluation of parasite fauna from the abomasum were as follows: (1) jug contents were poured into a 100 mesh U.S. Standard sieve and washed with fresh water; (2) retained material was transferred to a graduated Erlenmeyer flask, diluted with water to 1000 ml, thoroughly mixed by shaking, and quickly poured into a 50 ml vessel with handle attached which had been placed within a 1000 ml beaker; and (3) the 50 ml aliquot then was removed and poured portion by portion into a gridded petri dish and examined under magnification (7 to 30×). All worms as large or larger than adult-size *Trichostrongylus* spp. (small stomach worms) were removed, counted, and stored in 5 percent formalin for later identification.

When adult-size worms per aliquot numbered 25 or less, 3 aliquots were taken and a mean was computed; if more than 25 were present, the first aliquot alone was used. The number of adult-size worms per aliquot was multiplied by 20 to obtain an estimate of the total number. Ten or more males were cleared in phenol for species identification.

A standard term, APC (Abomasal Parasite Count) was established to express the average number of adult-size abomasal parasites from 5 or more deer, 1 year of age or older, collected without conscious selection, within 1 month, from a specific locale. In most instances the 5 or 10 deer were collected within a single 12-hour period.

After logarithmic transformation of data from all areas, Student's T-test was used to compare numbers of abomasal parasites in deer representative of suboptimal, optimal, and overpopulated density categories. Table 1 was prepared by fitting a log-normal curve to each set of data on average numbers of abomasal parasites in collections from the 3 population levels; probabilities then were calculated under the assumption that the 3 levels were equally represented.

Table 1. Percentage probability that, for a given Abomasal Parasite Count (APC), the sampled deer herd had attained the designated population density.

	% Probability		
APC*	Overpopulated	Optimal	Suboptimal
200	0	48	52
400	1	51	49
600	9	57	34
800	26	54	20
1,000	45	45	10
1,200	59	36	5
1,400	68	29	3
1,600	74	25	2
1,800	77	22	1
2,000	80	20	0
2,200	81	19	0
2,400	82	18	0
2,600	83	18	0
2,800	83	17	0
3,000	83	17	0

* APC values represent the average number of adult abomasal parasites from 5 or more deer, 1 year of age or older, collected randomly within 1 month from a given locality. Collections were made during all seasons.

On 6 of the 69 sites collections were made quarterly. These sites were used to evaluate possible seasonal influences in parasite burdens. Two were located in mountainous terrain, viz., Daniel Boone W.M.A., Caldwell Co., North Carolina, and Choccolocco W.M.A., Calhoun Co., Alabama; 2 in piedmont, viz., A. P. Hill Military Reservation, Caroline Co., Virginia, and Forks G.M.A., McCormick Co., South Carolina; and 2 in the coastal plain, viz., Ft. Stewart, Liberty Co., Georgia, and Eglin Air Force Base, Walton Co., Florida.

Experimental design for the seasonal study originally entailed collecting 5 deer 4 times per year (spring, summer, fall, and winter) from each of 6 sites for a period of 3 years (1967 to 1970). Public opinion later decreed collections on Eglin A.F.B. and Daniel Boone W.M.A. be discontinued after 2 years, otherwise, collections were completed as described.

Table 2. Seasonal changes in APCs of white-tailed deer from Daniel Boone W.M.A., Caldwell Co., N.C.; Choccolocco W.M.A., Calhoun Co., Ala.; A. P. Hill Military Reservation, Caroline Co., Va.; Forks G.M.A., McCormick Co., S.C.; Ft. Stewart, Liberty Co., Ga.; and Eglin Air Force Base, Walton Co., Fla.

Collection Site	Average Number of Abomasal Parasites in a Five Deer Collection											
	1967				1968				1969			
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
D. Boone	298	1011	295	574	470	804	601	687				
Choccolocco	1076	1905	1781	243	712	2358	682	317	900	3108	999	362
A. P. Hill	719	1060	736	208	535	1298	343	1063	2129	1696	1213	722
Forks	798	1192	1939	1418	1263	1957	2563	601	1190	2984	3669	695
Ft. Stewart	1936	1376	934	1540	1124	1316	1574	1861	2143	1459	1523	1120
Eglin	472	863	463	679	761	193	1146	668				

Analyses of data from these 6 areas (Table 2) were carried out in logarithms of total parasites. The form of analysis was that of a factorial experiment with 2 fixed effects to include area and season, with years comprising a random effect. Analyses were conducted on each area separately. Separate analyses were conducted for large, medium, and small stomach worms.

RESULTS

The parasites recovered, listed in order of decreasing prevalence, were as follows: medium stomach worms—*Skrjabinagia odocoilei, Ostertagia mossi*, and *O. dikmansi*; large stomach worm—*Haemonchus contortus*; and small stomach worms—*Trichostrongylus askivali, T. axei*, and *T. dosteri*. Only 15 of the 939 deer examined were free of abomasal parasites. The prevalence and distribution of these abomasal parasites were reported previously (Prestwood et al. 1973).

Of the 69 deer populations that comprised this study, game biologists considered 12 to be at suboptimal density; 27 at optimal density; and 30 overpopulated. When numbers of abomasal parasites were correlated with the biologists' evaluations of deer density on these areas, deer in the suboptimal category were found to harbor an average of 389 adult worms; deer in the optimal category averaged 745 adult worms; while deer in the overpopulated category averaged 1,573 adult worms.

Statistical analysis of abomasal parasite counts from the 3 population density levels disclosed highly significant differences ($P < 0.01$) when comparing suboptimal or optimal with overpopulated density categories. Differences between suboptimal and optimal were not significant.

Table 1, derived from wildlife biologists' evaluations of deer habitat, suggests the percentage probability that a herd with a specific APC was within one of the three prescribed population levels, assuming the 3 levels to be equally represented. This table indicated that an APC of 400 reflects a 49 percent probability that the herd sampled was in the suboptimal category and a 51 percent probability that it was in the optimal category. Thus, around 400 was considered the transition area between these 2 population levels. Similarly, an APC of approximately 1,000 became the transition area between optimal and overpopulated deer densities. Quantification of the entire range of necropsy findings was beyond the scope of this study. Trends, nonetheless, were apparent. Where APCs were high, in many instances mortality from other causes had or soon occurred. Where APCs were low, with a single exception, no serious disease problems were found.

When the 6 areas were examined individually to detect seasonal differences in parasite burdens, 2 showed significant differences ($P < 0.05$) among seasons (Table 2). On the Choccolocco W.M.A., Alabama, parasite burdens were highest in summer, and next highest in fall; while on the Forks G.M.A., South Carolina, burdens were highest in fall, and next highest in summer. Seasonal fluctuations of slightly less magnitude also occurred on the A. P. Hill Military Reservation, Virginia, but the peak parasite burdens were earlier than on the Choccolocco and Forks areas.

On 2 collection sites, viz., the Daniel Boone W.M.A., North Carolina, and Ft. Stewart, Georgia, seasonal patterns were not consistent, and at Eglin A.F.B., Florida, stomach worm numbers were highest in summer and lowest in fall in 1967, and summer lowest and fall highest in 1968. Generally, parasite levels were higher in summer and fall and lower in winter and spring.

In studying abomasal parasite/herd density relationships, separate analyses for small, medium, and large stomach worms revealed that additional relevant information was not gained by using individual species counts as opposed to total counts.

DISCUSSION

Subclinical parasitism, where the host shows no overt signs of distress, is ubiquitous in deer populations of the southeastern United States. At any specific time, each deer herd occupies some point within a parasitic *disease spectrum*. Low density populations have only token infections with abomasal parasites, but as deer population density increases, the intensity of infection with abomasal parasites increases.

Direct relationships between host density and parasitism have been described for several other animals. In studying the effects of stocking rates on parasitisms in beef cattle, Ciordia et al. (1971) established a direct relationship between cattle density and the number of gastrointestinal nematodes. Padaiga and Marma (1970) reported that fecal examinations of roe deer (*Capreolus capreolus*) suggested the level of infection with coccidia and strongylids was directly correlated with population density. Dunsmore (1971) demonstrated that liver coccidiosis among rabbits (*Oryctolagus cuniculus*) was density dependent.

Whether epizootics occur depends on the virulence of the disease producing organism, rapidity of transmission; and host resistance. Ease and rapidity of transmission increase with the density of host populations, and overcrowding often lowers the vigor of hosts so that they become more susceptible (Kendeigh 1961:228). Since a high APC usually is associated with high host density and frequently with overcrowding, a high APC implies an increased likelihood of losses from various other agents. The importance of APC in this regard is best illustrated through some diverse situations encountered during this study.

The numerous studies of overtly diseased deer herds have suggested that high APCs usually presage mortality; but, except for *H. contortus*, abomasal parasites are not the primary disease agent.

An episode involving *H. contortus*, the most pathogenic stomach worm of southeastern whitetails, should serve to illustrate the outcome of heavy infections of this species in deer. Overcrowding during high water levels in the Everglades (Collier County, Florida) resulted in extensive mortality. Deer were examined by the Diagnostic Laboratories Section, Division of Animal Industry, State Department of Agriculture, at Kissimmee, Florida, and the SCWDS. Haemonchosis was the cause of mortality. Infections averaged more than 2,000 *H. contortus* per deer. Hematocrit determina-

tions showed the animals to be markedly anemic.

In southeastern deer herds the most frequently encountered parasitic disease associated with high APCs involved 3 species of worms all of which at some stage occurred in the lungs. Large lungworms (*Dictyocaulus viviparus*) occurred in about 30 percent of the deer examined (Prestwood et al. 1971), while parasites of the genus *Parelaphostrongylus* occurred in about 60 percent (Prestwood and Smith 1969, Prestwood et al. 1974). These parasites, separately or in mixed infections, produced lesions ranging from mild bronchitis and peribronchitis with low levels of *D. viviparus* to fatal interstitial pneumonia where heavy infections of one or both of *P. tenuis* and *P. andersoni* also were involved. Detailed descriptions of *P. andersoni* lesions were given by Nettles and Prestwood (1976). Migrating larvae of *Parelaphostrongylus* spp. have been associated with "winter kills" of white-tailed deer in New York State (Cheatum 1949) and with interstitial pneumonia by other workers (Goble 1941).

One of the many incidents involving lungworm infection demonstrates the potential of APC as an early warning device. In Desha County, Arkansas, sick deer were reported by sportsmen and biologists. Subsequent examination of 5 deer revealed an APC above 3,000. Extensive pleuritis and pneumonia associated with *D. viviparus* and *Parelaphostrongylus* spp. infections were present. Before corrective measures were taken, widespread mortality occurred. Verminous pneumonia was diagnosed as the immediate cause of deaths. Annual APC monitoring in this instance would have alerted biologists to increasingly hazardous conditions.

A similar development involving an entirely different type of infectious agent occurred in the Mississippi River flood plain (Kellogg et al. 1970). Five deer collected from a hunt club within the endemic anthrax belt had an APC in excess of 4,000. Herd reduction was recommended on this and 2 adjacent hunt clubs where similar high deer densities existed. The club in question allowed their deer herd to increase, but members of the 2 adjacent clubs drastically reduced deer populations on their areas. Fifteen months later anthrax erupted in the higher deer population and inflicted from 60 to 90 percent mortality within 2 weeks. Significant mortality did not occur on the adjacent hunt clubs where deer density had been reduced.

After the original 69 area study was terminated in 1972, the Mississippi River basin became inundated in the spring of 1973, providing an unusual opportunity to investigate APC response to rapid crowding. For weeks, encroaching flood waters concentrated deer onto ever-shrinking islands. Significant numbers of deer were dying from a variety of stresses. The APC in this situation exceeded 12,000. Prior experience had shown that the maximum APC likely to be encountered in the Southeast under "normal" circumstances would be less than 5,000 before mortality reduced the herd and the APC.

The examples thus far presented relate to high density deer populations, where interpretation of APC values can be made with confidence. As lower APCs are encountered, however, evaluations must incorporate additional biological parameters. One factor of paramount importance is seasonal fluctuations in infection intensity. This probably occurs in varying degrees throughout most of the Southeast.

Recent studies by Canadian workers (Baker 1974, R. C. Anderson, personal communication) have shown that third stage larvae ingested by deer during cold weather molt to fourth stage, but then may enter a

period of dormancy in the abomasal wall rather than develop into adults. There is evidence that this dormancy ends in the spring when the larvae mature and initiate the summer cycle of transmission. The time of year in which abomasal samples are collected therefore is important. Mid-summer to early fall (July, August, September) is a critical period for southeastern deer due to changes in the food supply (Quicke and Bentley 1959, Maynard and Loosli 1969: 18), and collections made during this period usually reflect higher APC values than during any other season. This would be the most appropriate time to determine the APC in order to minimize the seasonal variable.

Generalizations concerning biological relationships rarely fail to have a few exceptions. Some instances where the APC relationships varied from the predominant pattern described herein have been encountered. For instance, the large stomach worm is a significant disease agent in itself (Foreyt and Trainer 1970, Prestwood and Kellogg 1971). Where an average of 1,000 or more *H. contortus* are encountered, mortality of adult deer may be in progress, and the next fawn crop probably will be depleted from *Haemonchus* infections alone.

It can be anticipated that collections made during or soon after a period of significant deer mortality would show an elevated APC, yet herd density may have been reduced adequately. If an area has been flooded for an extended period, the APC may indicate overpopulation for several months after the water has subsided. An APC may be outdated if appraisals are made prior to widespread ecological changes, such as burning or other types of land management programs that substantially alter carrying capacity. Where supplemental feeding or agricultural crops become an integral part of the deer's diet, the APC may be suppressed, thus accurately reflecting population level relative to available food. It is not safe to assume that an APC representing 1 locality necessarily applies to other nearby localities.

Table 3. Implications of APC values for samples taken from white-tailed deer during July, August and September.

APC	Deer Population Status
<500	Below carrying capacity. Herd increase appropriate.
500–1,500	Within carrying capacity. Hold at present level.
>1,500	Exceeds carrying capacity. Herd reduction needed, more so as higher APC values are encountered. Mortality risk high.

A series of APC determinations during the course of such events as described above has not been made, so it is not known exactly how long it would take the APC to adjust to the current herd status. The seasonal studies show that high APCs can develop in 4 months, and can subside in an equal period.

Suggested guidelines for interpretation of APC values are offered in tables 1 and 3. Table 1 was constructed from pooled data from all seasons and all areas. Since the seasonal studies indicated that APCs of some high density herds were suppressed during winter, it appeared that the technique would be even more reliable if APC determinations were made only during the seasonal peaks. Hence Table 3 was compiled for samples taken during July, August, and September, and the figures consequently are higher than those in Table 1. Since parasite dynamics are influenced by many ecological factors, general interpretations may have to be modified for local use, and inferences developed in the Southeast may not be applicable in other regions of North America.

Before a parasite or group of parasites can be used as an index to reflect relative host density, specific criteria must be met.

The index parasites must be virtually ubiquitous, they must be host specific, infection intensity must be directly related to host density, and the parasites probably should have a direct life cycle. The medium stomach worms commonly found in southeastern whitetails meet these criteria. The large and small stomach worms deviate from these requirements to an inconsequential extent, thus total abomasal parasite infection provides essentially the same guidelines as interpretations based only on medium stomach worms. Uses of this technique in other areas have not been explored.

The APC technique can complement, but not replace, standard methods for evaluating white-tailed deer herds. Additional research may be necessary for further development and refinement of this procedure for local application.

LITERATURE CITED

BAKER, M. R. 1974. Seasonal changes in abomasal worms (*Ostertagia* spp.) in white-tailed deer (*Odocoileus virginianus*) at Long Point, Ontario. M.S. Thesis. Univ. of Guelph, Guelph, Ontario. 65pp.

CHEATUM, E. L. 1949. A contribution to the life-history of the deer lungworm *Leptostrongylus alpenae* (Nematoda: Metastrongylidae) with observations on its incidence and biology. Ph.D. Thesis. Univ. of Michigan, Ann Arbor. 61pp.

CIORDIA, H., W. E. NEVILLE, JR., D. M. BAIRD, AND H. C. MCCAMPBELL. 1971. Internal parasitism of beef cattle on winter pastures: level of parasitism as affected by stocking rate. Am. J. Vet. Res. 32(9):1353–1358.

DUNSMORE, J. D. 1971. A study of the biology of the wild rabbit in climatically different regions in eastern Australia. IV. The rabbit in the south coastal region of New South Wales, an area in which parasites appear to exert a population-regulating effect. Aust. J. Zool. 19 (4):355–370.

FOREYT, W., AND D. O. TRAINER. 1970. Experimental haemonchosis in white-tailed deer. J. Wildl. Dis. 6(1):35–42.

FRENCH, C. L., L. C. MCEWEN, N. D. MAGRUDER, R. H. INGRAM, AND R. W. SWIFT. 1955. Nutritional requirements of white-tailed deer for growth and antler development. Pennsylvania State Univ. Agric. Exp. Stn. Bull. 600.

GOBLE, F. C. 1941. Tissue changes in white-tailed deer (*Odocoileus virginianus borealis*) accompanying natural infections of lung-worms (genera Protostrongylus and Dictyocaulus). J. Wildl. Manage. 5(2):141–158.

KELLOGG, F. E., A. K. PRESTWOOD, AND R. E. NOBLE. 1970. Anthrax epizootic in white-tailed deer. J. Wildl. Dis. 6(4):226–228.

KENDEIGH, S. C. 1961. Animal ecology. Prentice-Hall, Inc., Englewood Cliffs, N.J. 468pp.

LEOPOLD, A., L. K. SOWLS, AND D. L. SPENCER. 1947. A survey of overpopulated deer ranges in the United States. J. Wildl. Manage. 11(2): 162–177.

MAYNARD, L. A., AND J. K. LOOSLI. 1969. Animal nutrition. 6th ed. McGraw-Hill Book Co., New York. 613pp.

MURPHY, D. A. 1968. Deer range appraisal in the midwest. Pages 2–10 *in* White-tailed deer in the midwest. U.S. Dept. Agric. For. Serv. Res. Paper NC-39. 34pp.

NETTLES, V. F., AND A. K. PRESTWOOD. 1976. Experimental *Parelaphostrongylus andersoni* infections in white-tailed deer. Vet. Pathol. 13: 381–393.

PADAIGA, V. I., AND B. B. MARMA. 1970. (Invasion of the roe deer with parasites related to population density and conditions of life.) Zool. Zhur. 49(2):283–287. English Summary.

PRESTWOOD, A. K., F. A. HAYES, J. H. EVE, AND J. F. SMITH. 1973. Abomasal helminths of white-tailed deer in southeastern United States, Texas, and the Virgin Islands. J. Am. Vet. Med. Assoc. 163(6):556–561.

———, AND F. E. KELLOGG. 1971. Naturally occurring haemonchosis in white-tailed deer. J. Wildl. Dis. 7(2):133–134.

———, V. F. NETTLES, AND F. E. KELLOGG. 1974. Distribution of muscleworm, *Parelaphostrongylus andersoni*, among white-tailed deer of the southeastern United States. J. Wildl. Dis. 10(4):404–409.

———, AND J. F. SMITH. 1969. Distribution of meningeal worm (*Pneumostrongylus tenuis*) in deer in the southeastern United States. J. Parasit. 55(4):720–725.

———, ———, AND J. BROWN. 1971. Lungworms in white-tailed deer of the southeastern United States. J. Wildl. Dis. 7(3):149–154.

———, ———, AND W. E. MAHAN. 1970. Geographic distribution of *Gongylonema pulchrum, Gongylonema verrucosum*, and *Paramphistomum liorchis* in white-tailed deer of the southeastern United States. J. Parasit. 56(1): 123–127.

QUICKE, G. V., AND O. G. BENTLEY. 1959. Lignin and methoxyl groups as related to the decreased digestibility of mature forages. J. Anim. Sci. 18(1):365–373.

SEVERINGHAUS, C. W. 1949. Tooth development and wear as criteria of age in white-tailed deer. J. Wildl. Manage. 13(2):195–216.

VERME, L. J. 1969. Reproductive patterns of white-tailed deer related to nutritional plane. J. Wildl. Manage. 33(4):881–887.

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APPENDIX C

Endogenous Fat as an Indicator of Physical Condition of Southeastern White-tailed Deer (Stockle et al. 1978)

ENDOGENOUS FAT AS AN INDICATOR OF PHYSICAL CONDITION OF SOUTHEASTERN WHITE-TAILED DEER[1]

ARTHUR W. STOCKLE, Southeastern Cooperative Wildlife Disease Study, Department of Parasitology, College of Veterinary Medicine, University of Georgia, Athens 30602[2]

GARY L. DOSTER, Southeastern Cooperative Wildlife Disease Study, Department of Parasitology, College of Veterinary Medicine, University of Georgia, Athens 30602

WILLIAM R. DAVIDSON, Southeastern Cooperative Wildlife Disease Study, Department of Parasitology, College of Veterinary Medicine, University of Georgia, Athens 30602

Abstract: Data were collected from 440 white-tailed deer (*Odocoileus virginianus*) throughout much of the southeastern United States in order to determine relationships between specific fat indices and overall physical condition. Specific criteria were presented for evaluating physical condition of white-tailed deer. An improved method for measuring the amount of bone marrow fat was described. The employment of various fat reserves as indicators of physical condition indicated that kidney fat was superior to other indices. Heart and pericardial fat were found to be nearly as favorable as kidney fat in all seasons except winter. Limited data showed tail fat to be a favorable indicator of physical condition for winter and spring. Femur marrow fat content, by itself, was not a reliable indicator of physical condition.

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A number of investigators have used fat deposits in evaluating physical condition of wild ruminants. Cheatum (1949) described visual criteria for estimating bone marrow fat which he utilized as an index for physical condition of winter-killed deer in the Adirondack region of New York. His hypothesis that bone marrow fat accurately reflected physical condition was widely accepted and was expanded to include seasons other than late winter and early spring. Technique development progressed to include quantitative measurements of bone marrow fat (Greer 1968, Neiland 1970, Verme and Holland 1973). The misuse and limitations of bone marrow analyses led to the examination of other endogenous fat centers. While some techniques continued to be of a qualitative nature (Harris 1945, Riney 1955), others were quantitative (Riney 1955, Ransom 1965, Bear 1971).

Harris (1945) and Riney (1955) postulated the following order of fat utilization in deer: first the rump fat; followed by subcutaneous fat; fat around the kidneys, intestines, stomach, and heart, in that order; and finally, bone marrow fat. Deposition of fat was in the reverse order of absorption (Harris 1945, Riney 1955). Cheatum (1949) reported that bone marrow fat content in white-tailed deer of the Adirondacks did not fall below 50% until fat within the body proper was utilized.

Cheatum's (1949) visual technique involved a series of color and consistency levels to assess the amount of fat in femur marrow. Bischoff (1954) noted limitations of Cheatum's technique when assessing physical condition of black-tailed deer (*Odocoileus hemionus columbianus*). He concluded that only consistency of femur marrow fat could adequately be used to determine physical condition under the prevailing conditions. Since visual

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[2]Present address is Route 10, Box 102, Lake City, Florida 32055.

descriptions of bone marrow were subject to varying evaluations among different observers, Greer (1968) developed a compression method to indicate fat content in elk (*Cervus canadensis*). Femur fat levels determined by the compression method were highly correlated with levels determined by the ether-extract technique when marrow fat content exceeded 50%. Bear (1971) observed a possible correlation between bone marrow consistency and percentage fat content, whereas the relationship between color and percentage marrow fat was very poor. Riney (1955) found visual estimates of both color and consistency of bone marrow to be highly correlated with chemical analyses of bone marrow fat in red deer (*Cervus elaphus*). He also found that bone marrow fat was correlated with other fat indices including kidney, back, and abdominal fat. Riney (1955) and Ransom (1965) determined that while several fat deposits within the body proper were decreasing, the bone marrow fat content remained relatively constant until these other fat deposits decreased to a low level.

Riney (1955) and Bear (1971) evaluated indices such as kidney fat, back fat, thoracic fat, visceral fat, and heart girth in addition to bone marrow fat to determine the relative efficacy of these potential measurements. Of the indices examined, kidney fat appeared to be the most useful index.

Since evaluation of physical condition in deer has been the subject of much conjecture, this study was undertaken to determine the most reliable and feasible method of judging physical condition of white-tailed deer in the Southeast. Specific objectives were to: (1) evaluate the accuracy of a commercial fat extractor for measuring the percentage fat in femur marrow; (2) evaluate a visual approach for estimating the amount of femur marrow fat; (3) determine whether endogenous fat deposits vary with season or sex or age of the animal; and (4) evaluate the use of endogenous fat indices as a reflection of overall physical condition.

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MATERIALS AND METHODS

Collection Sites and Procedures

From the spring of 1968 to the spring of 1973, 440 white-tailed deer from 45 localities in 12 southeastern states collected for evaluation of parasitism and disease entities were assessed for endogenous fat deposits and physical condition (Table 1). In most instances, sex or age discrimination was not made during collections. All animals were obtained by shooting. Usually 5 randomly selected animals constituted a sample, although in some cases fewer or more animals were collected. Most areas were sampled only once; however, 6 areas were evaluated repeatedly for all seasons for at least 1 year.

Ages of deer were determined by tooth eruption and attrition (Severinghaus 1949). All deer from 6 months to 1 year of age were grouped as young deer, whereas deer over 1 year were grouped as adults.

All animals were necropsied within 24 hours and endogenous fat levels recorded. Specific measurements taken included: (1) a visual appraisal of color and consistency of femur marrow; (2) the percentage femur marrow fat as determined by use of a commercial fat extractor;[1] and (3) an estimate of the amount of kidney, heart, pericardial, and tail fat.

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[1]Hobart Fat Percentage Indicator for ground beef, Model FI01, Hobart Manufacturing Company, Troy, Ohio.

Qualitative estimates of endogenous fat deposits were categorized as zero, low, moderate, or high, whereas percentage femur marrow fat was recorded as a quantitative value.

Table 1. Collection sites for white-tailed deer in 12 Southeastern states, 1968-73.

County and State	*Season of Collection*	*Number of Deer*
Mountain Areas		
Allegany Co., Maryland	Spring, Summer	10
Garrett Co., Maryland	Summer	4
Doddridge Co., West Virginia	Winter	5
Hampshire Co., West Virginia	Winter	5
Hardy Co., West Virginia	Summer	10
Caldwell Co., North Carolina	Fall, Winter, Spring, Summer	20
Stone Co., Arkansas	Winter	10
Cleburne Co., Alabama	Fall, Winter, Spring, Summer	40
Yancey Co., Alabama	Spring	5
Low Plateau Area		
Edmonson Co., Kentucky	Summer	5
Piedmont Areas		
Caroline Co., Virginia	Fall, Winter, Spring, Summer	40
McCormick Co., South Carolina	Fall, Winter, Spring, Summer	40
Floyd Co., Georgia	Winter	5
Coastal Plain Areas		
Worcester Co., Maryland	Spring	5
Dorchester Co., Maryland	Fall	5
Kent Co., Maryland	Fall	5
Prince Georges Co., Maryland	Winter, Spring	20
Harford Co., Maryland	Spring	5
Craven Co., North Carolina	Spring	5
Stafford Co., Virginia	Spring	5
Beaufort Co., South Carolina	Winter	5
Berkeley Co., South Carolina	Winter	5
Hampton Co., South Carolina	Summer	5
Chatham Co., Georgia	Fall, Winter	10
Liberty Co., Georgia	Fall, Winter, Spring, Summer	40
Clay Co., Florida	Fall	5
Collier Co., Florida	Fall	5
Duval Co., Florida	Summer	5
Gadston Co., Florida	Spring	8
Walton Co., Florida	Fall, Winter, Spring, Summer	20
Baldwin Co., Alabama	Fall	5
Barbour Co., Alabama	Spring	5
Marengo Co., Alabama	Fall	5
Lincoln Par., Louisiana	Summer	5
Winn Par., Louisiana	Spring	13
Charleston Co., South Carolina	Winter	5
Mississippi Delta Areas		
Madison Par., Louisiana	Spring	3
Assumption Par., Louisiana	Winter	3
Concordia Par., Louisiana	Summer	5
Desha Co., Arkansas	Summer	5

Table 1. (Continued)

County	*Season of Collection*	*Number of Deer*
Coahoma Co., Mississippi	Summer	5
Issaquena Co., Mississippi	Fall	5
Laflore Co., Mississippi	Summer	10
Warren Co., Mississippi	Winter	4
Wilkinson Co., Mississippi	Summer	5
Total		440

Femur Marrow Fat Procedures

The femur marrow was exposed by striking the shaft of the bone with a hammer midway between the epiphyses. The entire marrow including that at the epiphyses was removed and examined. Utilizing a classification adopted from Cheatum (1949), femur marrow was categorized by color and consistency.

Following visual evaluation, the marrow from both femurs was macerated in a mortar to obtain a homogeneous mixture. A 10cc sample of this mixture was placed on the Hobart fat extractor plate and exposed to heat for 22 minutes. Liquids, including fats and water, were collected in a funnel which was inserted into a 10ml graduated cylinder beneath the heating unit. The funnel and sides of the cylinder were heated periodically to ensure that fat did not solidify on these surfaces. Since fluids other than lipids were present, water was added and the cylinder heated. From the resultant biphasic mixture, the true quantity of fat could then be visualized. The volume (ml) of fat recovered was divided by 10 (volume of initial sample) and the result recorded as percent femur marrow fat.

Since the Hobart technique for determining percentage fat in tissue other than ground beef had not been verified, femur marrow samples from 35 deer were evaluated simultaneously by the modified Hobart method and the Folch procedure. The Folch technique, used routinely for recovering total lipids from many tissue types (Folch et al. 1951, Sperry and Brand 1955, Folch et al. 1957), is considered to be a highly accurate, standard method for lipid analyses.

Other Endogenous Fat Procedures

Visual appraisals of the kidney, heart, and pericardial fat depots were made. A manual appraisal of the amount of tail fat was determined by palpating the base of the tail prior to skinning.

Kidney Fat Index

LIGHT–At least 75% of the kidney visible; obvious fat laid in a few thin streaks or narrow layers.

MODERATE–Thick layer of fat covering about 50-70% of the kidney surface.

HEAVY–Kidney completely encapsulated within a thick layer of fat.

Heart Fat Index

LIGHT–Trace of fat on basal region with or without a trace of fat on coronary groove.

MODERATE–Moderate deposit of fat on basal region, extending slightly down coronary groove.

HEAVY–Thick deposit of fat on basal region, extending well along coronary groove.

Pericardial Fat Index

LIGHT–Traces of fat at basal area; possibly light streaks extending to apex.

MODERATE–Zones of moderate amounts of fat at basal area; linear streaks of fat extending from base to apex.

HEAVY–Zones of fat up to 7mm thick at basal area; obvious linear streaks of fat extending from base to apex.

Tail Fat Index

BONY–No palpable fat between skin and coccyx.

LIGHTLY PADDED–Light amount of fat present; coccyx vertebrae could be felt; sharp points padded.

PADDED–Heavy deposit of fat present; unable to feel the coccyx vertebrae.

Determination of Overall Physical Condition

Excluding femur marrow, all of the above endogenous fat deposits in addition to factors presented below were used to assess the overall condition of each animal. Physical condition ratings were categorized in four levels:

Poor – No trace of fat on the kidney, heart, pericardium, omentum, or intestines. Carcass approaching emaciation. Tail bony and backbone very prominent before skinning. Gelatinous material may be present on the heart and omentum where fat was mobilized.

Fair – Zero or light fat on kidney, heart, and pericardium. Tail bony. Adequate skeletal muscle. Light deposit of fat on the omentum which may be pink in color.

Good – Moderate kidney fat, light to moderate heart and pericardial fat, lightly padded or padded tail, and fibrous material in omental fat. Fawns classified in good condition did not necessarily have any fat deposits provided the animals were not obviously in poor health.

Excellent – Heavy kidney fat, moderate to heavy heart and pericardial fat, padded tail, heavy subcutaneous fat, back fat extending from the tail into the lumbar region, which may be as much as 12 to 25 mm thick at the last sacral vertebrae.

Statistical Studies

Coded values for estimated endogenous fat deposits and physical condition, actual values for percent femur marrow fat, and other pertinent data were placed on computer cards. Analysis of variance, standard correlation, Spearman rank-order correlation, and regression analysis as available for Statistical Analysis System (Service 1972) were utilized for statistical analyses.

RESULTS

Comparison of Hobart and Folch Techniques

Values of percentage femur marrow fat obtained by the Hobart technique generally were consistent with values obtained by the Folch technique ($Y = 3.723 + 0.896X$). At levels above 10% the Hobart technique always yielded values within 5% of the Folch technique. When the marrow fat was below 10% by the Folch technique, the Hobart technique tended to yield values slightly below those of the Folch technique.

Femur Marrow Fat Studies

The color and consistency of femur marrow near the epiphyses often were different from that at the center of the femur. A white or light color indicated marrow with a high fat content. As the color deepened to pink, light red, and finally dark red or brown, fat content decreased in that order. Similarily, the graduation in texture varied from firm, dry, waxy consistency in marrow having a high fat content to a gelatinous, soft, or watery consistency in marrow having a low fat content.

A regression analysis on bone marrow color showed that 43% (r = 0.42456) of the variability in percentage femur marrow fat was related to marrow color. A regression analysis on marrow consistency showed that 59% (r = 0.58642) of the variability in percentage femur marrow fat was related to consistency. A regression analysis incorporating both color and consistency showed that 66% (r = 0.66079) of the variability in percentage femur marrow fat could be accounted for by combination of these 2 factors.

Average femur marrow fat levels varied considerably between seasons. Average femur marrow fat content was highest during the winter, while lower values were observed during the spring and summer. Variability among samples was great, and there was not a significant difference ($P > 0.05$) between sexes (Tables 2 and 3). Deer 1-year-old or younger had considerably less marrow fat than adults during the spring and summer months. Adult males had the highest marrow fat levels during the fall.

Table 2. Mean fat levels for male deer collected in Southeastern United States, 1968-73.

Season	Age Class	N	Percent Marrow Fat	Standard Deviation	Kidney Fat Index	Standard Deviation	Heart Fat Index	Standard Deviation	Pericardial Fat Index	Standard Deviation
Winter	< 1 yr	14	36	20.56	2.42	0.669	3.00	1.000	2.55	0.882
	> 1 yr	23	23	18.86	2.52	0.730	2.52	0.665	2.58	0.768
	All	37	28	20.30	2.49	0.702	2.67	0.806	2.57	0.790
Spring	< 1 yr	24	9	9.96	1.78	0.422	1.91	0.515	2.00	0.000
	> 1 yr	7	17	23.78	2.00	0.000	2.17	0.408	2.33	0.577
	All	31	11	14.19	1.83	0.384	1.96	0.499	2.08	0.288
Summer	< 1 yr	30	8	16.42	2.36	0.621	2.55	0.572	2.45	0.595
	> 1 yr	15	17	18.92	2.76	0.725	3.20	0.774	3.18	0.751
	All	45	11	17.64	2.49	0.675	2.77	0.711	2.70	0.728
Fall	< 1 yr	13	19	22.72	2.36	0.809	3.00	0.774	2.88	0.927
	> 1 yr	20	26	20.27	2.94	0.929	3.56	0.814	3.27	0.961
	All	33	24	21.22	2.70	0.912	3.33	0.832	3.12	0.947

Table 3. Mean fat levels for female deer collected in Southeastern United States, 1968-73.

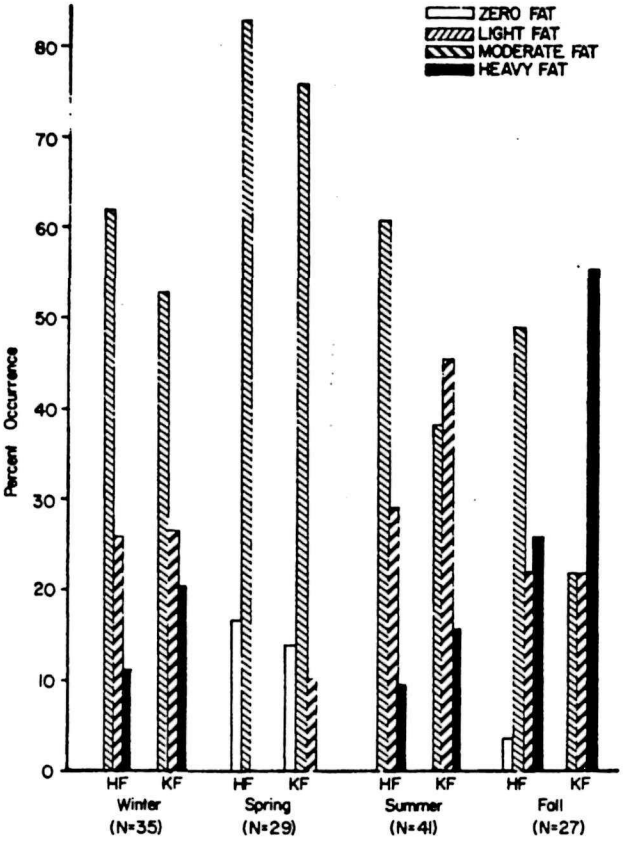
Season	Age Class	N	Percent Marrow Fat	Standard Deviation	Kidney Fat Index	Standard Deviation	Heart Fat Index	Standard Deviation	Pericardial Fat Index	Standard Deviation
Winter	< 1 yr	21	32	18.05	2.33	0.483	2.76	0.889	2.46	0.519
	> 1 yr	54	45	18.07	3.14	0.783	3.31	0.706	3.15	0.792
	All	75	41	18.94	2.90	0.795	3.15	0.799	2.98	0.789
Spring	< 1 yr	23	9	10.69	2.09	0.668	2.30	0.703	1.75	0.707
	> 1 yr	65	20	21.07	2.36	0.753	2.52	0.784	2.39	0.728
	All	88	18	19.43	2.29	0.737	2.46	0.765	2.27	0.758
Summer	< 1 yr	19	13	16.99	2.50	0.923	2.36	0.761	2.38	0.961
	> 1 yr	55	18	22.09	2.41	0.687	2.66	0.700	2.77	0.684
	All	74	17	20.89	2.43	0.747	2.59	0.723	2.68	0.765
Fall	< 1 yr	14	19	20.48	3.07	0.475	3.29	0.611	3.17	0.577
	> 1 yr	44	30	20.50	3.18	0.756	3.38	0.740	3.44	0.694
	All	58	27	20.86	3.15	0.690	3.35	0.705	3.38	0.672

Other Endogenous Fat Studies

Kidney, heart, and pericardial fat deposits exhibited similar patterns for seasons, sexes, and age groups. These organs attained the highest mean fat levels in the fall and lowest during the spring. Males and females exhibited similar patterns in all seasons except summer, when mean fat levels were noticeably higher for adult males than for adult females. A similar pattern occurred in deer 1-year-old and less but was not as pronounced. Adult females exhibited a slow deposition of kidney fat in the summer while females 1-year-old and less displayed more rapid deposition.

A larger proportion of females attained moderate or heavy kidney and heart fat reserves than did males in all seasons except summer (Figs. 1 and 2). In all seasons, both sexes exhibited higher kidney fat levels than heart fat (Figs. 1 and 2).

Fig. 1. Seasonal occurrence of heart fat (HF) and kidney fat (KF) levels in male deer of all ages.



The level of tail fat averaged higher in females than in males and in both sexes was higher in winter (females = 1.8; males = 1.6) than in spring (females = 1.6; males = 1.0).

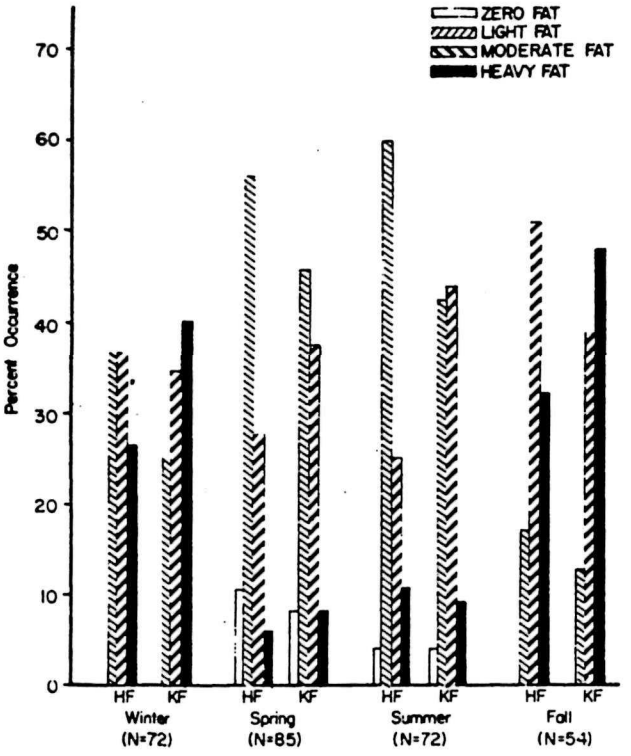
Correlation Between Fat Indices and Overall Physical Condition

Correlations between fat indices and overall physical condition are tabulated in Table 4. Kidney fat had the highest correlation for all seasons. Within seasons for which data were available, tail fat also was highly correlated. Compared to other fat indices tested, percent femur marrow fat had the lowest correlation values with overall physical condition.

DISCUSSION

The Hobart technique quantified the percentage fat by volume in bone marrow with a relatively high degree of accuracy (± 5%) but underestimated the amount of fat at levels

Fig. 2. Seasonal occurrence of heart fat (HF) and kidney fat (KF) levels in female deer of all ages.



less than 10% fat content as determined by the Folch technique. The degree of underestimation was inconsistent but exhibited a greater margin of error as the percentage fat approached zero. This discrepancy was attributed to the tendency of small quantities of fat to cling to the extractor plate and funnel despite periodic heating. At low fat levels the tissue also charred more easily thus providing a substrate to which fat adhered. Care therefore should be taken to enhance fat flow into the cylinder without applying excessive heat. The small margin of error encountered with this technique indicated that it was an acceptable method which required little training and equipment.

Regression analyses of visual estimates and percentage femur marrow fat (Hobart technique) indicated that consistency was a better indicator of marrow fat levels than color if only a single parameter was utilized. Combination of both color and consistency increased the accuracy of visual techniques. Since deer studied had marrow fat ranging between 0 and 90%, these visual techniques used in combination were considered to be reasonably reliable for estimating percentage femur marrow fat. This conclusion was consistent with those of Cheatum (1949) for white-tailed deer in New York and Riney (1955) for red deer in New Zealand. In contradistinction, Bischoff (1954) and Bear (1971) found only consistency could be correlated to percentage fat levels.

Table 4. Correlation between overall physical condition and fat indices by season of year. Note kidney fat has the highest correlation (fit) with physical condition and femur marrow fat the lowest.

Index	*Season*	*Correlation with Physical Condition*	*Significance Level*
Femur Marrow Fat	Fall	0.179	>0.10
	Winter	0.270	0.01
	Spring	0.376	0.001
	Summer	0.351	0.001
	All	0.314	0.001
Kidney Fat	Fall	0.683	0.001
	Winter	0.630	0.001
	Spring	0.776	0.001
	Summer	0.734	0.001
	All	0.715	0.001
Heart Fat	Fall	0.440	0.001
	Winter	0.261	0.01
	Spring	0.710	0.001
	Summer	0.734	0.001
	All	0.506	0.001
Pericardial Fat	Fall	0.570	0.001
	Winter	0.396	0.001
	Spring	0.809	0.001
	Summer	0.526	0.001
	All	0.570	0.001
Tail Fat	Winter	0.726	0.001
	Spring	0.664	0.001
	All	0.714	0.001

Fat indices are important to the investigator for they characterize the overall physical condition of the animal. In turn, physical condition portrays changing environmental and physiological demands in the near past and provides information on which management policies are based. The number of fat indices utilized should be minimal to avoid excessive costs, training, or time. Additionally, as suggested by Riney (1955), a useful indicator of physical condition should: (1) reflect condition equally well for both age groups and sexes in all seasons; (2) be reproducible by different technicians; and (3) reflect a continuous scale in physical condition.

Percentage femur marrow fat in the animals examined during this study did not fulfill these requirements. Although percentage femur marrow fat could be determined inexpensively, simply, and quickly with the Hobart fat extractor, marrow fat appeared to be the poorest indicator evaluated (Table 4).

Data from the present study as well as those by Riney (1955) and Ransom (1965) emphasize the following limitations to the use of marrow fat for determining physical condition: (1) changes in the upper range of physical condition are not reflected in marrow fat and (2) differential physiologic demands between sexes and age classes are not reflected in marrow fat. Irregular synthesis and utilization render marrow fat a highly questionable indicator of overall physical condition in the Southeast as a whole. Its usefulness in other regions and specific seasons where the technique has been used

successfully (Cheatum 1949), however, should not be overlooked, particularly when the animals approach inanition. It should be emphasized further that to utilize bone marrow fat as the primary or definitive indicator of physical condition may lead to a false conclusion.

Kidney fat was the best overall fat index for evaluating physical condition regardless of age, sex, or season (Table 4). The high correlation with physical condition is probably related to rapid response to physiologic changes and available food (Riney 1955, Ransom 1965, Bear 1971). Its value is justified, therefore, as an indicator of condition in all seasons, for all ages above 6 months, and for both sexes. The use of kidney fat as an indicator of condition previously was extended to include age classes younger than adults (Riney 1955) since the depot matures early. During the present study subjective kidney fat estimations did not differ significantly among observers.

Since heart and pericardial fat did not correlate as well with overall physical condition as did kidney fat, these parameters were not considered as reliable as the latter. The poorer overall relationship was attributed primarily to lower correlation in the winter (Table 4). For other seasons, these 2 indices were almost as useful as kidney fat. Like kidney fat, heart and pericardial fat responded early to physiologic changes and nutritional acquisition, thereby extending their reliability as indicators of physical condition to deer less than 1 year old for both sexes.

Tail fat correlated well with physical condition (Table 4) in the limited number of observations. It should be noted that during these periods of observation (winter and spring) physical condition ratings were either low or high on the scale. Tail fat probably would be a good indicator only at these 2 extremes, since deposition and utilization occur rapidly and since 1 sequence or the other is in motion. This would limit the reliability of tail fat to the winter and spring and probably to adults. Harris (1945) suggested a similar pattern.

The employment of various fat reserves as indicators of physical condition suggested that kidney fat was superior to other indices. Heart and pericardial fat were found to be nearly as reliable as kidney fat in all seasons with the exception of winter. Tail fat was correlated with physical condition during the winter and spring. Femur marrow fat content was not a suitable indicator of physical condition alone due to extensive variability between it and other parameters evaluated. A judgment of overall physical condition should include all available information.

LITERATURE CITED

Bear, G. D. 1971. Seasonal trends in fat levels of pronghorns, *Antilocapra americana*, in Colorado. J. Mammal. 52(3):583-589.

Bischoff, A. E. 1954. Limitations of the bone marrow technique in determining malnutrition in deer. Proc. Western Assoc. State Game and Fish Commissioners 34:205-210.

Cheatum, E. L. 1949. Bone marrow as an index of malnutrition in deer. New York State Conserv. 3(5):19-22.

Folch, J., S. Ascoli, M. Lees, J. A. Meath, and F. N. LeBaron. 1951. Preparation of lipid extracts from brain tissue. J. Biol. Chem. 191:833-841.

_____, M. Lees, and G. H. Sloane-Stanley. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226(1):497-509.

Greer, K. 1968. A compression method indicates fat content of elk (Wapiti) femur marrows. J. Wildl. Manage. 32(2): 747-751.

Harris, D. 1945. Symptoms of malnutrition in deer. J. Wildl. Manage. 9(4):319-322.

Neiland, K. A. 1970. Weight of dried marrow as indicator of fat in caribou femurs. J. Wildl. Manage. 34(4):904-907.

Ransom, A. B. 1965. Kidney and marrow fat as indicators of white-tailed deer condition. J. Wildl. Manage. 29(2):397-398.

Riney, T. 1955. Evaluating condition of free-ranging red deer (*Cervus elaphus*), with special reference to New Zealand. New Zealand J. Sci. and Tech. Sec. B 36(5):429-463.

Service, J. 1972. A user's guide to the statistical analysis system. North Carolina State Univ., Raleigh. 260 pp.

Severinghaus, C. W. 1949. Tooth development and wear as criteria of age in white-tailed deer. J. Wildl. Manage. 13(2):195-216.

Sperry, W. M., and F. C. Brand. 1955. The determination of total lipids in blood serum. J. Biol. Chem. 213:69-76.

Stockle, A. W. 1977. The use of endogenous fat as an indicator of physical condition of white-tailed deer (*Odocoileus virginianus*) in southeastern United States. M.S. Thesis, Univ. of Georgia, Athens. 122 pp.

Verme, L. J., and J. C. Holland. 1973. Reagent-dry assay of marrow fat in white-tailed deer. J. Wildl. Manage. 37(1):103-105.