FINAL REPORT JUL 2 9 2002

1999 Project Abstract
For the Period Ending June 30, 2002

TITLE: Winter Severity Index for Deer
PROJECT MANAGER: Dr. Mark S. Lenarz
ORGANIZATION: Minnesota Department of Natural Resources
Division of Wildlife
Forest Wildlife Populations and Research Group
ADDRESS: 1201 East Highway 2, Grand Rapids, MN 55744
WEB SITE ADDRESS: (If applicable)
FUND:
LEGAL CITATION: ML 1999, Ch. 231, Sec. 16, Subd. 010h

APPROPRIATION AMOUNT: $60,000

Overall Project Outcome and Results

The purpose of this project was to develop an improved understanding of the relationship between winter weather severity, deer condition, and ultimately deer survival. A primary objective of the project was to evaluate the feasibility of developing an index of deer condition based on weather measurements. This index would be used to determine if and when emergency feeding should begin during a severe winter.

Over the course of 3 years (2000-2002), winter weather data were collected daily and included measurements of snow depth and impaction and minimum and maximum ambient temperature. A total of 291 deer were live trapped and body condition was determined on 96 of these deer using a deuterium-dilution technique. Additionally, deer condition was determined using a body scoring system and ultrasonography, on 24 and 13 deer respectively.

During the 3 years of the study, winter severity represented 2 different extremes, either historically mild or severe. Initial results indicate that snow depth has a greater influence than ambient temperature in determining body condition in deer. During years with deep snow, fat levels of both fawns and does were significantly lower as early as January. Creation of a deer condition index will require additional data from years when winter severity is more moderate. Funding to continue the study have been secured through DNR's Heritage Endowment Funds.

Project Results Use and Dissemination

Thus far, final products of this research include 1 technical report (Carstensen and DelGiudice (2002), a M. S. Thesis (Carstensen 2002), and presentations to public audiences (e.g., Anoka H. S. and Grand Rapids H. S. biology classes), sportsmen's associations (e.g., Minnesota Deer Hunters Association, Deer River Sportsmen's Club), and at scientific conferences (The Wildlife Society's Eighth Annual Conference, 2001). Several substantial scientific manuscripts will be prepared for scientific peer-review publication upon completion of Carstensen's Ph. D. dissertation.

LCMR Work Program Final Report

Date of Work Program Approval: June 16, 1999

Project Completion Date: June 30, 2002
LCMR Work Program 1999

I. PROJECT TITLE: Winter Severity Index for Deer

Project Manager:	Dr. Mark S. Lenarz, Group Leader
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Total Biennial Project Budget:

$LCMR Budgeted	$60,000	$Match Budgeted	$5,000
$LCMR Spent	$56,435	$Match Spent	$4,711
$LCMR Balance	$3,565	$Match Balance	$289

A. Legal Citation: ML 99, Chap.231, Sec.16, Subd. 010h.

Appropriation Language: $30,000 the first year and $30,000 the second year are from the trust fund to the commissioner of natural resources for an agreement with the Minnesota Deer Hunters Association to determine the relationship between the winter severity index, deer condition, and deer mortality. This appropriation must be matched by at least $5,000 in nonstate money and at least $30,000 in-kind match. This appropriation is available until June 30, 2002, at which time the project must be completed and final products delivered, unless an earlier date is specified in the work program.

B. Status of Match Requirement: Resolved by the Executive Board Minnesota Deer Hunters Association on 10 July 1999 to provide $5000 as matching support to the $60,000 provided by the LCMR for the Winter Severity Index Study.

II. and III. FINAL PROJECT SUMMARY

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The purpose of this project was to develop an improved understanding of the relationship between winter weather severity, deer condition, and ultimately deer survival. A primary objective of the project was to evaluate the feasibility of developing an index of deer condition based on weather measurements. This index would be used to determine if and when emergency feeding should begin during a severe winter.

Over the course of 3 years (2000-2002), winter weather data were collected daily and included measurements of snow depth and impaction and minimum and maximum ambient temperature. A total of 291 deer were live trapped and body condition was determined on 96 of these deer using a deuterium-dilution technique. Additionally, deer condition was determined using a body scoring system and ultrasonography, on 24 and 13 deer respectively.

During the 3 years of the study, winter severity represented 2 different extremes, either historically mild or severe. Initial results indicate that snow depth has a greater influence than ambient temperature in determining body condition in deer. During years with deep snow, fat levels of both fawns and does were significantly lower as early as January. Creation of a deer condition index will require additional data from years when winter severity is more moderate. Funding to continue the study have been secured through DNR's Heritage Endowment Funds.

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IV. OUTLINE OF PROJECT RESULTS:

In cooperation with an existing research project, deer were live-trapped and blood samples were taken to assess body composition. Detailed measurements of ambient temperature and snow depth and density were assessed throughout the study area. Analyses of these data helped clarify the relationship between weather and deer condition and with additional years of data, it may be possible to predict deer condition from weather variables. Such an index could be used to set policy as to when emergency deer feeding should begin.

Result 1. An improved understanding of the relationship between weather severity and deer condition. Initial results indicate that snow depth is more important than ambient temperature in determining body condition in deer. During years with deep snow, fat levels of both fawns and does were significantly lower as early as January. Unspent balance reflects lower than expected costs for graduate student stipend. Completion Date: June 2002

LCMR Budgeted:	$60,000	Match Budgeted:	$5,000
LCMR Balance:	$56,435	Match Balance:	$4,711

Result 2. A better technique that would allow wildlife managers to determine the condition of deer in local areas, their chances of survival, and the need for emergency feeding was not developed. Additional data will be necessary to understand this relationship because winter severity during the project was either historically mild or severe. Data collection during years of moderate severity will be required for development of the technique. Completion Date: June 2002

LCMR Budgeted:	$0	Match Budgeted:	$0
LCMR Balance:	$0	Match Balance:	$0

Result 3. Educational materials that explain how deer condition changes in response to winter conditions, how winter conditions affect deer survival and the utility of using a new winter severity index to trigger emergency deer feeding. Although the initial results of the research were disseminated in the form of technical reports, a M.S. Thesis and presentations at public, sportsmen's, and scientific meetings (see below), educational materials were not prepared. Completion Date: June 2002

LCMR Budgeted:	$0	Match Budgeted:	$0
LCMR Balance:	$0	Match Balance:	$0

V. DISSEMINATION

Thus far, final products of this research include 1 technical report (Carstensen and DelGiudice (2002), a M. S. Thesis (Carstensen 2002), and presentations to public audiences e.g., Anoka H. S. and Grand Rapids H. S. biology classes, sportsmen's associations (e.g., Minnesota Deer Hunters Association, Deer River Sportsmen's Club), and at scientific conferences (The Wildlife Society's Eighth Annual Conference, 2001). Several substantial scientific manuscripts will be prepared for scientific peer-review publication upon completion of Carstensen's Ph. D. dissertation.

VI. CONTEXT

A. Significance: With the establishment of a dedicated account for emergency deer feeding, the question faced by deer managers is not whether to feed deer, but where and when emergency feeding should take place. To address this question, the Deer Winter Survival Work Group was charged by the 1997 Legislature (Chapter 216, Sec. 144) with developing an emergency deer feeding plan. This group recommended that the initiation of emergency feeding be triggered by the Winter Severity Index currently measured by DNR staff. They acknowledged that this index was a good tool for approximating deer mortality, but that research had never demonstrated a relationship between the current index and deer condition during the course of the winter. For this reason the work group recommended that research was necessary to determine whether a new and better index could be developed.

B. Time: Data were collected during 3 winter field seasons and lab analyses were conducted during the remainder of the year. Unfortunately, winter severity represented 2 different extremes, either historically mild or severe. Creation of a deer condition index will require additional data from years when winter severity is more moderate.

C. Budget History: This work built on and enhanced the DNR's research of deer and conifer cover in the Remer-Longville area. In the last 12 years, over $1,300,000 (RIM General Funds) have been expended on this project.

VII. COOPERATION:

Mr. Mark Johnson, Executive Director, Minnesota Deer Hunters Association, 460 Peterson Road, Grand Rapids, MN 55744

Dr. Glenn DelGiudice, Research Biologist, Forest Wildlife Populations and Research Group, Grand Rapids, and Adjunct Associate Professor, University of Minnesota, Department of Fisheries and Wildlife, St. Paul.

VIII. LOCATION:

All research took place in study areas located in northeastern Cass, and southwestern Itasca counties in north-central Minnesota.

JUL 29 2002

1 July 2002

Winter Severity Index for Deer

Dr. Glenn D. DelGiudice, Research Biologist, Minnesota DNR, Division of Wildlife, Forest Wildlife Populations and Research Group, Grand Rapids, MN 55744.

I. Abstract: This study was recommended by the legislatively mandated "Deer Winter Survival Work Group" in response to a recently established state policy of providing emergency feed to free-ranging white-tailed deer (*Odocoileus virginianus*) in Minnesota during *"severe"* winters. The Minnesota Department of Natural Resources' (MNDNR) wildlife managers require a practical, more effective means of assessing winter severity and its effect on the physical condition of free-ranging white-tailed deer. The winter severity index (WSI) currently used by the MNDNR provides an assessment of the environment (i.e., snow depth, ambient temperature); however, biologists still have an inadequate understanding of the effect of winter severity (represented by WSI) on the physical condition of deer and consequently, their chances for survival. This study is examining the research hypothesis that the winter condition of free-ranging white-tailed deer varies *predictably* in response to winter severity. During winters 1999-2000 and 2001-02, the primary objective of this study was to assess and monitor the condition (i.e., body composition) and cause-specific mortality of white-tailed deer as winters progressed and determine if there is a predictable, quantitative relationship between winter severity (using the current index or a more meaningful modification thereof) and condition that would provide wildlife managers with a more sound basis for decisions concerning emergency feeding. Field methodology included monitoring winter weather conditions (ambient temperature, snow depth, and snow density), capturing and determining *in vivo* the body composition (weight, fat, protein, minerals, and water) of adult and young-of-the-year, free-ranging white-tailed deer via the deuterium-dilution technique, and assessing cause-specific mortality. An advancement from past research involving captive deer, this study design permitted an assessment of the interactive effects of winter severity, *natural* energy and activity budgets, and *natural* food habits of the deer on their condition as winters progress. Statistical analyses included a variety of approaches to examining the relationship of body condition of deer to winter severity and cause-specific mortality.

II. BACKGROUND

Winter's Challenge, Research Hypotheses, and Objectives

Nutrition is the mechanistic thread from environmental variation (e.g., weather) to variation of deer (*Odocoileus* spp.) populations. This ecological relationship is important because populations are the functional unit of management. Winter (Nov-Apr) is the most nutritionally challenging season and has the most pronounced impact on the population performance (i.e., survival and reproductive success) of northern white-tailed deer (*O. virginianus*) (Mautz 1978). Winter is a time of diminished abundance, availability, and nutrient quality of their food resources, as well as increased energetic expenditures for mobility and maintaining thermal balance (Short et al. 1966; Moen 1976, 1978; Mautz 1978). Consequently, it is natural for northern deer to lose weight during winter (Moen and Severinghaus 1981, Severinghaus 1981, DelGiudice et al. 1992) primarily, as fat and protein, which serve as alternate sources of energy during undernutrition (Torbit et al. 1985, DelGiudice et al. 1990). Fat is the primary endogenous source of energy with protein catabolized initially at a sparing rate (Torbit et al. 1985, DelGiudice et al. 1990, Parker et al. 1993). However, as dietary energy deficiencies progress and fat reserves become depleted, catabolism of endogenous protein accelerates markedly (deCalesta et al. 1977; Torbit et al. 1985; DelGiudice et al. 1987, 1994; Moen and DelGiudice 1997). Clearly, prolonged, severe nutritional restriction leads to a moribound condition and decreased survival in individual deer and at the population level (deCalesta et al. 1977, Mech and Karns 1977, Moen and Severinghaus 1981, Severinghaus 1981, DelGiudice et al. 1994). In geographic areas where viable populations of predators are not present, starvation is the primary source of winter mortality for deer (Severinghaus 1981); however, in many areas in northern Minnesota, wolf (*Canis lupus*) predation is the major cause of winter mortality of deer coinciding with condition deterioration (Mech et al. 1971; Nelson and Mech 1986*a,b*; DelGiudice and Riggs 1996; DelGiudice 1998).

Past research of winter nutritional restriction of deer and changes in their body composition (i.e., fat, protein) or condition have involved captive or semi-captive deer (Torbit et al. 1985, DelGiudice et al. 1990, Parker et al. 1993). These studies provided useful baseline data; however, importantly, they did not include the interacting influences of winter severity, *natural* energy and activity budgets, or *natural* diets.

The present study was recommended by the legislatively mandated "Deer Winter Survival Work Group" in response to a recently established state policy of providing emergency feed to free-ranging white-tailed deer in Minnesota during *"severe"* winters. This new policy has prompted at least two important questions. First, what constitutes a "severe" winter? Second, at what point during an apparent severe winter should emergency feeding be initiated? To even begin to be able to answer these questions, the Minnesota Department of Natural Resources' (MNDNR) wildlife managers require a practical, more effective means of assessing winter severity and its effect on the physical condition of white-tailed deer. The MNDNR has routinely calculated their winter severity index (WSI) as an accumulation of points beginning 1 November. One point is accrued for each day with a snow depth $\geq$38.1 cm (15 inches) and 1 point for each day with an ambient temperature $\leq$ -17.8° C (0° F), which provides an assessment of the environment (i.e., weather conditions). DelGiudice (1997) reported that WSI was significantly related to percent winter mortality of adult female deer over an 8-year period in northcentral Minnesota, but thus far the relationship has not proven to be predictive. Biologists still have an inadequate understanding of the effect of winter severity (represented by WSI) has on the physical condition of deer and consequently, their chances for survival.

This study examined the relationships between winter severity, nutritional restriction and condition of white-tailed deer as winters progressed, and their subsequent survival (year-round). There were 2 specific research hypotheses. First, winter condition of free-ranging white-tailed deer varies *predictably* in response to winter severity. And second, survival varies predictably with nutritional condition and/or winter severity. Consequently, the primary objective of this study was to assess and monitor the condition (i.e., body composition) and cause-specific mortality of white-tailed deer as winters progressed, and determine if there was a predictable, quantitative relationship between winter severity (using the current index or a more meaningful modification thereof) and condition that might provide wildlife managers with a sound basis for decisions associated with an emergency feeding program. The survival of these study deer was monitored year-round.

Study Area

The study area for this research consisted of 4 trapping sites (located between 46°52' and 47°15'N latitude and 93°45' and 94°07' W longitude) along the eastern and southern boundaries of the Chippewa National Forest in northcentral Minnesota (DelGiudice and Riggs 1996, DelGiudice 1998). The trapping sites ranged in size from 10 to 19 km^2. The physiography and habitat were very similar among sites. Topography is undulant with elevations ranging between 400 and 475 m. Deciduous and mixed coniferous-deciduous stands were associated primarily with the uplands, and conifer swamps predominated in the lowlands.

III. METHODOLOGY AND RESULTS

Weather Data Collection

Minimum and maximum ambient temperatures were measured daily (November-March) in openings (i.e., forest clearings) on the study area. Mean daily minimum temperatures ranged from –21.6 to –4.4, -23.2 to –3.6 and –21.9 to –5.3°C, respectively, during winters 2000, 2001, and 2002. Ranges of mean daily maximum temperatures were –8.0 to 9.1, -6.8 to 8.0, and –11.2 to 1.5°C winters, respectively. Average weekly snow depths ranged from 0 to 17.1, 43.7 to 81.0, and 19.6 to 31.3 cm during early January-mid-March 2000, 2001, and 2002, respectively. Snow impaction typically showed a similar temporal pattern to depth until late February, when it decreased due to increasing snow density. Paralleling the deteriorating body condition of deer as winter progresses, the increasing supportability of snow becomes an added predatory advantage to wolves, the primary source of natural mortality of deer in north central Minnesota (DelGiudice 1998). Wolves have a weight-on-track load less than half that of deer, consequently, escape for deer can be increasingly hampered. In addition to providing baseline snow conditions (i.e., open habitat), a component of the currently used WSI with a pronounced influence on winter mortality of white-tailed deer (DelGiudice 1996, 1998, 2002), varied snow conditions associated with different habitat types may prove useful to development of a new WSI.

Deer Capture, Handling, and Body Composition Determination

We had 29, 199, and 74 deer captures by Clover trap and rocket net (Clover 1956, Hawkins et al. 1968), including recaptures, during winter 2000, 2001, and 2002, respectively. From these captures, 3 (2 fawns, 1 adult), 59 (15 fawns, 44 adults), and 28 (6 fawns, 22 adults) new females were recruited into the ongoing larger deer study and radiocollared for survival monitoring (DelGiudice 2000, 2001, 2002). Consistent with our efforts in past years, we used minimal amounts of bait (i.e., 2-3 handfuls of commercial deer pellets or horse feed mixture per trap) so as not to confound the study by altering the nutritional status, movements, or survival of captured deer. These deer were injected intramuscularly with about 1.4 mg xylazine HCl and 4.3 mg ketamine HCl per kg body weight, and handling included eartagging, extracting a last incisor for aging by cementum annuli (Gilbert 1966), radiocollaring (Telonics, Inc., Mesa, Arizona), weighing, blood- and urine-sampling, monitoring of body temperature, and morphological measurements.

During winters 2000, 2001, and 2002, body composition (i.e., body water) was determined *in vivo* in 13, 52, and 31 deer (adult females, male and female fawns), respectively (Carstensen 2002, Carstensen and DelGiudice 2002), by intravenous injection of 0.25 g deuterium oxide/kg body weight following the baseline blood sample; serial plasma samples were collected out to 120 minutes post-injection to permit assessment of equilibration (Rumpler et al. 1987, DelGiudice, unpubl. data). Additionally, body composition data derived by the deuterium-dilution technique were available for approximately 30 deer captured on these same trapping sites during severe winter 1997. Anesthesia was reversed by intravenous injection of 0.2 mg/kg yohimbine HCl (Mech et al. 1985). Up to 3 captured does were to be fitted with radio-controlled capture collars for (Mech et al. 1990, DelGiudice et al. 1992) to allow subsequent immobilization and handling every 3-4 weeks through late winter. However, due to cost and logistical considerations this smaller portion of the fieldwork was not attempted.

Analytical procedures.--Blood specimens collected during winter 2000 (and from 1997) were lyophilized and the captured water was analyzed for deuterium using infrared spectrophotometry (Byers 1979, Rumpler et al. 1987) Subsequently, predictive equations were employed to estimate body fat, protein, and ash (Robbins et al. 1974, Torbit et al. 1985, Rumpler et al. 1987, DelGiudice et al. 1990). Carstensen (2002, M.S. Thesis, accompanies this report) compared body composition of does and fawns between *severe* winter 1997 (pre-existing data) and mild winter 2000. By mid-winter 1997, does ($\geq$1 year old) had higher ($P < 0.005$) mean percent water (67.3 $\pm$ 1.5% [standard error]) and protein (20.6 $\pm$ 0.1%, mostly muscle mass), and less relative and actual fat ((7.6 $\pm$ 1.6% and 4.0 $\pm$ 0.8 kg, respectively) than does in *mild* winter 2000 (57.8 $\pm$ 1.5%, 19.9 $\pm$ 0.1%, 17.8 $\pm$ 1.6%, and 10.2 $\pm$ 1.1 kg, respectively). Additionally, fawns of winter 1997 had higher ($P = 0.12$) relative contents of water and protein, and less fat, than fawns captured during winter 2000 (70.1 $\pm$ 2.1%, 20.8 $\pm$ 0.2%, and 4.5 $\pm$ 2.2 versus 65.0 $\pm$ 2.0%, 20.4 $\pm$ 0.1%, and 10.1 $\pm$ 2.1%). Data from these 2 winters indicate that snow depth had a much stronger ($P < 0.05$) negative impact on fat reserves of deer than ambient temperature. This is consistent with snow depth's adverse effect on deer survival (DelGiudice et al. 2002). Further details are presented and discussed in Carstensen (2002).

Application of the deuterium-dilution technique to 83 live-captured deer during winters 2001 and 2002 generated approximately 830 blood samples; these samples are currently being analyzed in the laboratory as part of Carstensen's Ph.D. program at the University of Minnesota. Completion of these laboratory analyses will permit estimation of the body composition of these deer and incorporation of the respective data for an expanded statistical analysis and ecological interpretation.

Assessing Cause-Specific Mortality

Winter was defined as 1 November-31 May. Deer killed by wolves, other predators (e.g., bobcat [*Lynx rufus*]), or causes were identified based on evidence from the site (e.g., tracks, feces, or other sign of the specific predator and chase, blood) and carcass characteristics (e.g., wounds, tooth marks, patterns of consumption) (Mech 1970, Mech et al. 1971, Nelson and Mech 1986*a*). Date of death was estimated from the most recent date that a radio frequency was detected in "live mode," the first date that it was detected in "mortality mode," and site evidence (e.g., recent snowfall, tracks). All deaths were investigated within 3-4 days (DelGiudice 1998). Fat depots were assessed as permitted by carcass remains. When available, femur or other long bone marrow samples were collected and analyzed for fat content in the laboratory (Neiland 1970).

Winter survival (1 December-31 March) was lower for radiocollared does during severe winter 1997 (0.91) than during mild winter (0.93). Survival during winter 1997 would probably have been far lower, as it was during the preceding historically severe winter of 1996 (DelGiudice 1996, DelGiudice et al. 2002); however, several biological and ecological factors were also affecting deer survival during this winter of 1997, acting to minimize or limit the deer's risk of mortality (DelGiudice 1997, Carstensen 2002). Wolf predation was the leading proximate cause of winter mortality, although diminished condition was likely a contributing factor. Seasonal survival rates and cause-specific mortality rates for 1997 and 2000 are presented and discussed by Carstensen (2002, M.S. Thesis, accompanies this report).

Sample Sizes and Statistical Analyses

Trapping success on the winter range study sites depended, in large part, on winter severity; the more severe and prolonged winter weather conditions, the higher the success rate tends to be. Based on the results of a pilot study (winter 1996-97), during which the deuterium-dilution technique was employed, and on trapping efforts during 8 winters of varying severities, I expected we would be able to capture, handle, and determine the body composition of 25-40 deer during each of the next 2-3 winters. Also based on past experience on these sites, most of these individuals would be adult females; however, I expected up to10 fawns would be included each year as well (DelGiudice 1996, 1997). These expectations were fulfilled during winters 2001 and 2002; however, historically mild weather conditions during winter 2002 proved to be a limiting factor influencing data collection.

Statistical analyses were similar to what was anticipated in the original proposal. However, based upon the structure of the various data generated, actual sample sizes, and further consultation with a University of Minnesota statistician (Dr. Gary Oehlert), modifications of the anticipated statistical methods were implemented and are discussed in Carstensen (2002).

IV. PRODUCTS

Thus far, final products of this research include 1 technical report (Carstensen and DelGiudice (2002), a M.S. Thesis (Carstensen 2002), and presentations to public audiences (e.g., Anoka H. S. and Grand Rapids H. S. biology classes), sportmen's associations (e.g., Minnesota Deer Hunters Association, Deer River Sportmen's Club), and at scientific conferences (e.g., The Wildlife Society's Eighth Annual Conference, 2001). Several substantial scientific manuscripts will be prepared and submitted for scientific peer-review publication upon completion of Carstensen's Ph.D. dissertation All of these reports, articles, and presentations are providing our diverse clients with the study's objectives, an explanation of how the study has been conducted, detailed analyses and summaries of the data generated, an interpretation of these data, and most important, a synthesis of new useful information derived from an integration this study's results with those from previous pertinent research (DelGiudice et al. 2002). Specifically, we are describing and explaining advancements in our knowledge and understanding of the progressive effects varying severities of winter weather conditions have on the nutritional condition of white-tailed deer and how we can incorporate that knowledge into a more refined measure of winter severity. Management application of this knowledge and information will be in the form of a new or modified winter severity index that provides managers with a more reliable assessment of deer condition and a more sound basis for deciding when emergency winter feeding should be initiated.

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