

**An Index of Winter Severity for the
Overwintering Deer Population at
Black Rock Forest**

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A WINTER SEVERITY INDEX FOR DEER AT BLACK ROCK FOREST

ABSTRACT:

The severity of the winter season as it affects the health and vitality of the deer herd at Black Rock Forest, can be estimated on a relative account, by data collected during the winter months at the Ridge Top station. Winter severity parameters, such as temperature, wind speed, snow fall, and humidity, will allow for a more complete understanding of the health of the deer population as they emerge from the winter season. Since herd reproductive rates are entirely dependent on the physical condition of the female deer, estimates on herd health, made according winter severity, should be able to predict the future reproductive rates of the deer herd. With this information, the deer harvest quota for hunting season, determined according to predicted reproductive rates, can be adjusted to suit both the needs of the forest and the herd by ensuring that the relationship between forest resources and deer population numbers is maintained in equilibrium.

Winters are a critical time for the herd as overall body mass is ultimately threatened by low temperatures and high wind speeds that hasten body heat loss to the environment. In addition to the increase in the rate of body mass depletion, deer are forced to trample through soft and deep snows to search for adequate shelter and nutrition, creating greater demands for energy during a time when nutritive availability and value of deer forage are at their lowest. The available data offer two climatic variables that contribute most to herd health deterioration and will be included in the index. These are the wind chill equivalent temperature, a measure of temperature and wind speeds, and snow fall. The effects of cooling from low temperatures and

high wind speeds, and the hindrance of movement experienced as a result of increased snow depth and decreased support from soft snow, are the main environmental threats that force the herd into critical condition. By calculating the departure from the monthly average wind chill equivalent temperature and snow fall parameters for each winter month, a relative index of winter severity can be determined. The index is simply a sum of the degree of departure from the average monthly wind chill equivalent temperature and total snow fall for each winter month. Unfortunately, data from the Ridge Top station only dates back until 1995, making the calculated averages quite insufficient to represent the "normal" and tolerable winter conditions at the forest. However, the results do show relative severity in terms of the three winters. The 1995-1996 winter was the most severe, with all the monthly indices at extremely negative values. In contrast, the 1997-1998 winter was the mildest, with monthly index values over one thousand. Clearly the enormous range of the indices is the result of the poorly averaged wind chill equivalent temperature and snowfall data. The extremely short environmental data series prevents the estimation of a critical minimum winter severity index value which would determine the whether or not herd health will decline, stabilize, or improve. In addition, the chill factor needs to be adjusted for deer, and the snow pack data, (which include snow depth and hardness), is necessary. Before both parameters can be successfully integrated into a winter severity index, better and more climatic data are essential.

INTRODUCTION

Injury from Ignorance

Wildlife management in northeastern America has become inevitable during the past fifty or sixty years (Liscinsky, 1975). This necessity to properly manage populations of animals in the wild is unmistakably the result of our interference with mother nature's role of maintaining her wildlife and their habitats within a highly sensitive and complex structure of relationships. Our approach to nature has been entirely insensible resulting in significant alterations within and among species and entire ecosystems. Our obstructions have critically disrupted entire food webs at multiple levels, and the consequences are visible at a great cost to the species and their respective habitats. The human-induced population shifts among species in their natural habitat disrupt the predator-prey relationships that were once self-sustaining systems, able to maintain all their biological components in healthy balance with the environment. Predator-prey relationships, that subsist on all levels within a complex food web, in steady state, will pass along and recycle energy and nutrients, and maintain entire ecosystems in a healthful balance with their habitat. The reliance of one species on another, to be maintained at a minimum density, is clear. If one of these levels of the food web is disturbed, its sensitivity to such disruptions will result in an unnatural manifestation of habitat destruction by the creatures themselves.

The immediate task is to reconstruct the natural world into its original state of harmony that was completely disturbed by many years of indifference and ignorance. Wildlife management is essential now that many predatory

animals are extinct in northeast United States from unregulated hunting or human encroachment on their territory. The disappearance of the mountain lion, feral dog, and reduction in the coyote population, around the New York area, have led to an unfavorable growth in deer populations. Unchecked and overpopulated, the deer herd would not only exhaust all the resources of the forest, but would also persist in a horrible state of malnutrition and disease. Deer management, in areas absent of natural predators, is a necessary measure that prevents the deer from suffering ill-health, and allows the forest to prosper in its once natural state of equilibrium with the animals that survive on its resources. The goal of all forms of wildlife management is to essentially create a situation identical to the one of the past, where animals were once able to be self-maintained by these complex interactions with nature and with each other.

Repairing the Wreckage

Hunting is often the most widely accepted and practiced form of deer management. Other forms of deer management, such as the reintroduction of predators, fertility control, supplemental feeding, and transferring deer to other areas, present a much more difficult situation in terms of feasibility and expense. The area of this study, Black Rock Forest, is open to a limited number of hunters with permits, beginning in mid-November and lasting to mid-December. Hunting season takes place during a time of peak conception, within the herd. The increase in hormonal levels within the deer population offer the greatest opportunities for hunters to encounter big-antlered bucks who are frantically searching for does with which to breed. It is during hunting season that future management decisions are made, based on the

collection of biological information concerning the herd. Hunting season also takes place immediately before the onset of the most critical time for the herd, the often harsh and cruel winter months. In no other instance is the health and livelihood of the herd so highly challenged as during the cold, windy season of the northeastern states, whose unusually heavy snow falls and low mean temperatures take serious toll on the well-being of the herd.

Winter conditions are just another natural mechanism with which mother nature is able to control her populations of creatures. However, the unnatural circumstances created by humans over the past decades, still apply themselves in this instance. Deer entering the winter will ultimately have decreased survival chances if they are already malnourished due to lack of food from living in overpopulated conditions. Therefore hunting is viewed as a means of preventing future suffering, by ensuring that the herd emerging from winter will be in good physical condition, in proper social order according to age and sex ratios, and in balance with the resources of the forest.

Winters are the ultimate trial periods for the herd. Cold temperatures, heavy snowfalls, windy conditions and decreased food availability and nutrition make northeastern winters extremely trying on forest inhabitants. All these disadvantages of a harsh winter season, reveal themselves when the following hunting season brings in a malnourished herd, skewed in age or sex ratios. An unhealthy population of deer are the remnants of the overwintering population of deer that emerged from last winter with severely depleted body masses. Body mass is a direct indicator of health, as it suggests how the available nutrients of the forest were distributed inside the body of the deer. Under optimum conditions, nutrients are able to add to the living tissues of an animal, increasing body mass. During harsh winters,

available nutrients are usually so scarce that any forage consumed by deer is barely enough to keep the deer alive, let alone ensure the correct functioning of the most essential internal systems. Additional growth is highly unlikely.

Winter Severity: Environmental Conditions

Compared to other seasons, winters require the greatest energy expenditures as foraging deer are forced to endure high wind speeds while trampling through powdery snow on their search for suitable cover and nutritive needs. Deer that are unable to exceed the threshold of a given body mass at the onset of winter, will suffer greatly and possibly die due to winter's decreased food availability and nutrition, high wind speeds, cold temperatures and heavy snowfalls (Felhamer, 1960). Therefore the survival rates and the physical condition of the emerging herd, are a direct consequence of the intensity of the winter parameters, inherent to each region, as well as food availability. The deer population will suffer according to the intensity of the winter conditions and food availability.

Winter environmental conditions will almost always increase the rate of body mass depletion. The purpose of this paper is to quantify the effects of winter's unusually extreme conditions on the health of the herd by the derivation of a winter severity index. For Black Rock Forest, the index is a measure of the relative severity of the winter season represented by the degree of chill from temperature and wind speeds, and snow fall. Winter data from the Ridge Top station, located on top of Frog Hill in the northwest portion of the forest, about one and a half miles west of Black Rock Mountain. These data include temperature, wind speeds, relative humidity, solar radiation, snow fall and precipitation. The two most important winter

conditions for this area appear to be the chill factor, a measure of temperature and wind speeds, and snow fall as these parameters correlate most to the decline in herd health indicators. Daily snow pack data is not available at the station so the index is a sum of calculated wind chill equivalent temperatures and snow fall data.

It is difficult to determine which variable, snow fall or wind chill equivalent temperature has the greatest impact on the health of the herd since there are only three years of data. Verme (1965) awards chill factor greater significance than mobility hindrance in his study of overwintering deer in other northern states. In Cornwall, New York, winter severity parameters, such as temperature or snow fall are not as extreme as those regions located further north. Black Rock Forest experiences a mean annual snowfall of at 39 inches. Single snowfall events over the past three years have rarely dropped more than 18 inches. The exception was the severe winter of 1995-1996 which dropped 109 inches. Since 1970, total snow fall has not come close to total deposition during 1995-1996 winter. The winter of 1993-1994 experienced a total of 73 inches and prior to that, a total snow fall of 48 inches was dropped in 1988. Undoubtedly, the intensity of snow fall during the 1995 winter contributed greatly to the decline in herd health the following hunting season.

Winter Severity: Food Availability and Nutritional Value

Accurate acorn yield sampling was initiated in 1995, the same year that the operation of the Ridge Top station began. Acorn yields since 1995 correlate to the severity of the winters, in that the harshest winter had the lowest yield of acorns whereas the most mild winter had the greatest yield of viable acorns (see figure 5,6). Further data is necessary to quantify the importance of acorn yield in relation to winter severity. There have been conflicting opinions concerning the importance of nutrition over winter. Some studies have expressed the importance of food availability and nutrition to herd health during winters where conditions are more severe than the average winter season. Moen (1968) concluded that if highly nutritious foods are available, deer can tolerate highly adverse circumstances. However, other experiments indicate that food availability will not sustain a herd forced to endure extremely cold temperatures (Ransom 1967).

The main source of winter food for the herd comes from the acorn crop which is sampled prior to hunting season. Acorns are the most important source of protein and fat and their production varies according to the species of tree and environmental cues (Felhamer, 1960). With adequate nutrition over winter, assuming that the herd entering winter carried sufficient body mass, deer could possibly maintain their health and lessen the chances of significantly reducing their body mass. Body mass corresponds to reproductive potential, and if deer are unable to reach sexual maturity due to body mass depletion as a consequence of the winter months, reproductive rates will be greatly hampered (Mech et. al, 1990). Reproductive rates among the herd are entirely dependent on the physical condition of the female deer, or doe. Does in optimum physical condition will be able to divide available

figure 5

Number of Acorns per Acre

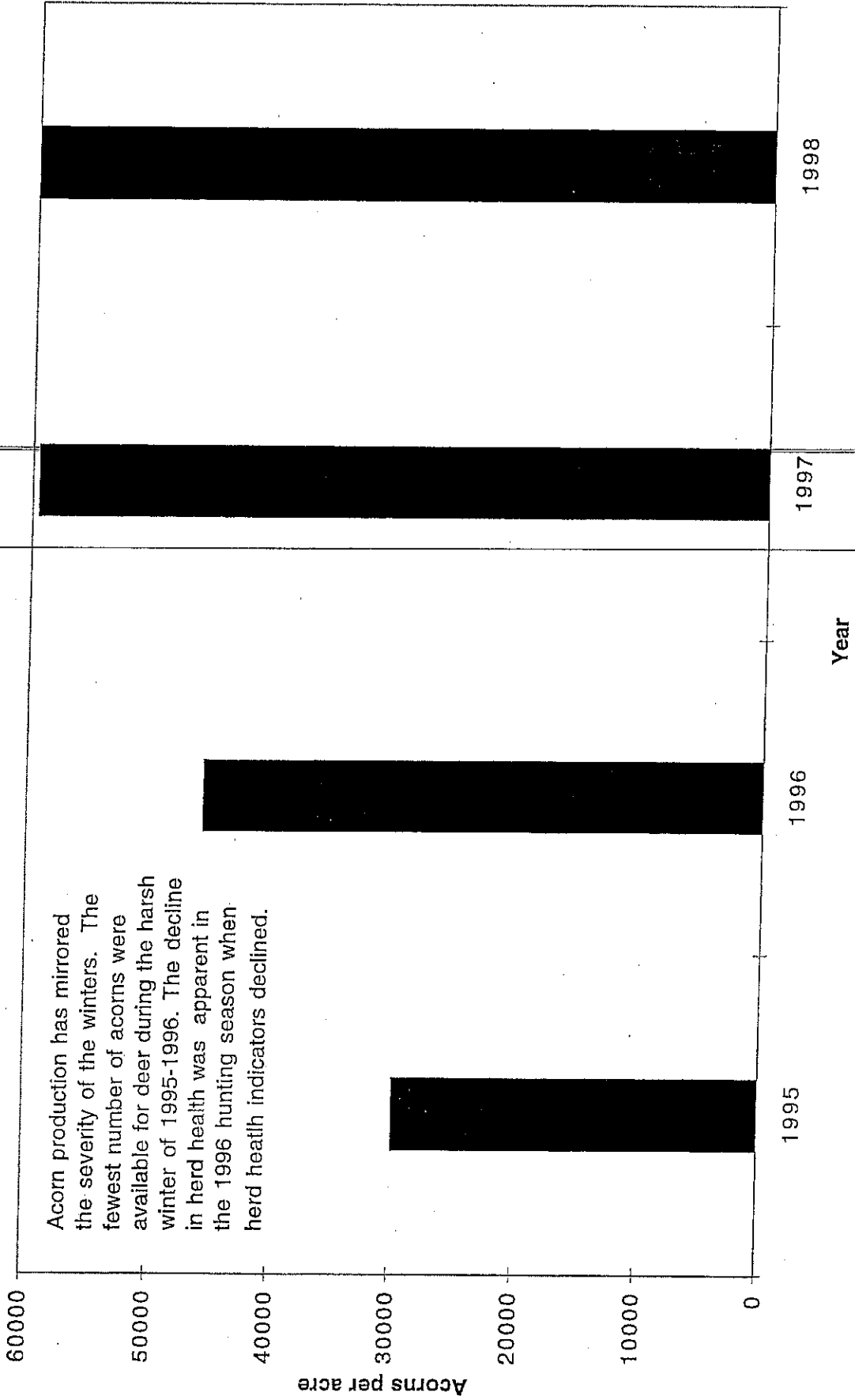
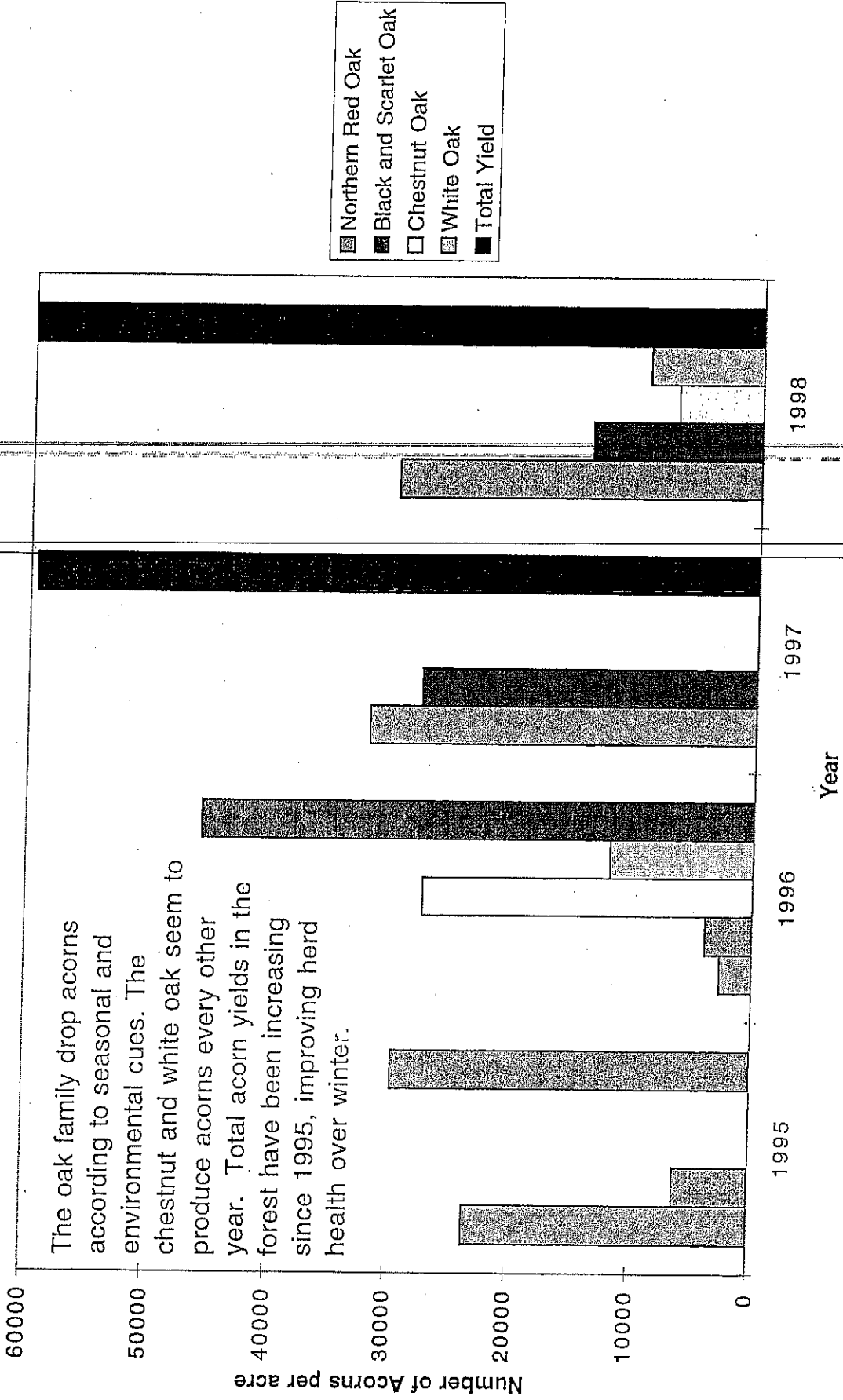


figure 6

Number of Acorns per Acre of Black Rock Forest



nutrients amongst herself and her offspring, whereas an under-nourished doe would not have enough stored energy to allow her to ovulate, let alone reproduce and conceive.

Winter Severity: Pre-winter Estimates on Herd Health

Since the physical condition of deer is most threatened during the winter months, the deer management strategy at the forest is to adjust the deer take during the hunting season following winter, based on the estimated reproductive rates of female deer leaving the previous winter. Hunting season occurs during the most active time of year, when hormonally-driven bucks are searching for females with which to breed. The deer harvest quota for hunting season prior to winter is determined according to the predicted reproductive rates of the herd that emerges from the previous winter months. The rut signifies the peak in the breeding season and begins in November and lasts until mid-December. Reproductive rates of the herd emerging from winter can be estimated according to the acorn and environmental data collected, before and during winter. Other essential data come from the previous hunting season. These data include information on sex and age ratios as well as information concerning the relationship between the deer and their habitat. Clearly the health of future generations of deer depends on the health of the pre-winter herd since they must rely on their fat reserves to maintain themselves over winter. All of this information figures crucially into the deer management scheme at the forest.

Extremely harsh winters, could produce high mortality among deer or a herd that suffers greatly from body mass depletion. If the deer herd is

significantly damaged due to the harsh effects of the winter season, female deer will breed late, if at all. If conception does not take place within the critical months of November to December, fawns will not have sufficient time to completely mature and survive the following winter. A succession of severe winters would increase the numbers of deer that enter winter in poor condition which would result in a cumulative effect where the herd is perpetuated the herd in very poor condition. Mild winters on the other hand, would allow the herd emerging from the winter season to enjoy the benefits of healthy body mass and nutrition, and therefore greater reproductive potential. In the latter instance, the deer manager would most likely increase the deer take during the following hunting season in order to

prevent overpopulation and subsequent resource depletion in the forest. The goal of deer management at the forest is ultimately to monitor the health of the herd, the acorn crop, and environmental conditions during the months preceding winter and those following. The purpose of closely monitoring these variables is to create a situation where the deer population is never exhausted during the unpredictable winter seasons nor from overpopulation due to high reproductive rates, and ensure that the forest is well-maintained.

If the previous winters have been unusually harsh due to extreme weather conditions, the cumulative effect could drive the resultant herd into extremely poor condition, and skew the age structure so that there were more fawns, with greater nutritive needs entering a season with highly decreased available nutrition. This type of pattern would manifest itself into a disaster for the herd, as the winters produced a herd in steadily worse and worse condition. Or, if population numbers are too great, while food is limited, the herd will suffer even more. As mentioned, the purpose of hunting season is to create conditions where the herd will never have to enter winter in a

depleted state of health, or enter with greater nutritive needs and in higher numbers, which make them more susceptible to winter's torments.

Winter Severity Index: A Location Specific Measure of Herd Health

It should be emphasized that the main purpose of understanding winter severity in relation to the physical condition of the herd is to accommodate the deer herd and the forest simultaneously. The degree of health depletion in all forest habitants is dependent on many variables, including seasonal conditions, food availability, and pre-existing age and sex ratios. The definition of winter severity will vary from across regions due to the differences in these three parameters. For deer in Black Rock Forest, the winter severity index will be calculated according to the estimated degree of chilling, (as a measure of wind speeds and temperature), and total snow fall over winter. The index is the sum of the deviations from the averages of the these two parameters. The derived winter severity index is a measure of the relative harshness of the winter season, which should translate directly into reproductive potential for the herd.

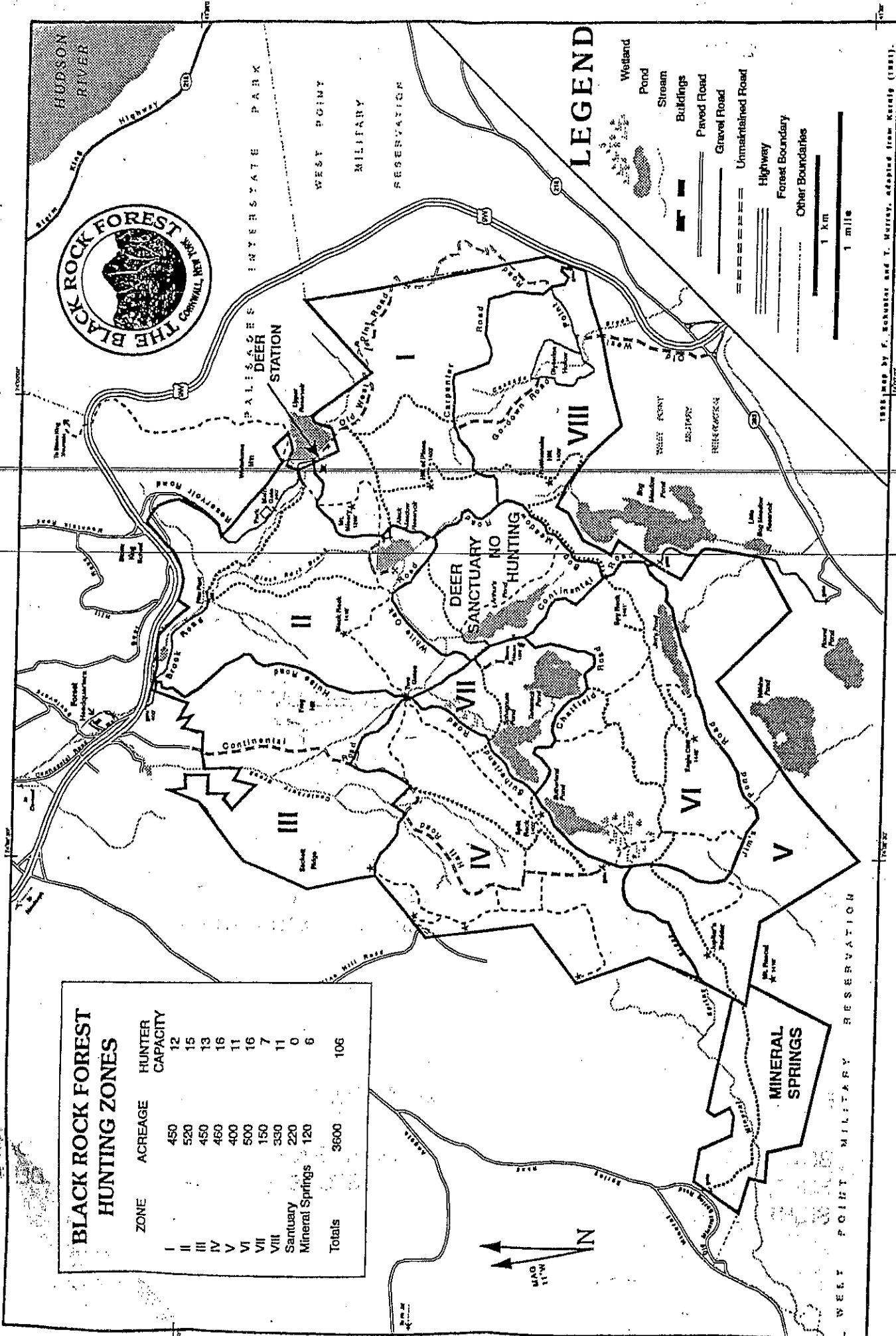
Black Rock Forest

Black Rock Forest is approximately 3800 acres of land, located about 4 miles to the west of the Hudson River on the northwest side of the Hudson Highlands. The terrain is quite mountainous which increases its surface area of roughly six square miles of forest (see figure 1). Black Rock Forest contains both mature and young forests, filled with evergreen and deciduous trees, as well as streams, ponds and wetlands. It is located in the towns of Cornwall and Highlands, Orange County, New York, and is situated on a foundation of gneiss bedrock and granite. The range of elevation runs from 450 feet at Peck's Pond to 1461 feet at Spy Rock. The forest is 74% oak, by volume density in acreage, with maples being the second greatest represented species of the forest. Other tree species include the birch, ash, and hemlock. The forest is home to a great number of animals despite the disappearance of many as well. The largest mammals in the forest are the white-tailed deer. Other mammals include mice, foxes, squirrels, and opossums, while wild turkeys are frequent as well. Though coyote are rare in the forest, they do show themselves through the discovery of the occasional deer kill. Practically non-existent are the black bear, beaver, porcupine, and bobcat (Brady, 1995).

Management History

The state of the forest after many years of alterations by human beings over the past century, have forced the white-tail population into a disagreeable relationship with the forest, as these changes directly influence the herd at Black Rock Forest. From the 1920's and enduring to the 1940's, young woodlands enriched the forest as a result of the previous cuttings. There was an abundance of available browse from the newly regenerated trees

Figure 1



ZONE	ACREAGE	HUNTER CAPACITY
I	450	12
II	520	15
III	450	13
IV	450	16
V	400	11
VI	500	16
VII	150	7
VIII	330	11
Sanctuary	220	0
Mineral Springs	120	6
Totals	3600	106

1985 MAP BY F. ROEBLER AND T. WURST, ADAPTED FROM KERRIS (1987).

and shrubs that were beginning their first stages of growth. These early stages of successional stands contained plenty of berries and hemlock stands were also prominent. During winter, conifer cover in Black Rock Forest, such as the hemlock stands, are the preferred and therefore most common areas where deer will bed down to obtain shelter and protection from the extreme cold. These areas are able to trap the heat from sunlight over the night. This type of environmental setting is ideal for deer as it provides winter shelter and abundant browse (Brady, 1995). From the late 1960's through 1970's, deer populations were maintained at high levels. Forest resources were abundant, as was the ability of the forest to sustain these greater populations of deer. In addition to these human-induced transitory benefits, the acorn crop provided supplemental nutrition for the herd.

Early management schemes at the forest were directed more towards rewarding man with the benefits of greater amounts of natural resources, such as lumber and fuelwood, rather than managing habitat with regards to its wildlife. More modern-day management at the forest began in the 1970's when goals were to secure the well-being of all components of entire ecosystems, and not just supply man with his capital interests. This type of plan was designed to incorporate more than just human profit into land management and to take greater notice of what consequences were ensuing within the different populations of animals and their domains as the result of many years of habitat alterations.

Tallying of deer harvests at Black Rock Forest were first recorded in 1970, and the first study of deer exclosures was established in 1971. Deer biological data, first recorded in 1984, marked the beginning of white-tail deer management at the forest. In 1989, it was concluded that the white-tail deer herd was the only population of animals that required consistent monitoring

and management. As mentioned, the destructive abilities of the herd on the resources of the forest is the outcome of much human interference with nature. We have eradicated the natural predators from the forest, eliminating the main source of population control for the herd. We have also created optimum habitat for the deer herd by clearcutting, which removes trees to allow room for seedling growth. This is clearly an unnatural situation that has led to the necessity of deer control.

Deer management at the forest now includes the assessment of deer population trends during hunting season and the determination of carrying capacities based on forest resources and environmental conditions.

Beginning in 1984, biological data were collected during each harvest season preceding winter, and from the collected data, analyses revealed the health of the herd with its relationship to hunting pressure (see figures 2,3). The deer take in the forest is determined according to indicators of herd health such as antler beam diameter and average weights, and the number of deer harvested. In 1989 the forest zoning management plan, in which the forest was sectioned off with a specific hunter density per acre, was enacted (see figure 1). Hunter capacity over the 3600 acres of forest is adjusted according to the estimated numbers of deer in the forest. The data from this seasonal deer harvest can then be translated into a better understanding of the sex and age composition of the herd. The primary indicators of herd health are the antler beam diameter, which is a measure of the thickness of the base of the antler, and weight according to age class (see figure 4). By 1989, a concrete management objective was determined, which was to sustain the overwinter deer at a density of 22-25 deer per square mile to guarantee that the herd and its habitat were in equilibrium (Brady, 1995). To ensure that the deer populations remain at a level complimentary to the resources of the forest,

figure 2

Buck Harvest by Age Class

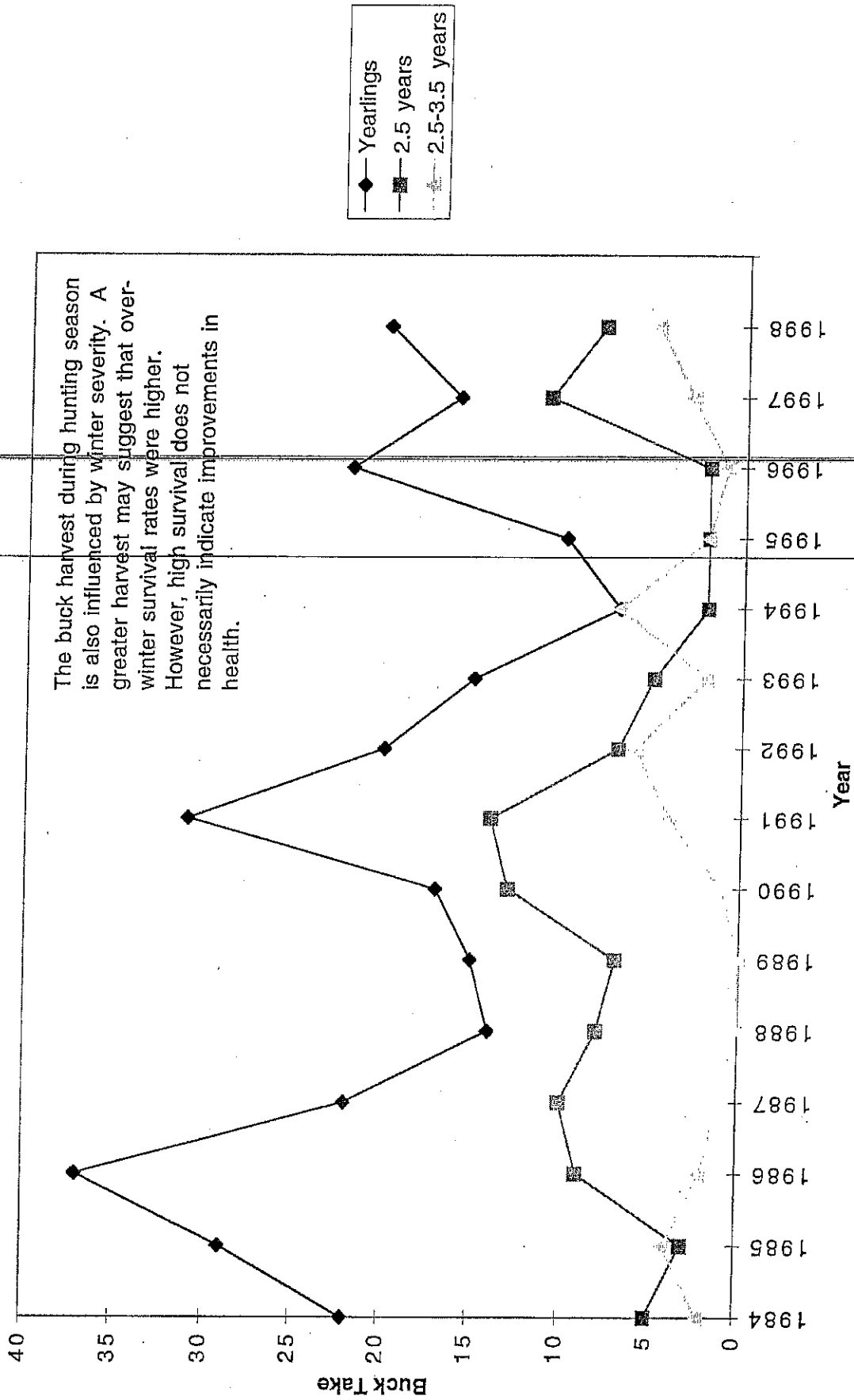
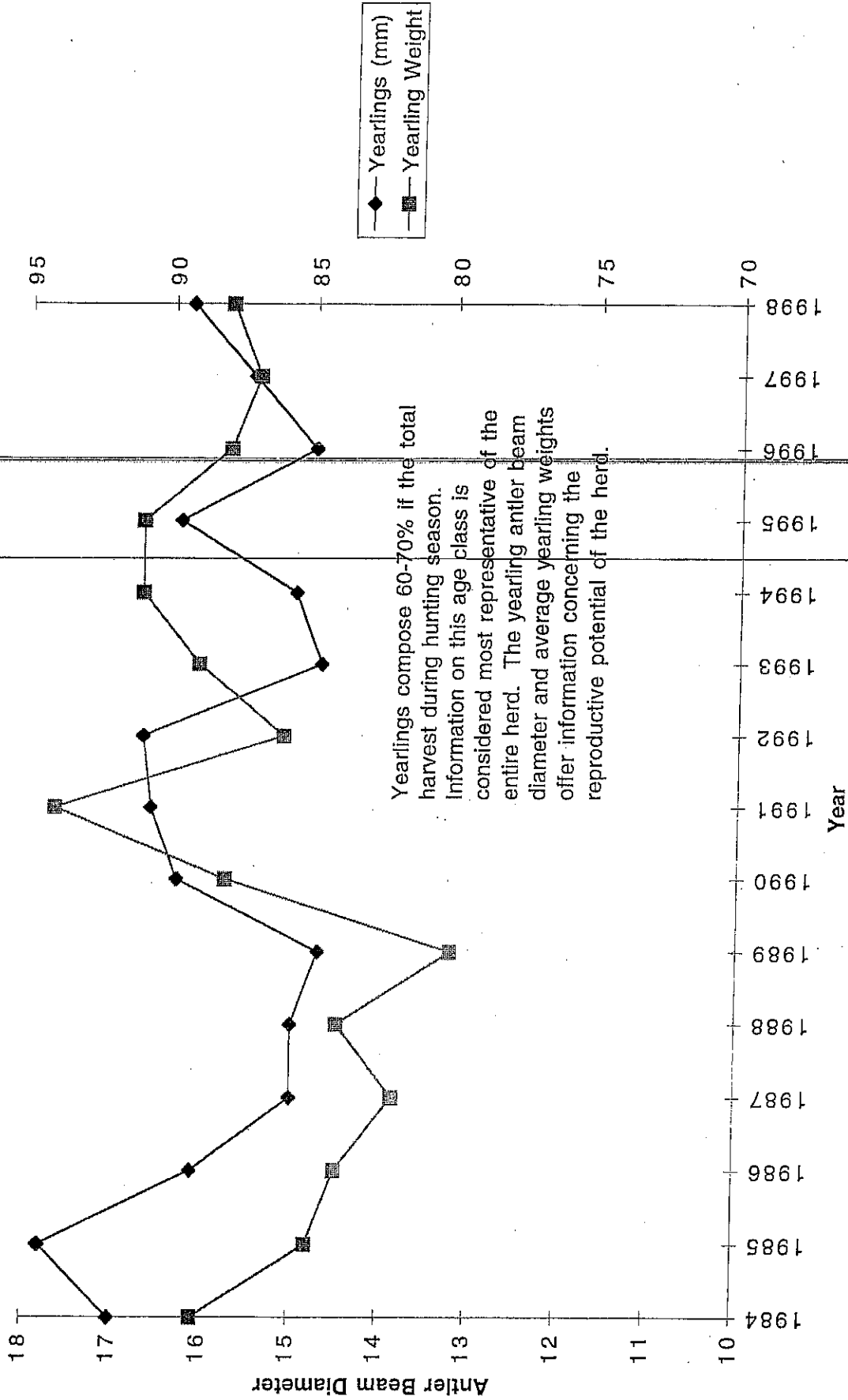


figure 3

Yearling Antler Beam Diameter and Average Yearling Weights



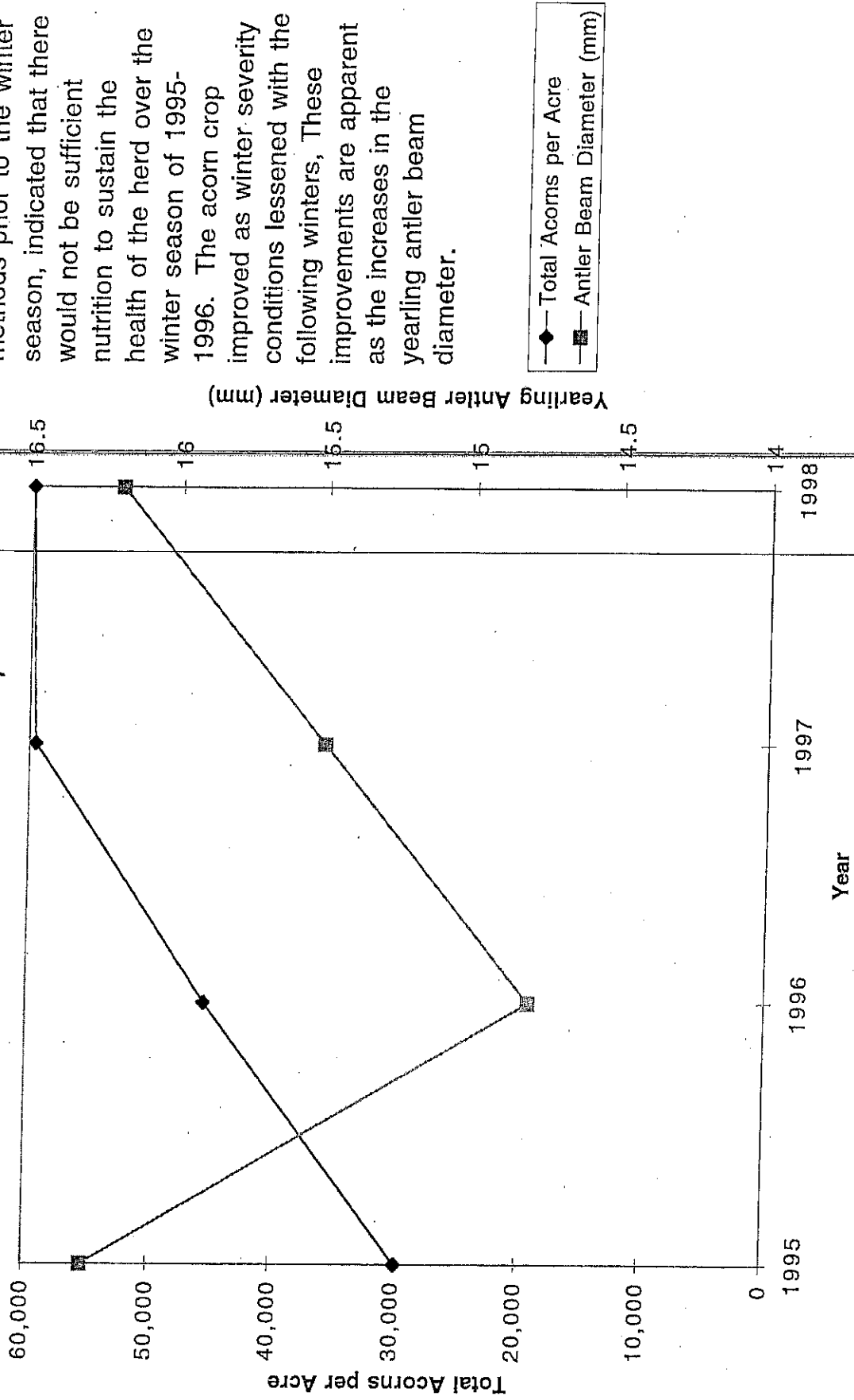
winter severity parameters and the acorn crop in relation to herd health, are also closely monitored.

During winter, the acorn crop remains to be of greatest importance to herd survival (see figures 5-7). Most of the trees at Black Rock Forest are between 70 and 100 years of age with the capacity of yielding a good acorn crop. Unfortunately, an overpopulated deer herd will decrease the diversity of the forest by overbrowsing the newly sprouting trees and shrubs, which prevent the introduction of new growth and important vegetation into the forest. Since the forest canopy is thick and high, because most of the trees in the forest are in a mature stage of life, the amount of sunlight able to reach the forest floor has greatly diminished. The combination of overbrowsing, and the reduction of light penetration to the soils, prevents the forest from diversifying itself. This severely limits the amount of available browse for the herd and the amount of tree species present in the forest. At one point during the 1960's-1970's, deer populations could have been as high as 40 deer per square mile (Brady, 1995). By controlling the population of deer, the degree of browsing in the forest can also be monitored. However, the total acorn yields in the forest are variable. Acorn availability controls the carrying capacity of the deer population at the forest, and this has lowered the carrying capacity to around 28-30 overwintering deer per square mile (Brady, 1995).

Winters in the forest, on average, have not been extreme when compared to our neighbors in the Adirondacks or in Minnesota, whose temperatures can reach extremely low with average snowfalls exceeding 20 inches over a succession of days. The winters at Black Rock Forest are moderate when compared to these other northeastern states, with an average snowfall of 39 inches over 38 years and a level of snow pack that seldom exceeds 18 inches. Based on the winter conditions at the forest, only 120 days

figure 7

Acorn Number and Herd Health



The total number of acorns, determined by sampling methods prior to the winter season, indicated that there would not be sufficient nutrition to sustain the health of the herd over the winter season of 1995-1996. The acorn crop improved as winter severity conditions lessened with the following winters. These improvements are apparent as the increases in the yearling antler beam diameter.

◆ Total Acorns per Acre
■ Yearling Antler Beam Diameter (mm)

of environmental data, starting with the end of December and lasting until the end of March, will be considered in this study, when the worst of winter bears its weight on the herd. Reports on winter severity for Black Rock Forest in Cornwall, New York, are based on the observations and measurements that detail the harshness of the winters, the population density, herd health, and available food.

Problems with Deer Overpopulation

As mentioned, the most urgent problem of an overpopulated deer habitat, aside from herd health, is their effect on the well-being of the forest. Deer will virtually consume any browse within their reach which includes anything from seedlings to higher branches when they stand on their hind legs. Overbrowsing will drastically alter forest regeneration and diversity. The problems begin, and do not cease, once high deer densities put intense pressure on the forest by overbrowsing. High deer densities endanger the regeneration of tree species in the forest, which are essential habitats to many animals. A well-maintained and healthy forest is critical to the survival of many animals, and if trees are unable to reproduce themselves because of overbrowsing, entire ecosystems will suffer. Some trees are more susceptible to browsing than others. The species most commonly affected by deer overbrowsing are those with equally important values in the timber industry like the sugar maple, red maple, yellow birch, black cherry, and white ash (Jordan, 1976). In addition, forests with fewer species are more susceptible to insects and diseases, further delaying reforestation efforts.

Low seedling densities are direct evidence of overbrowsing and are very damaging to soil quality, drainage, and plant competition (Jordan, 1976). Overbrowsing alters plant species composition, distribution, and abundance,

reducing the diversity of the plant species in their first stages of life. These changes result in a whole series of negative impacts on forest ecology.

Animal communities are put at risk by the decrease in available vegetation and cover. Given time, overbrowsing will seriously reduce habitat quality and in turn harm herd health. Deer, like all species, rely on food, water, and shelter, for basic healthy survival. Without food, herd health will deteriorate, lowering body weights and consequently reproductive rates, decreasing the rate of winter survival, and increasing the likelihood of disease.

Another reason for deer management, aside from reduced forest quality and herd health, is increased frequency of run-ins with humans. As the boundary between nature and the rapidly expanding urban and rural territories becomes less and less defined, such unfavorable encounters as automobile accidents, and crop and property damage, will become more frequent. There is a cultural carrying capacity for a given area, which defines the maximum number of deer that can coexist compatibly with the local human populations. This capacity varies according to the sensitivities of the local populations of people to the presence of deer. Sensitivities depend on local land-use practices, local deer densities, and the basic attitudes and priorities of nature's neighbors (Ellingwood, 1975).

An overabundance of deer will certainly place excessive demands on the forest with much resulting damage. When forest resources are minimal, due to overbrowsing, deer are more likely to venture out into human territory in order to search for food, not differentiating a between a cherished and blossoming garden or a farmer's newly planted crops. More deer on roadways increases the probability of vehicle accidents, and property damage, increasing the pressure for immediate control with the complaints that will

most definitely follow. In addition, preliminary studies suggest that a correlation exists between high deer densities and the incidence of Lyme disease that can be contracted by humans (Ellingwood, 1975).

Black Rock Forest, with all its diversity and natural beauty would suffer the maladies of foraging deer if it were not for a strict and sound management plan. In order to ensure that both species and habitat benefit, and that reasonable human requests are satisfied to curb the incidence of encounters with foraging or hormonally-driven deer, a highly controlled hunting season prior to winter is supplemented as a preventive measure for such unpleasant occurrences. Financial and practical restraints on other types of management, such as birth control or the re-introduction of predators into the forest make hunting the most feasible application of herd control. Hunting is the most widely used form of management among the northeastern states. Hunting enables the forest management to properly adjust the deer population to a suitable level that will satisfy the necessary requirements of the forest, herd and nearby humans. Flora and fauna benefit and the herd is maintained in a healthy and viable condition, increasing their chances of survival during the harsh and critical winter months. Neighboring human populations will enjoy more land-use practices and safety with reduced conflicts from deer accidents and property damage.

Mother Nature as the Ultimate Deer Manager

Winter severity for Black Rock Forest, because of limitations on data, is primarily a measure of wind chill equivalent temperatures and snow fall. Like most northeastern states, these two variables accelerate body mass depletion by heat loss and increased energy expenditures. The relative importance of these two parameters should vary according to the intensity of

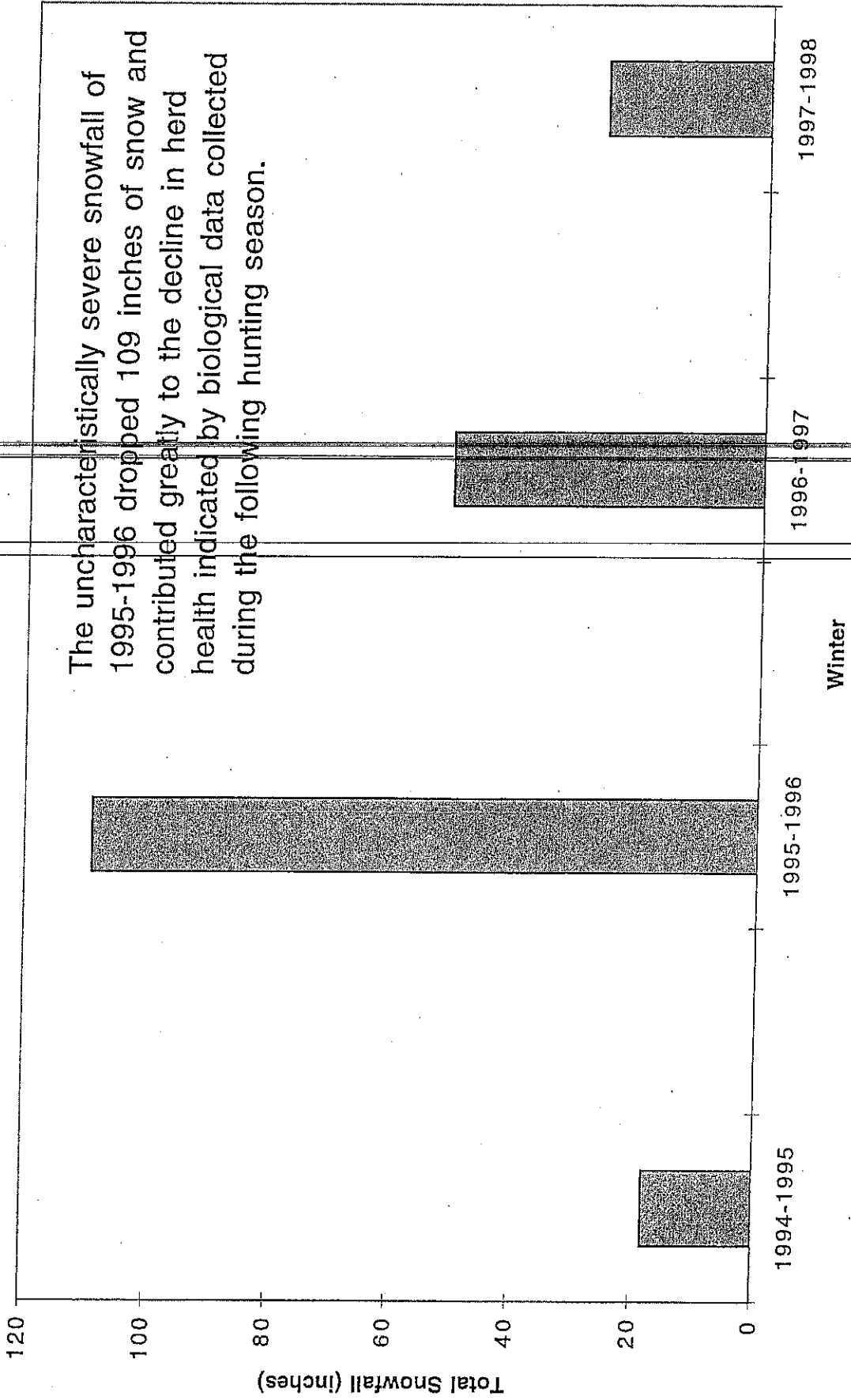
each. The index should allot greater weight to snowfall when there is a lot of snow on the ground. Similarly, when wind speeds and temperatures reach intense intolerable levels, chill factor should be given greater importance. At Black Rock Forest, total snow fall seldom exceeds 39 inches on average, therefore, the 109 inches of snow during January in the 1995- 1996 winter should contribute greatly to depletion in herd health (see figure 8).

In areas where snow fall is great, like in Nova Scotia, snow depths, densities, and hardness are of great importance (Kessal, 1969). When a deer sinks to chest height in snow, they are exhausted by the effort of plowing through powder to search for food or shelter, and cannot live for long periods in such snowy conditions. During winter, the energy output required for a deer to feed often exceeds that supplied by the food eaten. However, if snow hardness exceeds the weight of the animal on the snow, they can walk on top or will only sink to a fraction of its total depth (Kessal, 1969).

Energy expenditures and limits on food during winter severely influence the body mass in both sexes. This decrease is the result of increased energy expenditures and heat lost to wind speeds and low temperatures, in a period of limited food availability and nutrition. During winter, food consumption by white-tailed deer in northern regions rarely meets with their daily energy demands. Deer and other northern ungulates, will experience annual mass and fat cycles that closely coincide to seasonal change in forage nutrition and availability (Short et al. 1966; Mautz 1978). Northern deer gain mass during late spring and summer, deposit fat during fall and catabolize fat reserves and lose mass through winter and early spring (DelGiudice et al. 1991, 1992). The cyclical changes in characteristics of deer that are forced to forage during winter are a distinct result of a lower quality diet and the energetic expenditures associated with travel (DelGiudice et al. 1992)

figure 8

Total Yearly Snowfall For Black Rock Forest



Unfortunately, winter browse, in some areas, can be very low in nutrition and digestibility, being most woody vegetation. (Ullrey et al. 1964, 1967; Verme and Ullrey 1972; Mautz et al. 1976). Verme et al. (1972), studied the effects of forage and snow pack on the herd and determined that these parameters contribute to the rate of mass loss of deer. In recent years, deer at Black Rock Forest have been lucky enough to avoid such unhealthy circumstances when the acorn crop was abundant and snowfall was light.

Deer management is essential simply because there are natural limits to the number of deer that a given habitat can support. In the Northeast, these limits depend on the quantity and quality of deer forage and/or the availability of a good winter habitat. The biological carrying capacity is the number of healthy deer that a given parcel of land can support over an extended period of time. Effective deer management is necessary in order to prevent the populations from overshooting the carrying capacity which would threaten the well-being of other plant and animal species, and conflict with land-use practices, human safety and possibly health. There are obviously financial and logistical constraints that require deer management to be practical and fiscally responsible. So far, the most feasible option of deer control has been through the implementation of a strictly monitored hunting season.

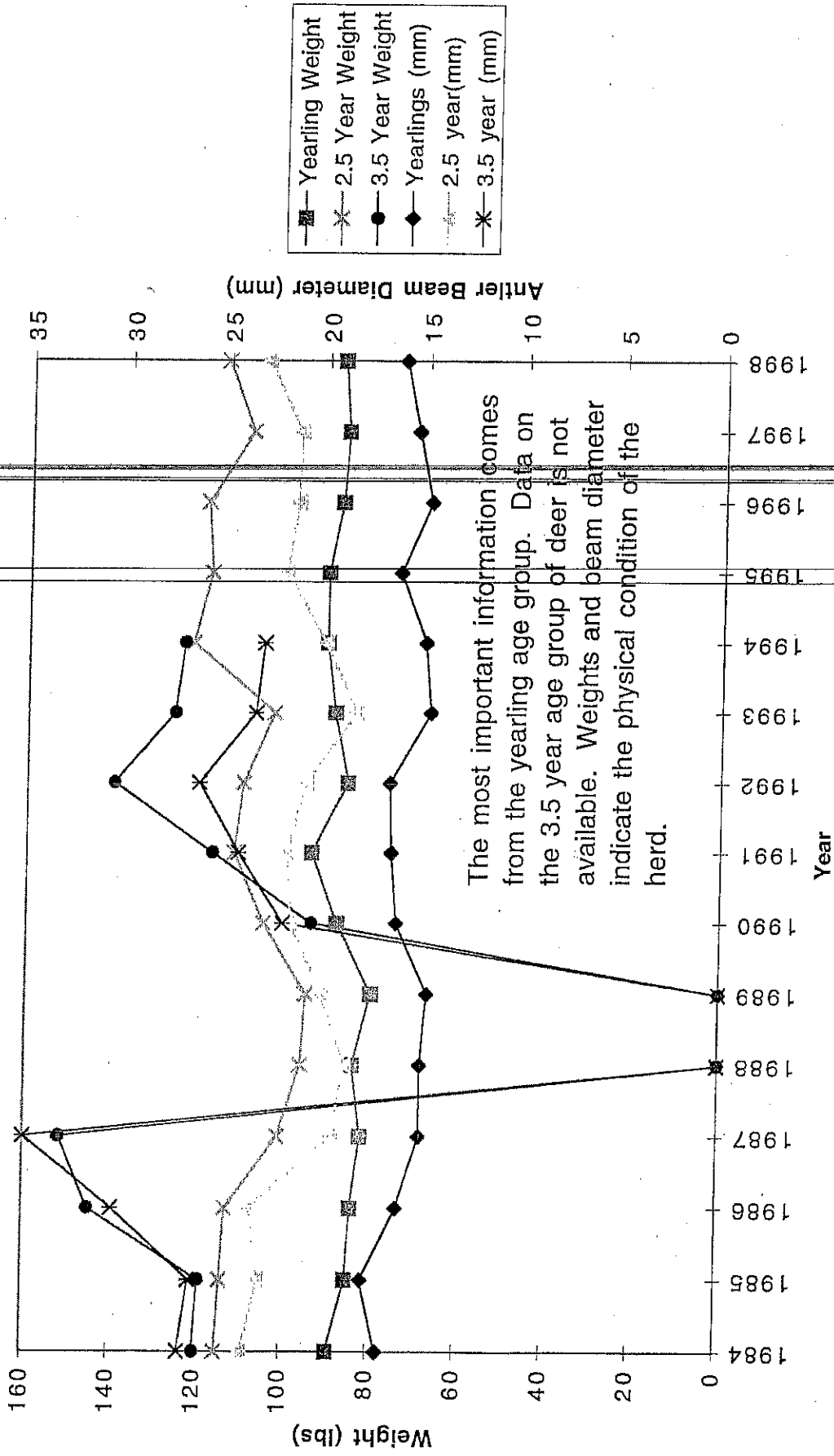
From mid-November to mid-December, the management scheme at Black Rock Forest allows licensed hunters to take a pre-determined quota of deer, reducing, stabilizing, or increasing the buck take, according to ecological and social requirements. Since the reproductive rates of the herd depend entirely on the population of the female deer, deer management at the forest designates the numbers of antlerless deer allowed to be killed. The hunting season and number of allowed hunters is also adjusted accordingly. Since the

state of the forest is represented by herd health, (a healthy herd generally suggests that the forest is in good condition since overbrowsing would lead to a food shortage, unhealthy deer, and a poor forest conditions), information on the herd, provided by the sample population during hunting season, is the foundation for all management decisions.

According to indicators of herd health, obtained by the measurements made at the mandatory deer check stations, the forest manager can assess the physical state of the herd through the sample population of deer brought into the stations. If the sample population appears in poor physical condition, the hunting pressure is increased to accommodate both the health of the herd and the health of the forest. Biological information supplied by measurements obtained during hunting season are critical to deer survival during winter. If the measurements suggest that the herd is already in poor physical condition, then their chances of survival as the temperatures drop and snowfall and wind speeds grow are significantly reduced. The deer take during hunting season is determined according to biological information collected at the deer check stations (see figure 4) and according to how many deer are likely to survive the winter with the given resources of the forest. For Black Rock Forest, the acorn crop is sampled prior to winter to determine how much nutrition will be available for deer over winter. The deer take during hunting season is made according to the physical condition of the herd, estimations of the age and sex ratios, forest resources, and the unpredictability of the winter season. These factors will determine how many deer should be allowed in the winter forest range.

figure 4

Biological Data: Weights and Beam Diameters According to Age Class



Taming the Deer Populations: Prodigious Breeding and Survival Techniques

Reproductive Potential

Deer populations are capable of growing rapidly due to their high reproductive potential and good survival techniques, characteristics that force the necessity for sound management. The age and nutritional level of the doe greatly influence her reproductive capabilities. Females from the best range, those with access to the most nutritious food, water supply, and shelter, will produce more fawns than those from a poor range. The number of fawns annually produced by female deer increases with age. There is also a great tendency for young females to give birth to a larger percentage of male offspring than older females.

Female deer come into estrus about three times a year. The first breeding season begins at the start of November. If seasonal and food conditions are favorable, the deer can breed prodigiously. Under good circumstances, female fawns will breed when they are seven or six months old and 10-15% will have twins (Marchinton, 1984). Nearly all older females will breed under optimal conditions and most will have twins. While this type of prodigious breeding makes the white-tail a very good prey species, it also allows deer populations, when unchecked by deer management, to become out of control with their natural habitat.

In the right environmental circumstances, does of two years or older can produce twins annually, while yearlings typically give birth to single fawns. On excellent range, adult does can even produce triplets, yearlings can produce twins and fawns can be bred and give birth during their first year of life. Some female fawns have their first estrus at 7 or 8 months of age and can produce their own fawns at 14 or 15 months of age; most of the doe in this age

range breed a month or two later than the older does (Mech et. al, 1990). In the absence of a strict management policy, namely through hunting these kind of reproductive rates can result in a deer herd doubling its size in just one year.

Under less than optimal conditions, particularly during winter, female hormones will prevent further ovulation. Pregnant females are even capable of reabsorping their fetus to obtain the extra nutrients if winter conditions are extreme and food availability is minimal. The mating season for deer begins in September and lasts into late January, reaching a peak in mid-November. Under the right circumstances, most of the adult females will have been bred by December, ensuring enough time for the growth and development of her offspring in preparation for the obstacles of the winter season. The consequences of late conception are quite damaging to the herd since they are very sensitive to alterations in sex and age ratios.

Winter Survival Techniques

Deer have adapted many techniques for coping with the harshness of the winter season. They voluntarily restrict their feed intake and their activities during winter, which appears to have evolved a physiological adaptations for energy conservation when temperatures are low and food resources limited (Moen 1978). These adaptations lower their metabolic rates (Mautz 1978; Marchinton and Hirth 1984). They will also restrict their home-range size and increase their shelter-seeking behavior for premium thermal cover (Verme and Ullrey 1984). Deer will acquire a winter coat with increased insulating properties and shift their activities to minimize exposure and maximize energy conservation. This is accomplished by strictly foraging during the warmer daylight hours (Ozoga and Verme 1970). Fat reserves from the previous seasons, are a critical alternative source of energy that may

contribute >20% of the whole body composition of an adult doe during late fall and early winter (McCullough and Ullrey 1983), and provide up to 30% of the energy requirement throughout winter (Mautz 1978). In addition to survival techniques, insulation and energy are provided by the fat reserves deposited during summer and autumn, when food resource and availability are favorable. Despite these extra energy sources and energy maximization strategies, there is an overall reduction in body weights among the herd following winter

Methods of Sampling the Deer Herd

At Black Rock Forest, there are three main methods of sampling the herd, in relation to population, health, and sex and age ratios. As previously stated, the first and most accurate sample of the herd are the deer brought in by the hunters at the deer check stations. At these stations, the deer are aged by the jaw aging technique and their health is determined according to certain biological components. These are the antler beam diameter, (YABD) and average weight. Other sampling methods include the deer tracking census, (DTC), which reveals the minimum overwintering deer herd, (the deer density per square mile), and by the study of accidental deer kill, either by predators or vehicle collisions. These sampling methods allow for a more accurate picture of the overwintering deer herd at Black Rock Forest.

Deer Check Stations

The deer check stations supply the most reliable and important information concerning the deer herd in the forest, on which practically all management decisions are based. These stations are the main source of biological information where unbiased samples of the herd provide information on sex and age ratios. The determination of harvest sex ratios are then translated into population dynamics. The physical data collected at the stations assess the relationship of the deer populations with the forest. If the sample population of deer appear in good physical health, this suggests that forest resources are adequate and indicates that the forest is also benefiting from the number of foraging deer. The collection of biological data at the forest began in 1984. The trends in antler beam diameters and weights

of the yearling class, and the total deer harvest are reflected by the severity of the winters (see figure 9).

The sample population of the herd are represented by the buck and doe killed during the season. At these mandatory check points, deer age and sex ratios are determined through biological aging techniques which are then used to figure out the age and sex structure of the population. The sample will not represent the herd if the deer take is low. Each year the buck take can suggest the population level of deer in the forest. High deer takes during harvest time are indicative of high over-winter survival from an accumulation of previous winters. However, high overwinter survival rates do not necessarily translate into a healthy overwinter survival (see figure 10).

If herd survival is too high, due to a succession of mild or moderate winters then the population increases, and the deer take should increase as well.

Data obtained from aging deer, according to the amount of wear on the teeth and teeth replacement, shows the age composition of the deer population. This data will indicate the degree of annual addition of new offspring to the herd, as well as the average life span and the rate of decline of various age groups over a period of time. While studying deer ages, the deer can be divided into two groups; those under two years of age and those above that age. The factor which determines the age group is the presence or absence of the deciduous teeth, which are equivalent to baby teeth in humans. and the degree to which these teeth have been replaced by permanent ones.

The physical condition of the herd is assessed by the mean antler beam diameter and the average weights of the deer brought in. Under poor food conditions, the antlers will look like spikes; consisting of the main beam only. Spikes are more common in yearling deer because antler growth begins

figure 9

Biological Data and Population Numbers of the Yearling Age Group

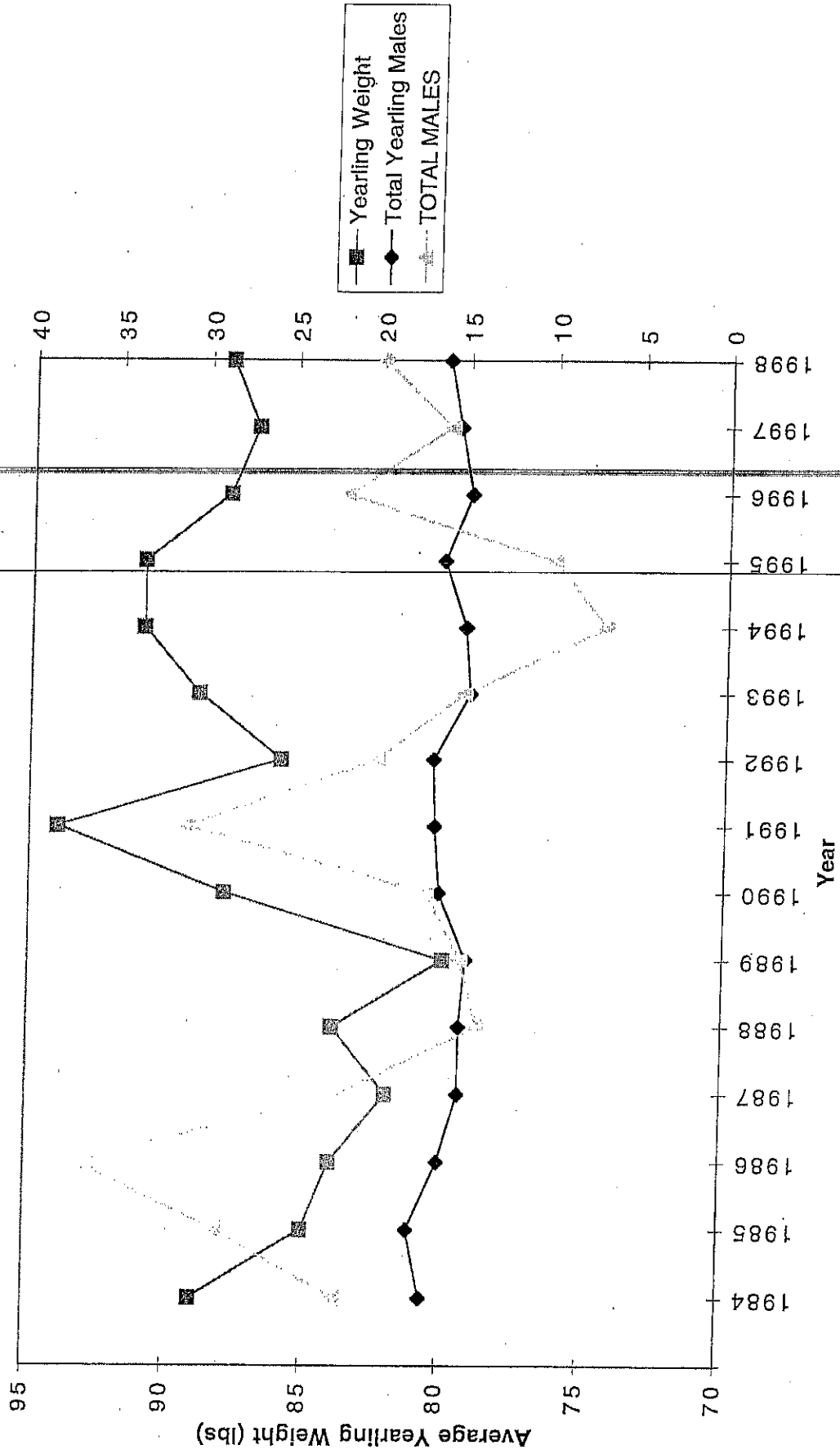
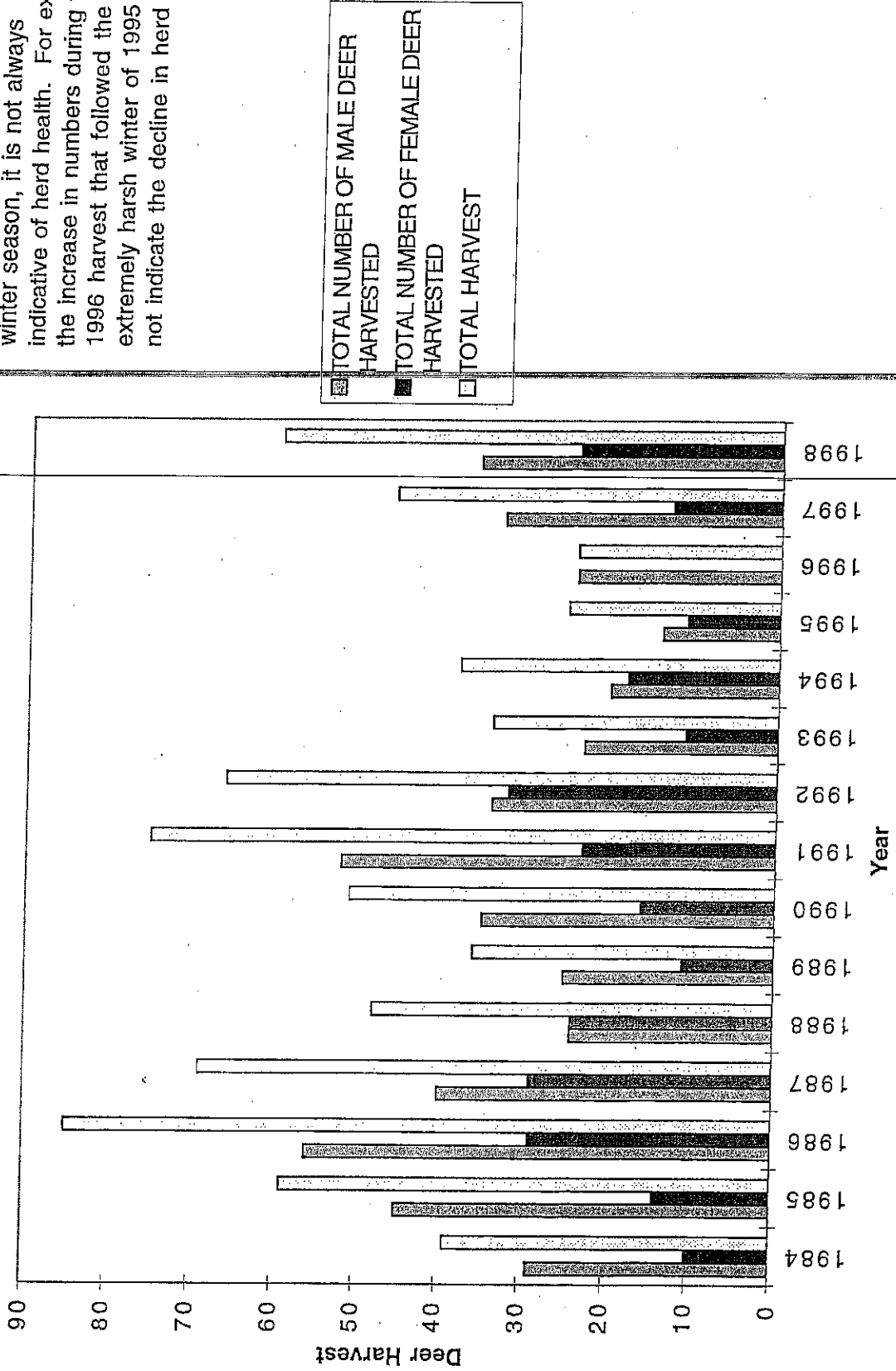


figure 10

Total Deer Harvest

Though the yearly harvest of male deer can suggest the relative severity of the winter season, it is not always indicative of herd health. For example, the increase in numbers during the 1996 harvest that followed the extremely harsh winter of 1995 would not indicate the decline in herd health.



■ TOTAL NUMBER OF MALE DEER HARVESTED
 ■ TOTAL NUMBER OF FEMALE DEER HARVESTED
 □ TOTAL HARVEST

at this stage when the deer is growing rapidly. Also, antler development is tied closely with the animal's nutritional needs. More of the nutrients in the body of a young buck must be invested into body growth which is why there are less nutrients available for antler growth and development. Antler beam diameters measured at the deer check stations are directly indicative of buck health. Since 60-70% of the sample population brought into the stations consists of yearlings, due to the timing of hunting season, the yearling antler beam diameter, (YABD), is the main measurement used to estimate the health of the entire herd (see figure 11).

Deer Tracking Census

During winter, tracking deer tracks provides another method of sampling the herd. The tracking census during winter months determines the number of deer per range of forest area by counting deer tracks after freshly fallen snow. Deer tracking determines the minimum overwintering population, the number of deer per group, and the deer density. (see figures 12, 13). The number of deer per range of forest area during winter depends on food resources. A low minimum overwintering density suggests that food resources are inadequate which will result in body mass depletion. Overwintering deer groups move according to food availability.

Accidental Deer Kill

Another sample of the herd is provided by the deer carcasses found on roadways or mutilated by predation. Female deer killed during highway accidents, allows the manager to look at the number of fetuses she carried. The greater the number of fetuses, the better the physical condition of the deer herd and the reproductive rates. The size of teats is another indicator of

the reproductive success of the deer population. If the teats of a yearling doe are over a certain length, she bred when she was a fawn and was therefore well-nourished. According to these three sampling methods, the deer manager will make decisions to lower the population by increasing the deer take after seeing that the deer are low in weight, have small antler beam diameters, and resulting low reproductive rates.

Methods and Materials

Winter environmental data was obtained from the Ridge Top weather station situated in the northwest region of the forest, on top of Frog Hill. Data at the station includes temperature, wind speeds, humidity, precipitation, snow fall, and solar radiation. Since the deterioration in herd health over winter, (indicated by reduction in the yearling antler beam diameter), is partly due to body heat lost to the environment, it is necessary to determine the amount of body heat lost as a result of high wind speeds and low ambient temperatures. To determine the chill factor experienced by the overwintering herd, a formula for wind chill equivalent temperature, which incorporates wind speeds and temperature, was used to understand the degree of cooling (see table I). The main problem with this formula is that is applicable only for bare skin. However, in the absence of proper instruments, which have been used to measure overwintering deer in other northeastern states (Verme 1968), this formula will have to suffice.

Table II shows the total wind chill equivalent temperatures and total snow falls for each winter month during the three years (see figure 15). The total monthly wind chill equivalent temperatures were calculated by adding all the daily wind chill equivalent temperatures according to daily temperature and wind speed records. These monthly wind chill equivalent temperatures totals were corrected by dividing by 10. The corrected totals of wind chill equivalent temperature were then averaged over the three years to obtain the average wind chill equivalent temperature for each month during winter (see table III, figures 16,17). These monthly averages will be considered "normal" or average chilling conditions for each month during winter.

Table I

TABLE I				
source: "windchill" <i>Encyclopedia Britannica Online</i>				
< http://www.eb.com:180/bol/topic?tmap_id=228159000&tmap_typ=dx >				
Wind chill factor is a measure of the cooling power of air o bare skin in relation to temperature and wind speed.				
One formula to express the heat (in kilogram calories) lost by one meter of skin in one hour is:				
$K = [10.45 + 10 \times (\text{square root of } v) - v] (33 - t)$				
in this formula v equals wind speed in meters per second and t equals air temperature in degrees Celsius.				
From this formula, windchill equivalent temperature (T_e) can be derived, which is the standard wind speed that would produce the same heat loss as the given temperature and wind speed.				
$T_e = 33 - (K/22.04)$				

Table II

TABLE II			
TOTAL MONTHLY WINDCHILL EQUIVALENT TEMPERATURE AND SNOWFALL			
	windchill		snowfall
12/1/95			
TOTAL	-243.0	-24.3	19.3
1/1/96			
TOTAL	-224.7	-22.5	38.5
2/1/96			
TOTAL	-177.2	-17.7	19.3
3/1/96			
TOTAL	26.5	2.7	21.0
	-618.3	-61.8	98.0
12/1/96			
TOTAL	41.0	4.1	10.5
1/1/97			
TOTAL	-282.7	-28.3	2.0
2/1/97			
TOTAL	-70.1	-7.0	5.0
3/1/97			
TOTAL	-68.7	-6.9	19.0
	-380.6	-38.1	36.5
12/1/97			
TOTAL	-47.0	-4.7	6.0
1/1/97			
TOTAL	20.4	2.0	1.5
2/1/97			
TOTAL	11.3	1.1	7.5
3/1/97			
TOTAL	1117.2	111.7	1.0
	1102.0	110.2	16.0

Table III

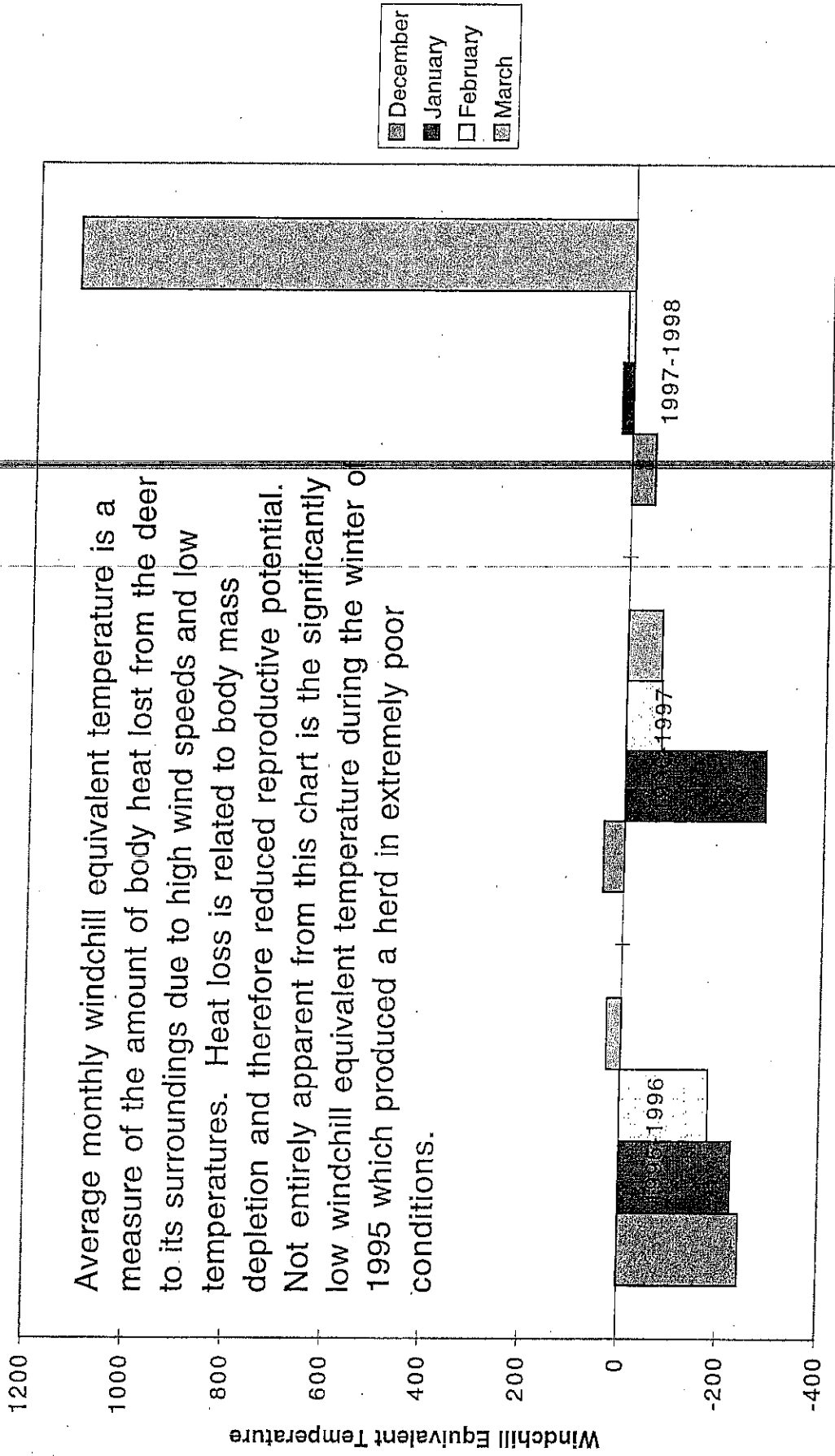
TABLE III			
AVERAGE MONTHLY WIND CHILL EQUIVALENT TEMPERATURE AND AVERAGE MONTHLY SNOW FALL FOR DECEMBER THROUGH MARCH			
	windchill		snowfall
December			
1995-1996			
TOTAL	-243.0	-24.3	19.3
1996-1997			
TOTAL	41.0	4.1	10.5
1997-1998			
TOTAL	-47.0	-4.7	6.0
AVERAGE	-83.0	-8.3	11.9
January			
1995-1996			
TOTAL	-224.7	-22.5	38.5
1996-1997			
TOTAL	-282.7	-28.3	2.0
1997-1998			
TOTAL	20.4	2.0	1.5
AVERAGE	-162.3	-16.2	14.0
February			
1995-1996			
TOTAL	-177.2	-17.7	19.3
1996-1997			
TOTAL	-70.1	-7.0	5.0

Table III

1997-1998				
TOTAL	11.3	1.1	7.5	
AVERAGE	-78.7	-7.9	10.6	
March				
1995-1996				
TOTAL	26.5	2.7	21.0	
1996-1997				
TOTAL	-68.7	-6.9	19.0	
1997-1998				
TOTAL	1117.2	111.7	1.0	
AVERAGE	358.3	35.8	13.7	

figure 15

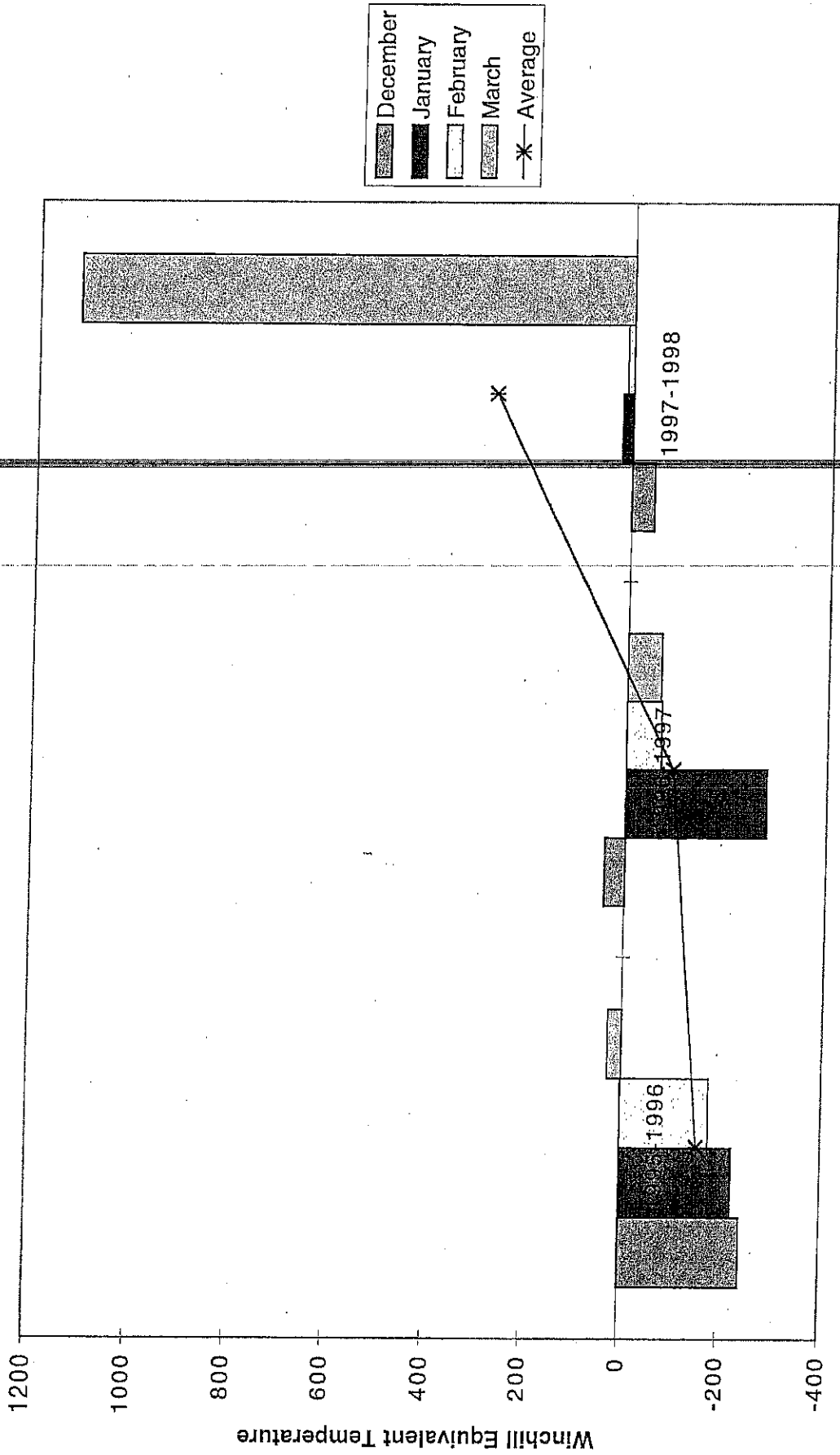
Comparing Monthly Windchill Equivalent Temperature



Year

figure 16

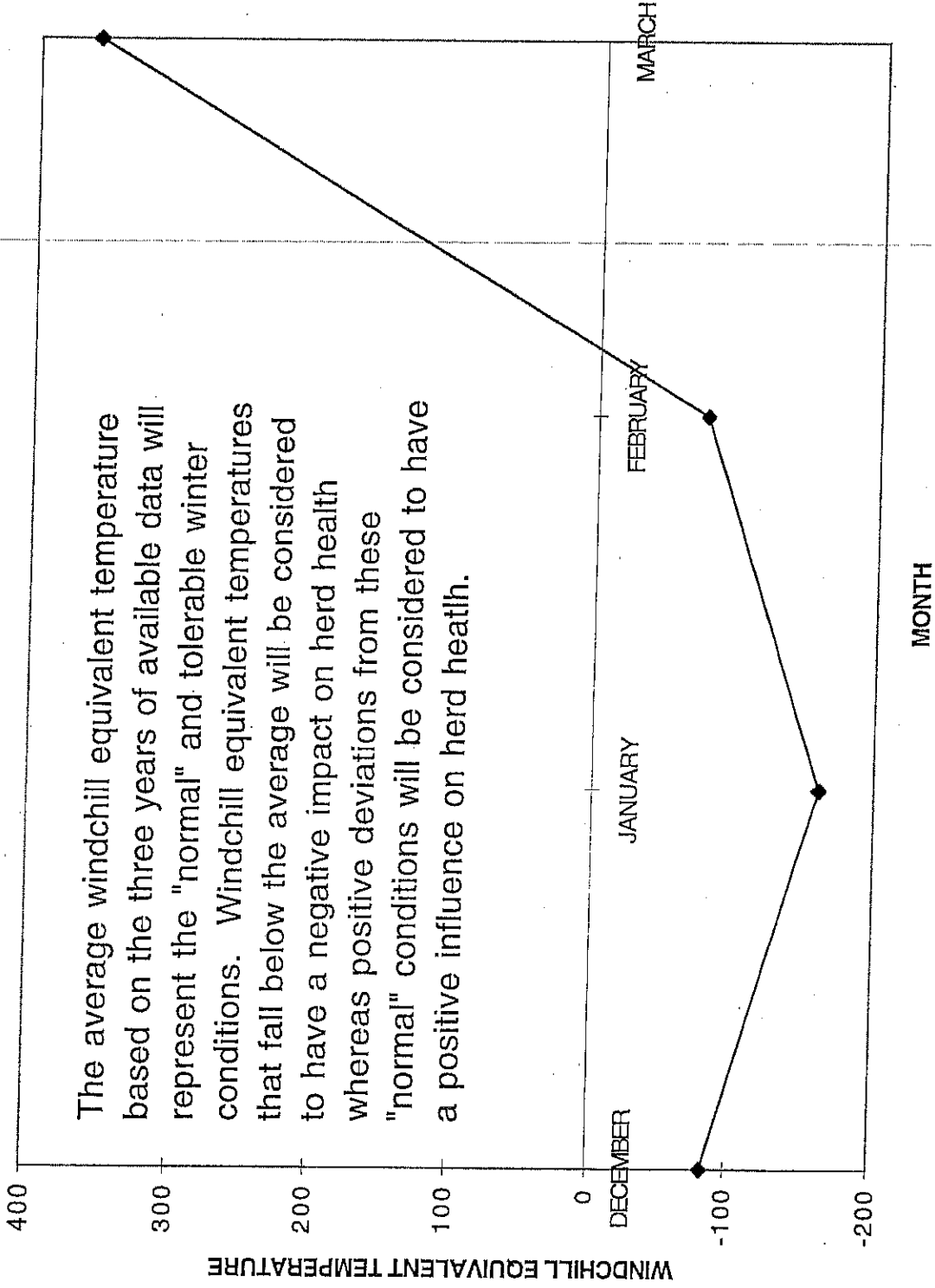
Monthly Windchill Equivalent Temperature



Year

figure 17

AVERAGE MONTHLY WINDCHILL EQUIVALENT TEMPERATURE



The average windchill equivalent temperature based on the three years of available data will represent the "normal" and tolerable winter conditions. Windchill equivalent temperatures that fall below the average will be considered to have a negative impact on herd health whereas positive deviations from these "normal" conditions will be considered to have a positive influence on herd health.

The second climatic variable which contributes to herd health deterioration over winter is snow pack, a measure of snow density and depth. Again, this information is unavailable for the forest, so the average monthly snow fall was supplemented. Average monthly snow fall, for the months of December through March was determined from daily snow fall values over the three consecutive winters (see table II, figure 19). These averages will be considered "normal" monthly snow fall conditions.

After "normal" conditions for the forest have been loosely defined, monthly departures for each month of each winter will be entered into the winter severity index for each parameter (see figures 18,20). The determined monthly "average" of these parameters is then subtracted from monthly average of snow fall and wind chill equivalent temperature for each winter month of each year. Since greater than "normal" snowfall is considered to have a negative impact on the herd, a positive snow fall index values should be changed to negative. Likewise, a calculated negative snow fall index, (less than average snow fall), should be entered as a positive value in the winter severity index, since less than average snow fall will have a positive influence on the herd as energy expenditures are decreased with lighter snow falls. Likewise, a negative departure from the wind chill average should be entered as a negative value since below "normal" wind chill equivalent temperature is considered to increase the rate of heat lost to the environment. The calculation of the yearly winter severity index requires the addition of these two departures from the average of the monthly wind chill and snow fall data for each month and then the addition of each index of each winter month (see table V).

Table V

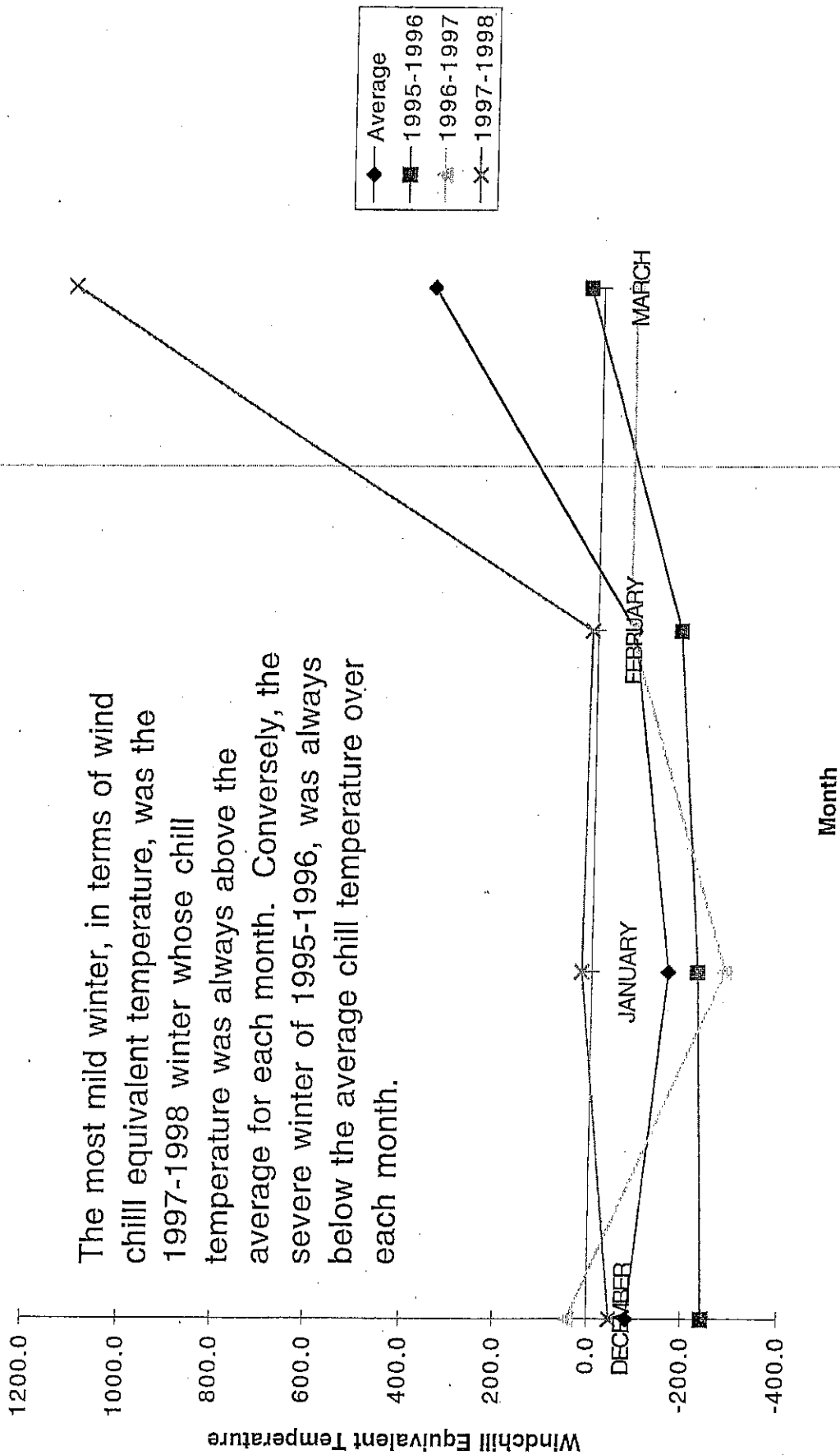
CALCULATING THE WINTER SEVERITY INDEX FOR BLACK ROCK FOREST ACCORDING TO THREE CONSECUTIVE WINTERS				
AVERAGE MONTHLY PARAMETER FROM WINTER OF 1995-1996 THROUGH WINTER OF 1997-1998				
	DECEMBER	JANUARY	FEBRUARY	MARCH
WINDCHILL	-83.0	-162.3	-78.7	358.3
SNOWFALL	11.9	14.0	10.6	13.7
Winter severity index is the departure from the monthly average of snowfall and windchill				
	Snowfall index	Windchill index	Windchill/10	WSI
Winter 1995-1996				
Dec	-7.3	-160.0	-16.0	-23.3
Jan	-24.5	-62.4	-6.2	-30.7
Feb	-8.7	-98.5	-9.9	-18.5
Mar	-7.3	-331.8	-33.2	-40.5
	-14.7		-49.2	-63.8

Table V

	Snowfall index	Windchill index	Windchill/10	WSI
Winter				
1996-1997				
Dec	1.4	124.0	12.4	13.8
Jan	12.0	-120.4	-12.0	0.0
Feb	5.6	8.6	0.9	6.4
Mar	-5.3	-427.1	-42.7	-48.0
	-3.9		-30.3	-34.2
1997-1998				
Dec	5.9	36.0	3.6	9.5
Jan	12.5	182.8	18.3	30.8
Feb	3.1	90.0	9.0	12.1
Mar	12.7	758.9	75.9	88.6
	18.6		79.5	98.1

figure 18

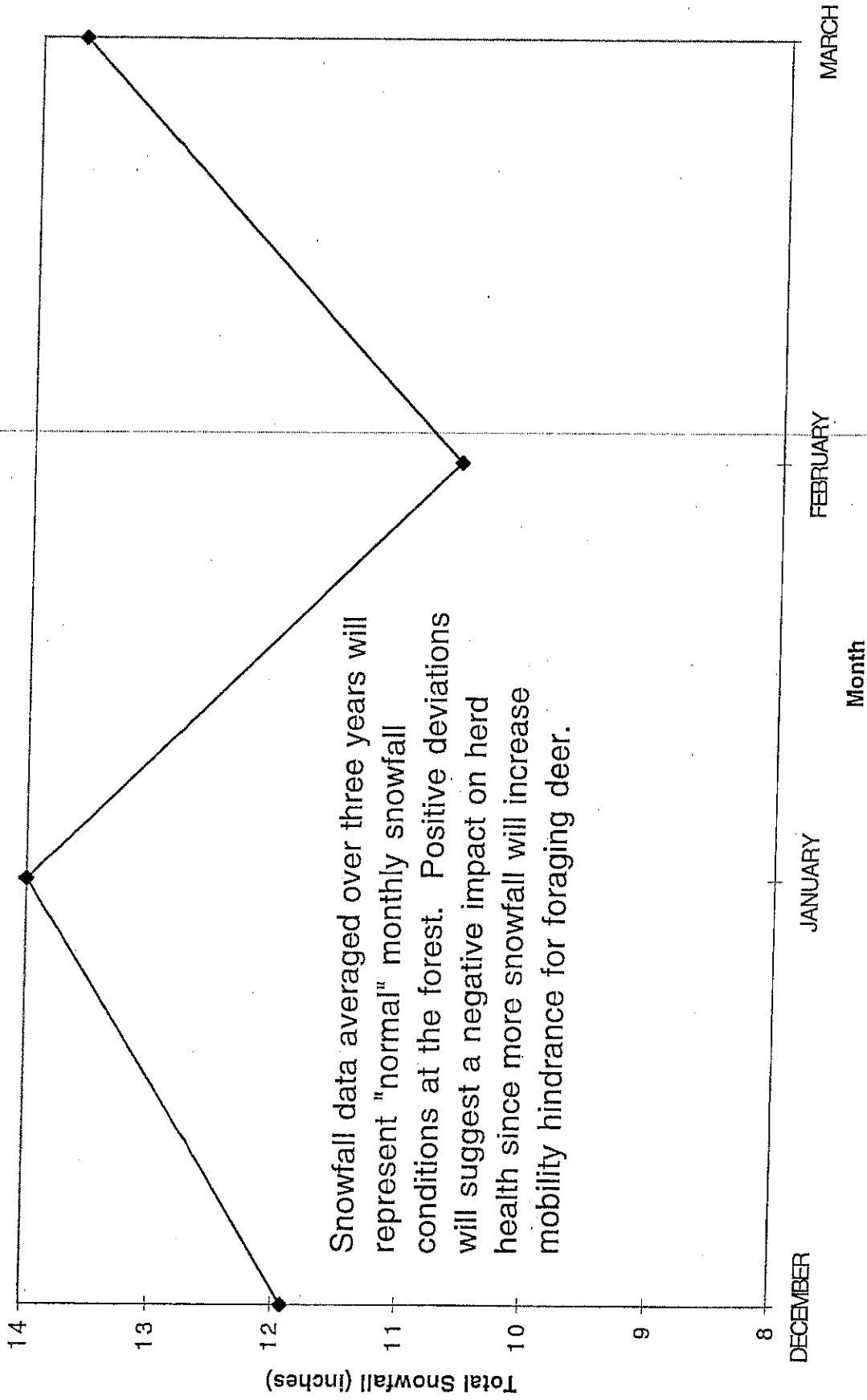
Departure From Average Monthly Windchill Equivalent Temperature



The most mild winter, in terms of wind chill equivalent temperature, was the 1997-1998 winter whose chill temperature was always above the average for each month. Conversely, the severe winter of 1995-1996, was always below the average chill temperature over each month.

figure 19

Average Monthly Snowfall for Three Consecutive Winters at Black Rock Forest

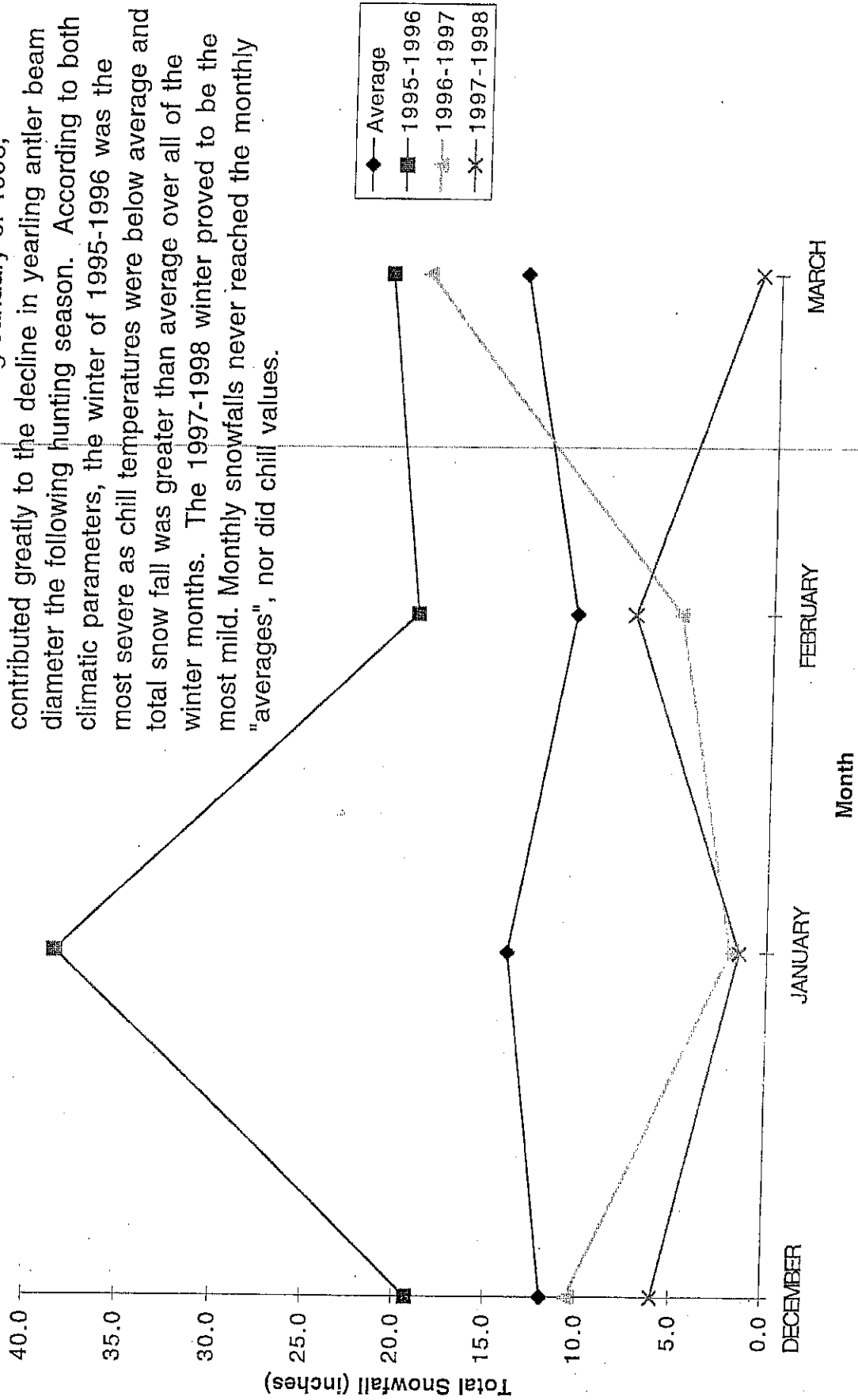


Snowfall data averaged over three years will represent "normal" monthly snowfall conditions at the forest. Positive deviations will suggest a negative impact on herd health since more snowfall will increase mobility hindrance for foraging deer.

figure 20

Departure from Average Monthly Snowfall

The excessive snow fall during January of 1996, contributed greatly to the decline in yearling antler beam diameter the following hunting season. According to both climatic parameters, the winter of 1995-1996 was the most severe as chill temperatures were below average and total snow fall was greater than average over all of the winter months. The 1997-1998 winter proved to be the most mild. Monthly snowfalls never reached the monthly "averages", nor did chill values.



Results

From table II, we see that the highest wind chill equivalent temperature was during March of 1998 at 111.7 and that the greatest positive departure from a monthly average was also during March of 1998. Table II shows that wind chill equivalent temperature was lowest, or most severe, during January of 1997 at -28.3, but from table IV, we see how the greatest negative departure from "normal" wind chill equivalent temperature was during March of 1997. Table II also shows that the greatest snow fall was during January of 1996 and the this month also had the highest negative departure from "normal" snow fall conditions (see table IV, figure 23). Lowest total monthly snow fall over the three years was during March of 1998. However, the smallest positive departure from "normal" snow fall conditions was during December of 1996.

All departures from the "normal" monthly wind chill equivalent temperatures and "normal" monthly snow fall conditions, during the severe winter of 1995-1996, were negative. Likewise, the winter of 1997-1998 had zero negative monthly index values for both parameters. The winter of 1996-1997 possessed two negative wind chill equivalent temperature index values during January and March. The March index represents the most negative departure from "average" monthly wind chill equivalent temperature over the three winters. For the 1996-1997 snow fall index, this winter had 5.3 inches greater than "average" snow fall during March, where all other months during this winter less than "average" snow fall (see table IV).

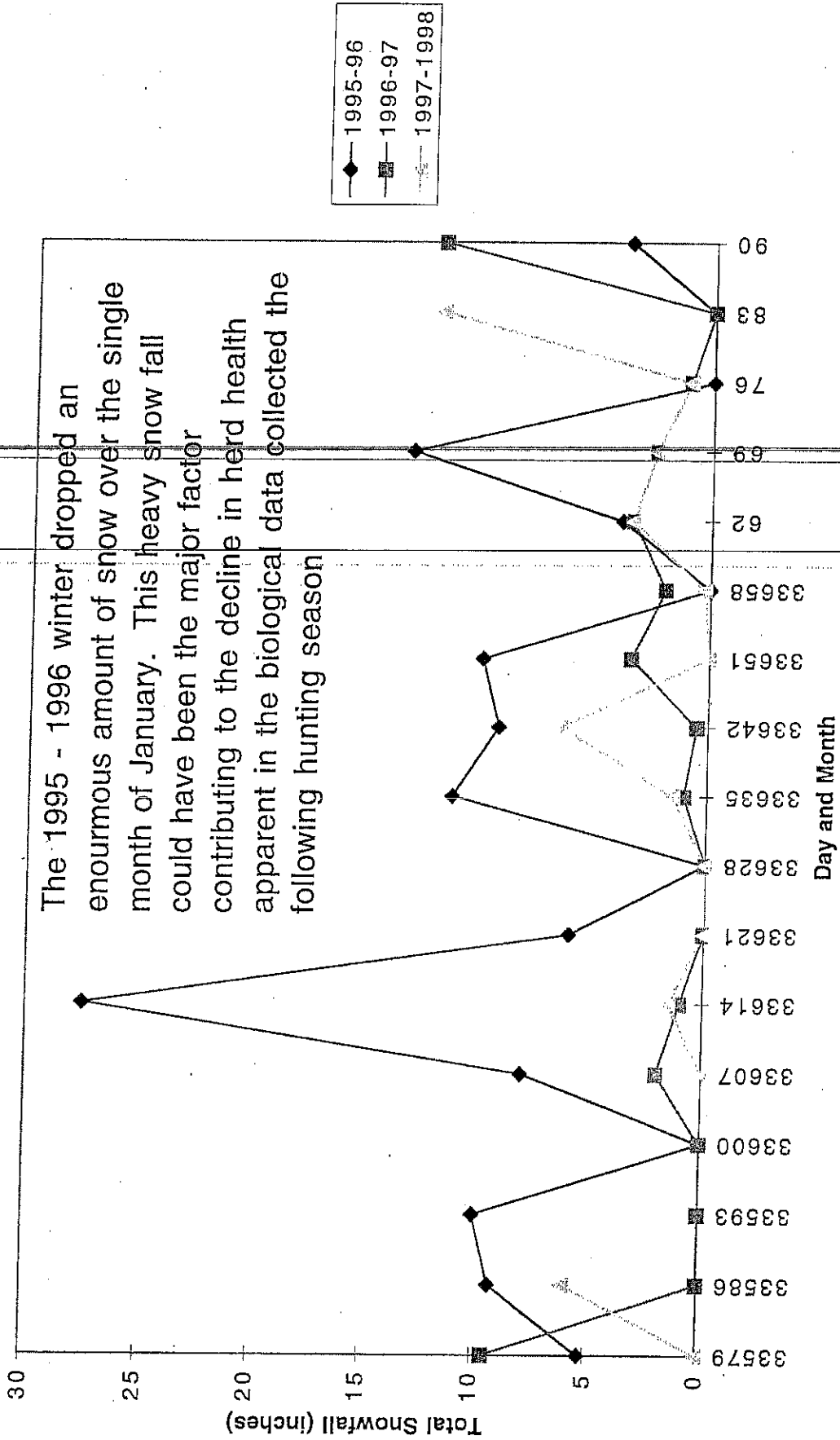
The winter severity indices for Black Rock Forest across the three months ranged from -63.8 during 1995-1996 to 98.1 during the winter of 1997-1998, equaling a difference of 161.9. The difference between the winter of

Table IV

TABLE IV					
AVERAGE MONTHLY PARAMETER FROM WINTER OF 1995-1996 THROUGH WINTER OF 1997-1998					
	DECEMBER	JANUARY	FEBRUARY	MARCH	
WINDCHILL	-83.0	-162.3	-78.7	358.3	
	-8.3	-16.2	-7.9	35.8	
SNOWFALL	11.9	14.0	10.6	13.7	
DEPARTURE FROM AVERAGE	WINTER OF 1995-1996				
	DECEMBER	JANUARY	FEBRUARY	MARCH	
WINDCHILL	-160.0	-62.4	-98.5	-331.8	-652.7
	-16.0	-6.2	-9.9	-33.2	-65.3
SNOWFALL	-7.3	-24.5	-8.7	-7.3	-47.8
				TOTAL	-113.1
DEPARTURE FROM AVERAGE	WINTER OF 1996-1997				
	DECEMBER	JANUARY	FEBRUARY	MARCH	
WINDCHILL	124.0	-120.4	8.6	-427.1	-414.9
	12.4	-12.0	0.9	-42.7	-41.5
SNOWFALL	1.4	12.0	5.6	-5.3	13.7
				TOTAL	-27.8
DEPARTURE FROM AVERAGE	WINTER OF 1997-1998				
	DECEMBER	JANUARY	FEBRUARY	MARCH	
WINDCHILL	36.0	182.8	90.0	758.9	1067.6
	3.6	18.3	9.0	75.9	106.8
SNOWFALL	5.9	12.5	3.1	12.7	34.2
				TOTAL	140.9

figure 23

Weekly Total Snowfall from December 1 - March 31 at Black Rock Forest



1995-1996 and the winter of 1996-1997 is only 29.6, compared to the difference between the winter of 1996-1997 and the winter of 1997-1998 which was 132.3 (see table V).

Discussion

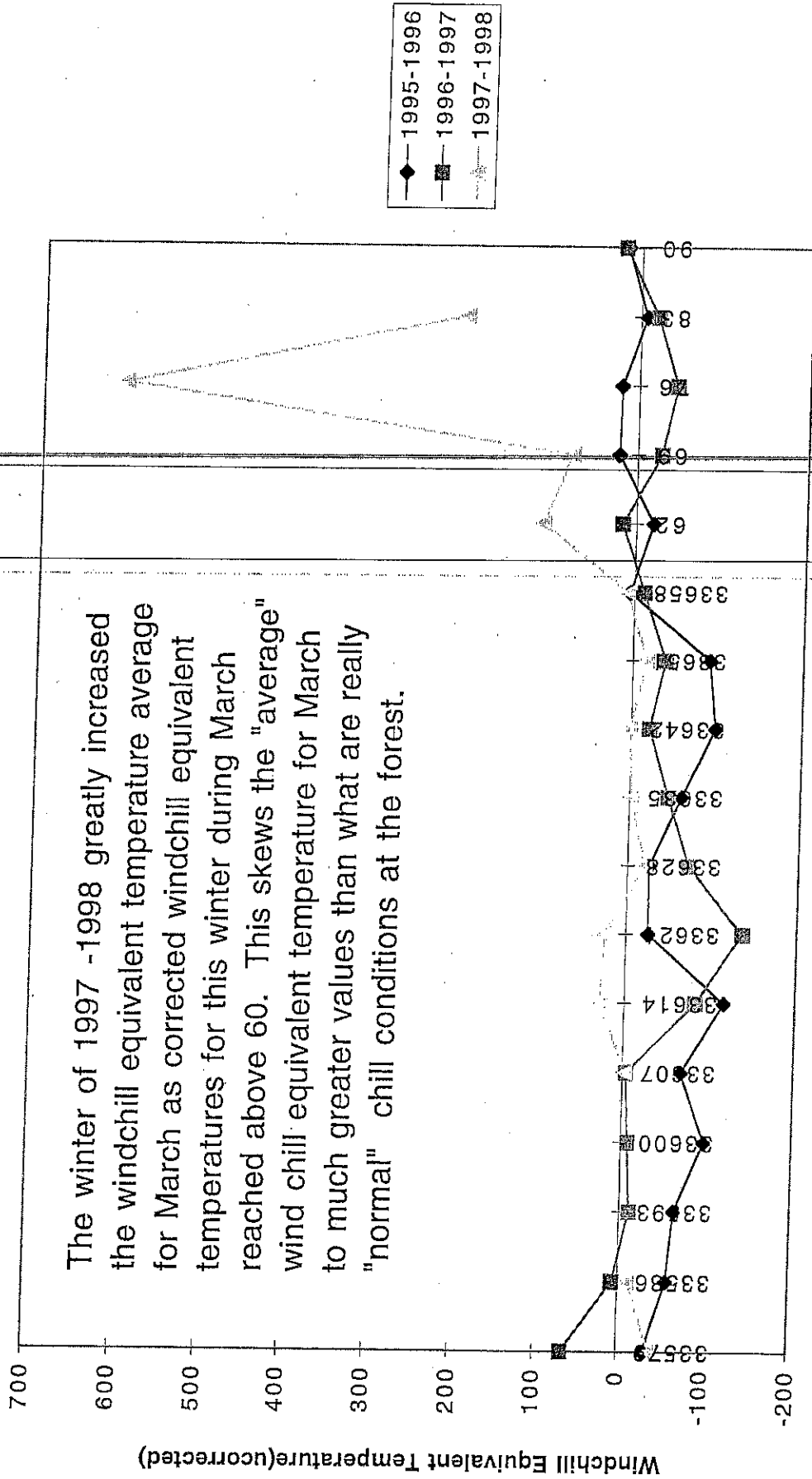
Rating the Winters: Environmental Parameters

Based on the numerical derivations of the winter severity index, it can be concluded that the 1995-1996 winter was most severe, with the most negative value of -63.8 and the winter of 1997-1998 was clearly the most mild, with an index value of 98.1. The winter index value of 1996-1997 lies closer to the severe winter of 1995-1996 with an index value of -34.2. Since these values only describe winter severity in relative terms, we can consider the winter of 1996-1997 to be mildly severe, or moderately harsh.

Since there are only two environmental parameters considered in the calculation of the index, it can be assumed that the pattern of decreasing winter severity reflected in the relative harshness of the three winters, is strictly a measure of wind chill equivalent temperatures and snow fall. Looking closely at the monthly totals and departures from "average" conditions, we notice how the 1996-1997 winter had the most negative corrected wind chill equivalent temperature of -28.3 during January, yet was not rated the most severe according winter severity index values, (see table II, V). This method of winter severity index calculation ignores the possible effects of intense wind speeds and low temperatures over a short time period, (such as during January of 1997), and considers only the cumulative result of severe winter conditions over the four months (see figure 21,22). The winter that we define as being the most severe, had all of its index values below zero. This means that during the winter of 1995-1996, the monthly wind chill equivalent temperatures were lower than "average" and monthly snow fall was greater than "average" for all four months of that winter (see figures 18,20). The 1996-1997 winter had two negative wind chill equivalent

figure 21

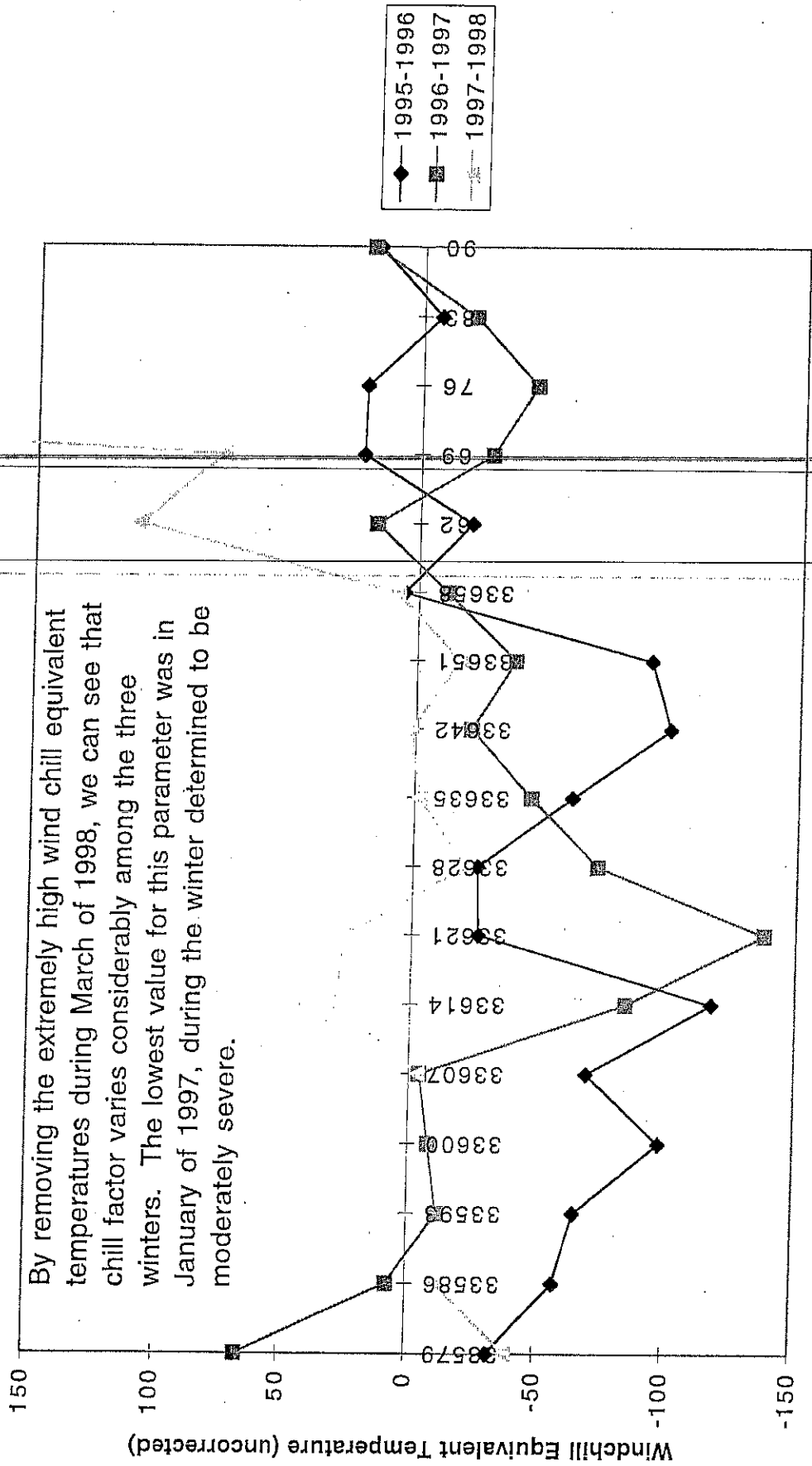
Weekly Windchill Equivalent Temperature from December 1 - March 31 at Black Rock Forest



Day and Month

figure 22

Weekly Windchill Equivalent Temperature from December 1 - March 31 at Black Rock Forest



Day and Month

temperature indices and one negative snow fall index over the four months of winter.

There is little doubt that the winter of 1997-1998 was the most mild as both of its index values were the most positive for all months. This winter had the highest wind chill equivalent temperatures and lowest snow falls during the four months of winter.

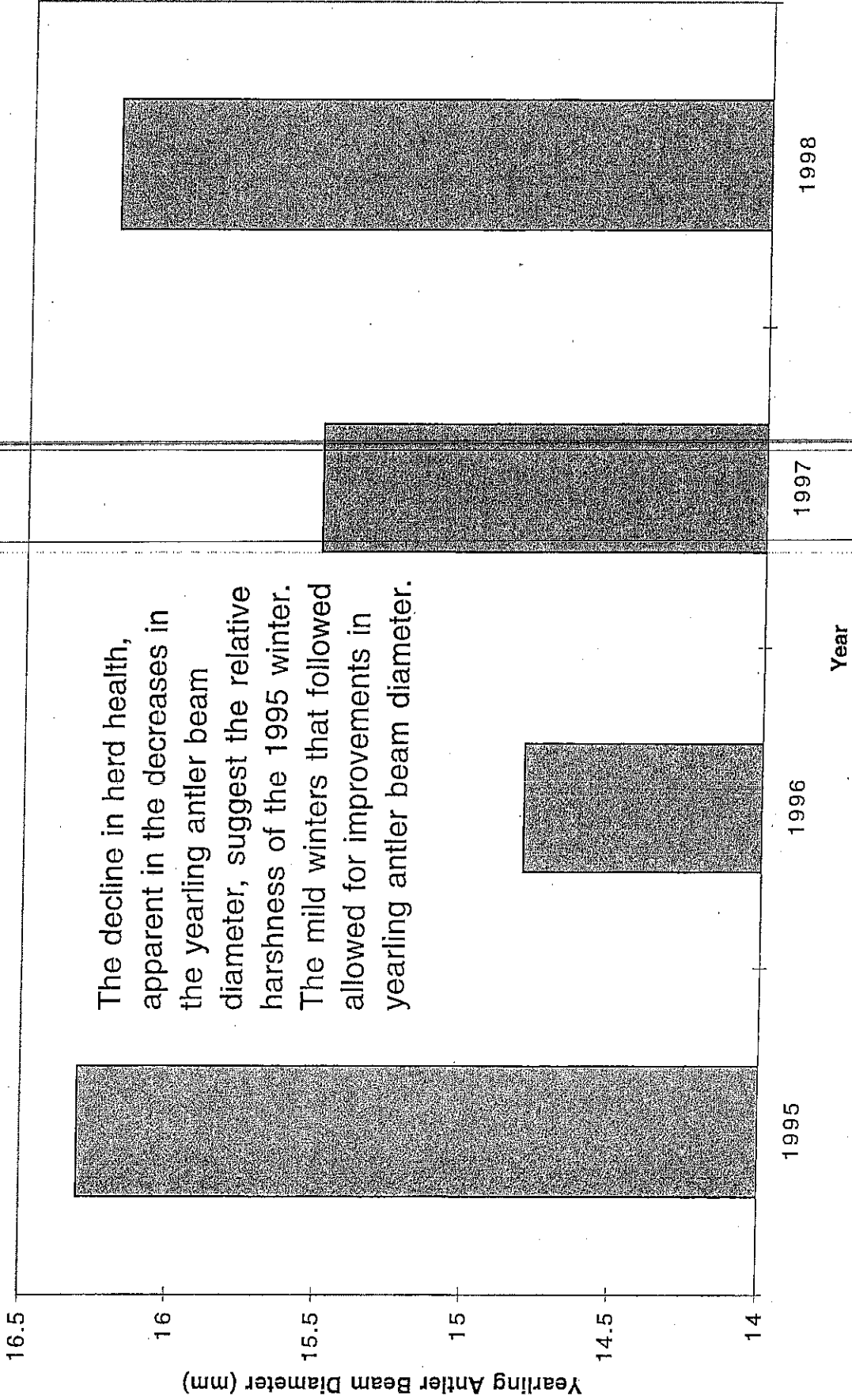
Winter Severity and Herd Health

It is possible to rate relative winter severity according to trends in the yearling antler beam diameter over the three consecutive winters (see figure 14). It can be concluded that the yearling class, sampled prior to the winter season in 1995, returned the following season in 1996, after enduring the harsh winter, with greatly depleted the antler beam diameters. The following two winters considered in this study showed improvements in yearling antler beam diameters as snow fall lessened and wind chill equivalent temperatures increased (see figures 15, 8). Based on biological information alone, the 1995-1996 winter appears to be the most severe. It would be difficult to determine the relative severity of the 1996-1997 and 1997-1998 winters simply by looking at yearling antler beam diameter, since the effects of the harsh winter of 1995-1996, will create a lag in health improvements as the herd requires time to recuperate from a weakened condition due to body mass loss and lack of nutrients.

According to the calculated winter severity index values, we rated the 1996-1997 winter as being mildly severe or moderately harsh. Previously discussed, this winter more closely resembled the severe winter of 1995-1996 than the mild winter of 1997-1998 in terms of index values which indicate the cumulative effects of wind chill equivalent temperatures and snow fall

figure 14

Trends in Yearling Antler Beam Diameter



during the four months of winter. If this winter is considered to be moderately severe, in terms of wind chill equivalent temperature and snow fall, then one would expect little improvement, if any, in yearling antler beam diameter, especially after the harsh winter season of 1995-1996. From figure 14, we notice how improvements in beam diameter are relatively great, considering the relatively negative index value of the 1996-1997 winter, and also considering the serious post-winter injuries to herd health from the winter of 1995-1996. One could assume that another variable plays a role in determining the health of the overwintering herd.

Conclusions

Winter Severity and Acorn Availability

The physical condition of the herd, indicated by the yearling antler beam diameter, is a direct consequence of the amount of available nutrition in the forest and the severity of the winter conditions. The winter survival of the deer population clearly depends on the amount of available nutrition in the forest. The primary overwintering food source comes from the acorn crop, which provide both ample protein and fat for the herd. Acorn availability during winter can be greatly decreased, when they become trapped underneath the frozen ground, making them completely inaccessible for foraging deer.

The supply of acorns at Black Rock Forest, come from the oak tree family, which includes the Northern Red Oak, Black Oak, White Oak, and Chestnut Oak (see figure 6). In 1995, and 1997, there were no white or chestnut oaks, and the northern red oak predominated. In 1996 and 1998, all four types of oak were present (see figure 6). The relationship between the acorn crop and yearling antler beam diameter is almost a linear one (see figure 7). The extremely low yield of 1995, was highly insufficient to sustain the health of the herd during the unusually harsh winter of 1995-1996, and yearling antler beam diameter decreased in 1996. Since 1995, the total amount of acorns in the forest has been increasing (see figure 5). From 1997-1998 the total yields in the forest have been extremely favorable, with total numbers per acre exceeding 50,000. The slight discrepancy in the linear relationship between yearling antler beam diameter and the total number of acorns per acre is between 1997-1998, when the high yields remained constant yet the yearling antler beam diameter continued to increase.

The winter severity index of 1996-1997 suggests that the winter was more harsh than mild, which would possibly imply further decreases in herd health or a stabilization of their already weakened condition from the previous winter season. Despite these considerations, there were definite increases in antler beam diameter apparent in the sample of yearlings brought into the deer check stations in 1997. The improvements must be a result of the ample acorns that were able to supply the herd during the moderately severe winter of 1996-1997. The improvement of winter conditions during 1997-1998 continued to increase the antler beam diameter of the herd despite the stabilization of the total number of acorns per acre. It is possible to understand the effects of the winters on the deer population at Black Rock Forest by studying the mast crop of the fall preceding the winter, the degree of cooling and the amount of snow fall.

Recommendations

Problems with the Index Calculation

There appear to be three technical problems to the previous calculated winter severity index values. The considered "average" wind chill equivalent temperature and snow fall, are clearly not representative of normal wind chill equivalent temperatures and snow fall. A longer environmental data series, preferably initiating with the collection of the deer biological data in 1984, are necessary. In addition, a precise formula that would express the degree of chill experienced by the herd would also improve the quality of the results. Wind chill equivalent temperature does not consider the insulating properties of deer winter coat, nor does it consider metabolism, or the often rapid movements of deer, that would increase cooling power. Snow pack data is unavailable, which also provides another inaccuracy in the derivation of the index values. It is essentially the hardness and depth of the snow that increase energy expenditures through snow and not total snow fall. In order for the index to be successfully integrated, more and proper measurements of snow compaction and wind chill are necessary.

Winters with highly negative index values will most probably deteriorate herd health and winters with extremely positive conditions will benefit the herd with gentle wind speeds, above normal temperatures, and light snow fall. It will be difficult to determine whether or not herd health will improve, remain the same, or decline, for winters that fall somewhere in between mild and severe without supplemental information on acorn yields. Proper equipment that could accurately gauge the heat loss from deer or a compaction device that could measure the relative energy dissipated as deer

struggle through deep soft snows would improve the index values to a large degree.

Suggestions

Verme (1968) calculated a winter severity index for deer in upper Pennsylvania using a chillometer to record atmospheric chill production and a compaction gauge, which measure snow depth and compaction quality of the snow. The use of such instruments can offer a much more precise measure of winter severity depending on the climate variability, acorn production, and population levels of the area.

Other experiments could be investigated in order to better understand the relative role of food availability on the rate of body mass loss, compared to wind chill and snowpack conditions. Studies conducted on a contained overwintering deer population, where deer were supplied with ample amounts of food, high in nutritional value, during extreme winter conditions, would suggest the degree of body mass depletion due to chilling and energy expenditures alone (Verme, 1962).

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