WHITE-TAILED DEER POPULATION MANAGEMENT IN THE NORTH CENTRAL STATES

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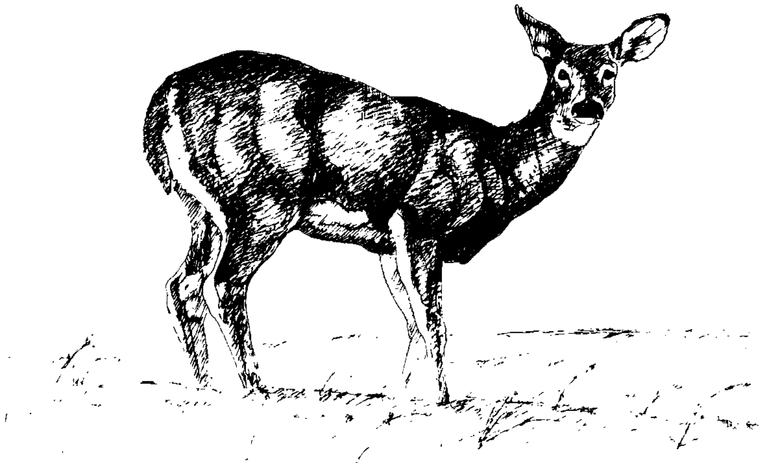
Alan Crossley



WHITE-TAILED DEER POPULATION MANAGEMENT IN THE NORTH CENTRAL STATES

Proceedings of a Symposium held at the 41st Midwest Fish and Wildlife Conference, Urbana, Illinois, 10 December 1979

Ruth L. Hine and Susan Nehls
Editors

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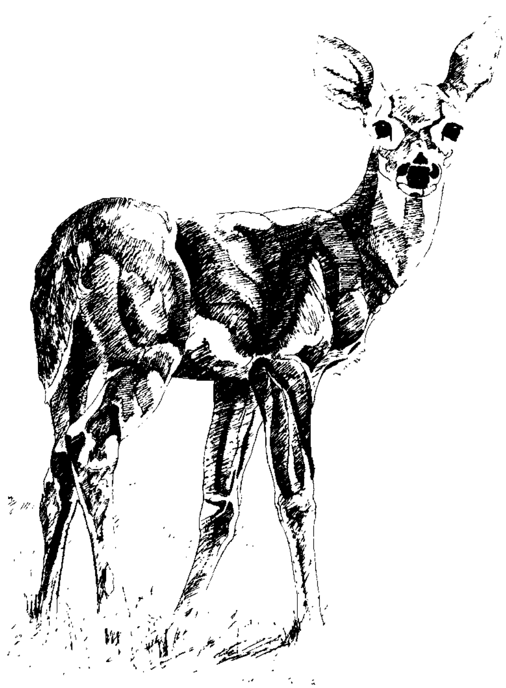

The white-tailed deer is the "bread and butter" game animal for nearly all the states in the north central part of the United States. The welfare of this deer has more influence on the policies, the politics, the finances, and the sociology of the hunting public in this region than any other game species, except perhaps the pheasant in South Dakota.

The whitetail has generated vast numbers of scientific studies, precipitated many acrimonious debates, caused more highs and lows in organizational morale, has triggered departmental reorganizations, and even has been the political downfall of state legislators. The scientific literature could keep a reviewer busy month after month. Volumes have been written on deer biology and countless sporting journals tell how to hunt the animal. In spite of the literally millions of written words about the whitetail, we are unaware of any single volume which deals with the pertinent population management concepts that must be dealt with annually by the managers and administrators responsible for today's deer herds. The collection of papers in this symposium has been designed to fill this void.

A loosely organized group of biologists known as the Midwest Deer and Wild Turkey Group served as an informal committee to carefully consider the major elements in the deer management formula. It was decided, after due consideration, to restrict the symposium subject to the species management problems and not include habitat management. Two major reasons for this decision were: many deer herds occur on private lands where little or no opportunities for range manipulation are available, and there was a definite limitation on both time and space for the symposium.

Working with leaders of the North Central Section of The Wildlife Society, they set about to recruit the most competent deer workers in the region to contribute to this book.

This collection of papers attempts to deal with the major phases of species management for the white-tailed deer. It looks at the basic tools and techniques, such as aging deer, determining populations, and measuring the harvest. It also considers various causes of mortality, factors influencing productivity, and goes all the way to the human dimensions of dealing with the hunters, the general public, and the administrators. In the Appendix are highlights of an extensive chronology of white-tailed deer in Wisconsin, prepared by a noted conservation historian.

We are more than grateful to the authors for their contributions to this symposium, which will bring under one cover the pieces of the management puzzle and sort them out in a logical and useful manner.

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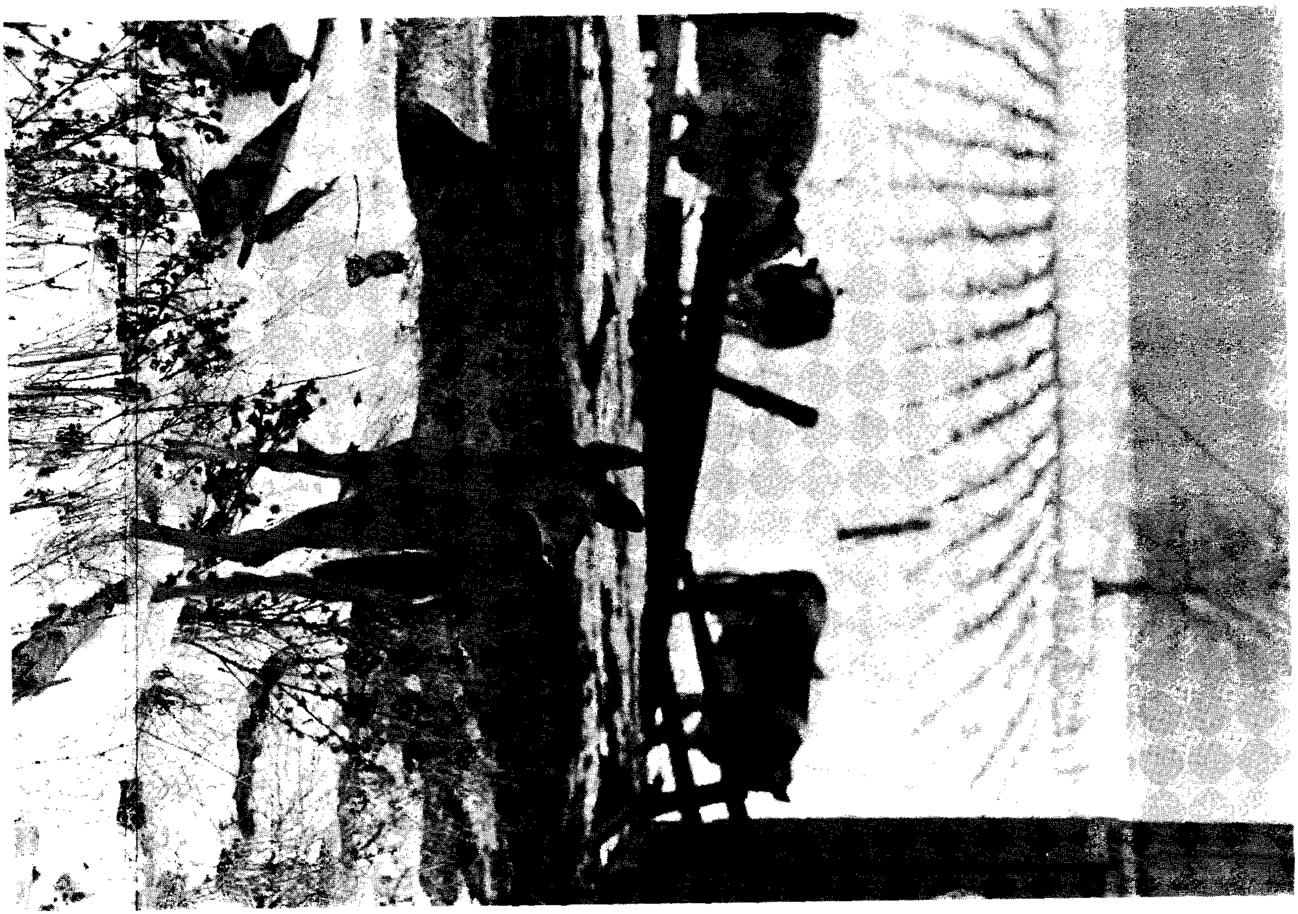

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DEER POPULATION ESTIMATORS IN THE MIDWEST FARMLAND

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Abstract: Estimating deer population numbers or trends is useful in formulating harvest regulations, long-range management goals, and public relations programs, and in evaluating harvest goals and habitat management practices. Techniques vary between states and depend upon agency management goals, manpower, tradition, habitat, deer density, and weather conditions. Population estimators currently in use in the Midwest Farmland include: deer-vehicle accident reports, sex-age-kill estimates, roadside observations, aerial surveys, registered buck kill, hunter kill-effort, track counts, conservation officer estimates, crop depredation reports, population models, and landowner surveys. Most states rely on more than one estimator in an attempt to obtain comparable results. Numerous sources of bias are involved and some questionable assumptions must be made. It is doubtful that these techniques can measure changes of less than 20% in population size. Finding new population estimators that can be statistically evaluated and can accurately predict population change should be a major goal of future research.

INTRODUCTION

The Midwest Farmland is generally defined as the bluestem prairie region which consists of agricultural land interspersed with oak-hickory, cottonwood-elm, or beech-maple timber types. Portions of 12 states are included in this region: eastern North Dakota, South Dakota, Nebraska, and Kansas; northern Missouri; southern Minnesota, Wisconsin, and Michigan; all but the southern tip of Illinois; and Iowa, Indiana, and Ohio (Fig. 1). Generally, white-tailed deer (*Odocoileus virginianus*) density is low because of lack of extensive timbered habitat. However, high reproductive rates, minimal overwinter loss, and good body condition are benefits provided by extensive use of agricultural crops for food (Mustard and Wright 1964, Watt et al. 1967, Nixon et al. 1970). Farming is the major land use and because of problems with landowner intolerance for crop damage, deer populations must be carefully controlled. Because of milder winters and the wide distribution of their major food source, deer do not concentrate in winter yards as in the more northern parts of their range.

History indicates that significant changes in deer management have taken place in the Midwest Farmland. Deer were common when settlers first arrived and were used extensively for food, clothing, shelter, and tools. But, a growing demand for food, by an expanding human population, brought about market hunting and habitat destruction which substantially reduced deer numbers during the late 1800's. In the early 1900's, state legislatures began closing or restricting hunting seasons in an attempt to reduce harvest. During the 1930's and 1940's, populations increased rapidly in response to restricted hunting, establishment of refuges, effective law enforcement, restocking, and habitat improvement. By the 1940's and 1950's, increased deer densities produced widespread crop damage and hunting seasons were once again instituted to harvest the surplus. Since then, scientific management of deer has become increasingly difficult because of unique biological, social, economic, and political problems. Resource managers have attempted to establish a balance between landowner tolerance for crop damage and deer populations that are extremely vulnerable to harvest.

THE NEED FOR POPULATION ESTIMATORS

The need for proper management decisions, based on sound biological data, is dictated by well-informed and organized sportsman and nonhunter groups, competition for available habitat from other land uses, and competition for conservation dollars. The ability of resource managers to accurately predict deer population size or trends is the cornerstone to formulating management goals, hunting regulations, and public relations programs.

Management goals should be developed in response to deer density, available habitat, crop depredation, landowner attitudes, and hunting and nonhunting recreational uses. A classic statement at this point would be that population levels should be maintained near carrying capacity. Carrying capacity has generally been defined as the maximum number of deer that an area can support without damage to the habitat (Hosley 1956:224). But, determining the carrying

Gladfelter, Lee. 1980. Deer population estimators in the Midwest farmland. Pages 5-11 *in* Ruth L. Hine and Susan Nehls, eds. White-tailed deer population management in the north central states. Proc. 1979 Symp. North Cent. Sect. Wildl. Soc. 116 pp.

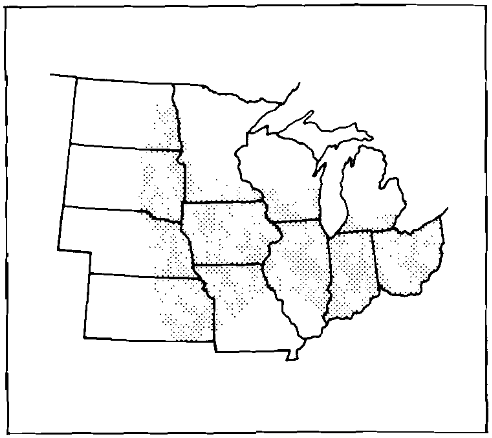

FIGURE 1. *The Midwest Farmland.*

capacity in agricultural areas where timber provides cover and crops provide an abundant food source is difficult. Statewide deer densities in the Midwest Farmland range from 0.2 to 3.0 deer per km² (Nixon 1970) but in some refuges where hunting is restricted and agricultural crops are available, winter concentrations exceed 80 deer per km². Therefore, potential carrying capacity is great but realistic population levels depend upon the management goals of the conservation agency.

Hunting seasons are the most effective management tool available to the resource manager. Once management goals have been established, hunting regulations should be formulated to obtain the desired deer harvest. Harvest can be applied annually and hunting regulations are usually flexible enough to provide for full resource utilization while equitably distributing benefits to the hunter. Successful accomplishment of management goals through hunting regulations can only be assured when the public is convinced that sound biological data have been collected and presented. Agencies that have good public support for their programs have much more latitude in their ability to manage the resource.

FACTORS AFFECTING POPULATION ESTIMATORS

Population estimators are designed to measure some degree of change in deer population levels. A knowledge of why populations change is important in developing good estimators. Population changes may take place because deer move to more suitable habitat. This movement may be in response to heavy hunting pressure, overpopulation, habitat changes, and food shortages. Population changes may reflect differential mortality and natality rates. Mortality rates are influenced by legal and illegal hunting, disease, predator density, food supply, and accidents. Natality is generally related to nutritional level, weather, disease, and population density.

Animal behavior should be considered in selecting proper population estimators. The type of habitat selected by deer affects their observability and accessibility. A knowledge of movement is essential because immigration or emigration may drastically affect survey results on small study areas. Study areas should be selected that are large enough to contain daily home ranges and seasonal movements of deer. Other behavioral characteristics that must be considered are social aspects (family groups, breeding, herding), ability to avoid detection, and daily and seasonal activities (feeding, watering, breeding, fawning).

Other factors involved in developing population estimators include habitat composition and configuration, land use patterns, manpower, money, and tradition. Population estimators for hardwood timber and open agricultural habitat differ from those used in coniferous forest habitat. With current budgetary restrictions in most conservation agencies, the cost of conducting population estimates is an important consideration, especially for large survey areas. Often the cost of various techniques is directly related to achieved accuracy. A knowledge of local weather is also important because it affects visibility, animal behavior and movement, human comfort, and equipment operation.

TECHNIQUES CURRENTLY IN USE IN THE MIDWEST FARMLAND

Population estimators have been developed from information collected in the following ways:

(1) Field observations that rely on visual contact during the survey period, such as roadside observations, aerial surveys, population estimates by field personnel or landowners, and sex and age ratio counts.
(2) Observation of deer sign or damage, such as track counts and crop depredation reports.
(3) Examination of dead deer for use in calculating sex-age-kill estimates, buck kill, and deer-vehicle accident reports.
(4) Information obtained from hunters to provide estimates of deer harvest and hunter effort.

Conservation agencies have developed many different population estimators in response to their individual management goals (Table 1). Estimates are made on areas ranging in size from statewide to large hunting zones, counties, small management areas, state forests, and military reservations. Management goals may require a population estimator that indicates trends or one that provides a total estimate. Most states employ several different techniques for comparison purposes. This paper will not deal with specific techniques for each population estimator since references are given that provide this information. Emphasis will be placed on comparing techniques currently in use and exploring advantages, disadvantages, bias, and precision of each.

Deer-Vehicle Accident Reports

Many states are using the number of deer-vehicle accidents per billion miles traveled as a population trend indicator (Table 1). Jahn (1959) evaluated the use of deer-vehicle accidents as a trend indicator in Wisconsin but found that it was not a precise index of an-

TABLE 1. *Population estimators used by the states in the Midwest Farmland.*

Population Estimator	States
Deer-vehicle accident reports	IA, IL, KS, MI, MN, MO, NE, OH, WI
Sex-age-kill estimates	IA, IL, KS, MI, MO, OH, SD, WI
Roadside observations	IN, KS, MI, NE, WI
Aerial surveys	MN, MO, ND, WI
Registered buck kill	NE, OH, WI
Hunter kill-effort	IN, KS
Landowner surveys	KS, WI
Track counts	OH
Conservation officer estimates	IA
Crop depredation reports	MO
Population models	MN

nual change when compared to other population indices. He cited poor record keeping as the major problem. However, McCaffery (1973) found a significant relationship between number of deer-vehicle accidents and number of antlered bucks harvested in Wisconsin. He concluded that this technique could provide a reliable index to population change if an accurate record of loss is kept and an accurate estimate of the number of automobile miles driven is available. This demonstrates the relationship between deer-vehicle accidents and other indexes but comparisons with known population trends are needed to increase reliability.

The major assumption with deer-vehicle accidents is that the number of deer killed, when related to vehicle mileage, accurately reflects population fluctuations. Some problems, which may be minimized by assuming a constant bias each year, are poor reporting by field personnel and disappearance of carcasses from the scene of the accident. Local meat prices may be responsible for changes in rate of carcass loss. Other factors that may affect this index are construction of new highways, changes in traffic patterns or speed, and degree of cooperation from other state agencies. Reported highway kill is a minimum figure since many accidents are not reported or animals escape only to die later. One advantage to this technique is that information can readily be broken down on a regional basis if detailed records of automobile mileage are available. Cost of reporting is minimal since field personnel are already required to be at the scene of an accident to remove or tag dead animals. Biological data such as sex, age, reproductive status, and body condition can also be obtained. This is probably the best and most economical technique available for statewide estimates of population trends.

Sex-Age-Kill Estimates

Many states use biological data collected during hunting seasons to estimate deer population size (Table 1). This technique involves measuring changes in sex and age ratios in the harvest (Petrides 1949, Lauckhart 1950, Davis 1963, Hanson 1963). Some researchers have developed formulas for change-in-ratio estimates (Rupp 1966, Overton and Davis 1969) and others have worked with determining precision (Paulik and Robson 1969, Eberhardt 1969). The basic input factors required are: sex and age ratios, harvest, hunter effort, nonhunting mortality, and natality (Eberhardt 1960, Lang and Wood 1976).

Wisconsin utilizes a sex-age-kill method to estimate the buck population which is then expanded to a total population estimate (Creed et al. 1978). The adult buck population is estimated for some year in the past by adding up the subsequent legal harvest of adults alive in that particular year, until the youngest age class (shown by age structure) of the year of interest, passes out of existence or becomes extremely small. This total is then divided by 0.8 which assumes that 80% of the bucks are recovered as a result of hunting. The buck estimate is then multiplied by an expansion factor (*E.F.*) that is compiled annually for each hunting zone according to the following formula:

$$E.F. = 1.00 + (B/D) + (B/D)F$$

where B = corrected percentage of yearling bucks (percentage yearling bucks divided by the number of male fawns per 100 female fawns), D = percentage yearling does, and F = number of fawns per doe.

A comparative analysis indicated that sex-age-kill estimates averaged only 70% of the pellet survey results in northern Wisconsin while in southern Wisconsin, they were similar to pre-season population predictions (Creed et al. 1978). An explanation for this may be increased vulnerability of deer in southern Wisconsin, lower nonhunting mortality, and heavier hunting pressure which results in the harvest of 80% of the adult bucks.

Another method of change-in-ratio analysis requires sex and age ratios before and after the hunting season (Gilbert 1978). This can be used when one age class is more susceptible to hunting pressure, or when one sex and age class is hunted more heavily than others. To determine fall or winter sex and age ratios from field counts, it is assumed that all animals have an equal chance of being counted. Downing et al. (1977) found that there was rarely a period of time when this assumption was correct for every sex and age class. Care must be taken in determining sex ratios since small errors in this figure will be magnified many times when computing total estimates (Dasmann 1952).

The primary limitation to the sex-age-kill method is obtaining accurate input data. Harvest estimates from check stations are subject to error due to nonregistration (ranging from 1% in Nebraska to 22% in Minnesota). Harvest estimates from postcard surveys are influenced by hunter bias and nonreporting error. Biological data collected by professional field personnel at check stations are preferable to data obtained by gas station operators, grocery store owners, sportsmen, and other nonprofessionals. But even with professionals, inconsistencies in aging deer can occur regardless of whether the tooth wear and replacement or incisor sectioning method is used (Ryel et al. 1961, Gwynn 1978). Determining of nonhunting mortality is also questionable because of the difficulty in accurately measuring this loss.

The major assumption with this technique is that vulnerability is equal and therefore sex and age ratios in the harvest truly represent those in the wild. The danger with this assumption is that differences in vulnerability are caused by behavioral traits of animals as well as hunter selectivity for larger animals. There is evidence that 1½-year-olds are slightly more vulnerable to hunting than older deer (Eberhardt 1960) while fawns are the most vulnerable age class (Van Etten et al. 1965).

Roadside Observations

Several states use roadside counts to provide population trends and estimates of sex and age ratios. Indiana estimates deer density on some military reservations with roadside counts (Stormer et al. 1974). This technique is an adaptation of the line transect method of estimating abundance described by Gates et al. (1968). Prescribed routes are driven, deer are counted, and an estimate of right angle distance between the deer and observer is made to determine sample area. Counts over the same routes must be repeated several times to enable statistical evaluation (Lueth 1970). Eberhardt (1968) suggests that both sighting distance and flushing distance be recorded and recommends the use of radio telemetry to study animal responses to observers.

The basic assumption with this method is that deer are randomly distributed and that they are not attracted to, or avoid, roadside areas. Weather greatly influences deer behavior and observability so a standardized set of weather factors is required before conducting this survey.

Michigan, Nebraska, Kansas, and Wisconsin use field observations to determine sex and age ratios or number of fawns per doe. Population estimates are then developed from harvest data utilizing observed ratios. Ratios can be determined before (Michigan) or after (Kansas) the deer season and can be used to develop productivity indices (Nebraska). Problems with this survey include inaccurate record keeping by field personnel and mistakes in identifying sex and age of observed animals.

Aerial Surveys

Aerial surveys of big game species have been studied extensively in North America (Saugstad 1942, Buechner et al. 1951, Petrides 1953, Edwards 1954, Erickson and Siniff 1963, Siniff and Skoog 1964, Lovaas et al. 1966, LeResche and Rausch 1974). Most studies report factors that bias their results and the attempts made to standardize techniques.

Aerial surveys are used by Missouri, Minnesota, and Wisconsin to provide total population estimates in winter concentration areas or on small game management areas. Minnesota uses aerial surveys to estimate total deer populations in county-sized areas by expanding density estimates obtained from randomly selected sections. North Dakota uses the aerial survey of permanent study areas to provide population trends for large management areas.

Adequate snow cover is probably the most important factor in counting deer in hardwood timber habitat. Watson et al. (1969) found that animals with good contrast between themselves and their background were seen more often than animals with low contrast. In Colorado, Gilbert and Grieb (1957) found that aerial crews counted 34% of the total mule deer *(O. hemionus)* present with poor to fair snow conditions but 45-49% with good to excellent snow conditions. McKenzie (1972) reported the number of deer sighted increased as snow cover increased but good snow conditions were present only once during the 5-year study in North Dakota.

Height above ground, speed of aircraft, transect width, and time of day are important factors in standardizing aerial surveys (Graham and Bell 1969, Caughley et al. 1976, Norton-Griffiths 1976). It is also important to document differences between observers, pilots, aircraft, habitat, terrain, and deer densities (Jolly 1969*a*, *b*). Using a helicopter instead of a fixed-wing aircraft provides slower speeds and increased maneuverability (Buechner 1950, Aldous 1956). Good statistical design is necessary if bias is to be estimated or if expanded population estimates are calculated (Caughley and Goddard 1972, Caughley 1974).

One important aspect of aerial surveys should be a comparison of aerial counts to ground counts to obtain the percentage of animals seen. This will enable the resource manager to expand survey results to a population estimate so that a rate of harvest can be determined. Gilbert and Grieb (1957) used drive counts to estimate total population size for comparison with aerial counts.

Some of the major disadvantages of the aerial survey are: (1) difficulty in observing animals from the air and measuring proportion seen, (2) variation between pilots, observers, and aircraft, (3) high cost, and (4) obtaining suitable weather conditions. However, the aerial survey provides a valuable technique for future use with continued refinement and the possible incorporation of photography or remote sensing.

Registered Buck Kill

Nebraska and Ohio use the adult buck harvest as an indicator of population trends. Harvest figures are compiled from mandatory check stations and compared to buck harvest in previous years. One major assumption is that changes in the harvest represent fluctuations in the population. Bias may be consistent from year to year or may vary due to changes in hunting pressure, length of season, weather conditions, crop harvest, hunter selectivity, hunting regulations, hunter success, and nonhunting mortality. If possible, these factors should be evaluated when comparing harvest figures.

Wisconsin uses the buck harvest independently to indicate trends and also to estimate total population size. Population size calculations assume that the registered buck harvest represents removal of from 12% to 14% of the total population (McCaffery 1973). The removal percentage is determined from the age structure of the harvest.

Other Estimators

Several other methods are used to obtain deer population estimates or trends:

(1) Kansas and Indiana use the change in hunter effort per deer harvested as a population trend indicator. Information on hunter harvest and effort are obtained from questionnaires sent to hunters. Accuracy is subject to truthful reporting by hunters, sampling error, and differences in vulnerability of animals due to behavior, sex, age, or season regulations.

(2) Kansas and Wisconsin periodically survey a random sample of landowners who are asked to estimate the number of deer on their land, and in Kansas opinions on hunting and deer damage are also obtained (Peabody 1976). Survey results are used as a trend indicator but probably are more important in measuring landowner attitudes.

(3) Track counts are used to estimate population trends in Ohio. This technique is described in the paper by Mooty.

(4) Conservation officers in Iowa estimate the number of deer in their assigned territories each winter (Gladfelter 1972). These estimates are influenced by the number of deer seen during field activities, number of roadkills processed, and hunter success during the previous season. It is difficult to accurately estimate deer numbers in a county-sized area so this technique is utilized as a post-season indicator of population trends.

(5) Crop depredation reports received from landowners are used as a deer trend indicator in Missouri. Damage to crops, orchards, and young trees may be influenced by deer population size, amount of food available, weather, and other factors. Korschgen (1962) found that landowner complaints about deer damage in Missouri became more numerous when more than 50% of the deer's diet consisted of agricultural crops.

(6) Population modelling is being used in Minnesota (and tested in many other states) to estimate population trends and predict effects of various season regulation changes. Computer simulations of population changes are provided following input of sex and age data, reproductive rates, harvest rates, and sex and age specific mortality factors. Good input data are essential. At the present time, the most valuable asset of population modelling is indicating areas of weakness in input data.

CONCLUSIONS

In my opinion, most deer population estimator techniques probably cannot measure changes of less than 20% in deer populations. Utilizing more than one population estimator allows comparisons that enhance the probability of detecting more subtle changes. Resource managers have a good knowledge of assumptions and limitations for each technique, but tend to overlook them because of the difficulty in accurately measuring their effects. Techniques which are not reliable or cannot be measured statistically should be discontinued so that resources can be used in other areas. It is easy to criticize the accuracy of population estimators but the ability of resource managers to utilize this information is apparent by many successful hunting seasons and a healthy, growing deer herd. With the development of complex systems for manipulation of the harvest in small geographic areas and good law enforcement, deer management can become more precise. Therefore, if improved management capabilities are to be fully utilized, more accurate population estimators will be needed. The easy techniques have already been considered.

New techniques should be designed to facilitate accurate data collection and recording and statistical analysis. Assumptions should be defined and then measured to identify variability. All facets of deer behavior, mortality, natality, sex and age structure, vulnerability, and hunter harvest should be explored for possible clues to the accuracy of estimator techniques. New techniques should be tested in areas of known deer population size. They should be justified in terms of expenditure of money and manpower and accomplishment of management goals. Increased research in this area by conservation agencies and educational institutions will be important to the future of deer management in the Midwest Farmland.

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Wisconsin DNR

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MONITORING DEER POPULATIONS IN THE NORTHERN FORESTED AREAS OF THE MIDWEST

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Abstract: Population management of white-tailed deer *(Odocoileus virginianus)* requires reliable census data. Over the past 50 years numerous techniques have been developed and evaluated. Some methods which have not proved workable are string counts, bed counts, roadside counts, and highway mortality. Methods of limited usefulness include deer drives, strip counts, various mark-recapture systems, and aerial counts. Some techniques in current use in northern forests of the midwestern United States are counts of trails, tracks, sex-age-kill analysis, pellet group counts, and population modelling. Numbers of deer trails (paths) have been correlated with other indexes of deer abundance in Wisconsin, and show promise as an efficient and accurate way to census deer in forested areas. Roadside track counts will estimate deer populations, but are limited by the non-random distribution of suitable roads and traffic volume. Use of the sex-age-kill technique for monitoring deer populations requires data on age ratios, legal kill, hunting effort, and the rate of natural mortality. At present, the pellet group count is the preferred deer census method for northern Midwest forests. This method lends itself to unbiased random sampling, and appropriate statistical analysis. However, large amounts of manpower are required to complete the counts. Estimating deer numbers by population modelling is becoming increasingly popular. Models require baseline data on natality and mortality. The techniques employed by various agencies are often a compromise between manpower, money, needs, and efficiency.

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INTRODUCTION

It is difficult to obtain accurate and efficient counts of free-ranging ungulates. However, such knowledge is essential for population management. The white-tailed deer in the northern forested areas of the midwestern United States (Fig. 1) is no exception. Heavy forest cover and the secretive nature of deer make them very difficult to census. Direct counts are not reliable because the observer never knows what proportion of the population has been sighted. For this reason wildlife managers usually rely on counts of sign left by deer. This paper emphasizes the review and application of these indirect counts.

Most of the methods used to census deer in the northern forest are census indexes, i.e. counts or ratios which are relative in some sense to the total number of animals in a specified population (Overton and Davis 1969:404). As such, these methods are merely a refinement and systematic application of the hunter's technique of "reading sign" to determine animal numbers (Bennett et al. 1940). Be humbled by the fact that, as wildlife resource managers, we are merely defining the limits of a relationship which has been known to exist since man became a hunter.

The ideal census method for deer would be precise, accurate, inexpensive, fast, and easy to apply at any time of the year. Bergerud (1968:22) stated that the literature abounds with methods and unverified results of big game counts (Hazzard 1958). Further, he proposed the following minimum standards: (1) that the accuracy of the method be verified with a known population, or (2) that 2 completely independent census methods give similar results.

Census techniques for white-tailed deer have shown a degree of imagination on the part of the investigators, ranging from field counts to complex multivariate models. Most techniques must meet one overwhelming criterion – to fit within the limited budgets of most wildlife agencies.

METHODS IN GENERAL USE

Trail Counts

Bartlett and Stephenson (1929) attempted to use trails to census deer in wintering areas in Michigan. However, the use of trails to census deer during the snow-free period is a recent innovation. McCaffery (1976) used 50 0.4-km transects/1,000 km² to estimate deer populations in Wisconsin. Completion of these counts required 3-4 man-days/1,000 km². The number of deer trails was positively related to other indexes of deer abundance such as the adult buck kill ($r = +0.91$), pellet group counts ($r = +0.89$), and sex-age-kill ratios ($r = 0.94$). Best survey results (closest agreement with "best" population estimate available for the particular area) were ob-

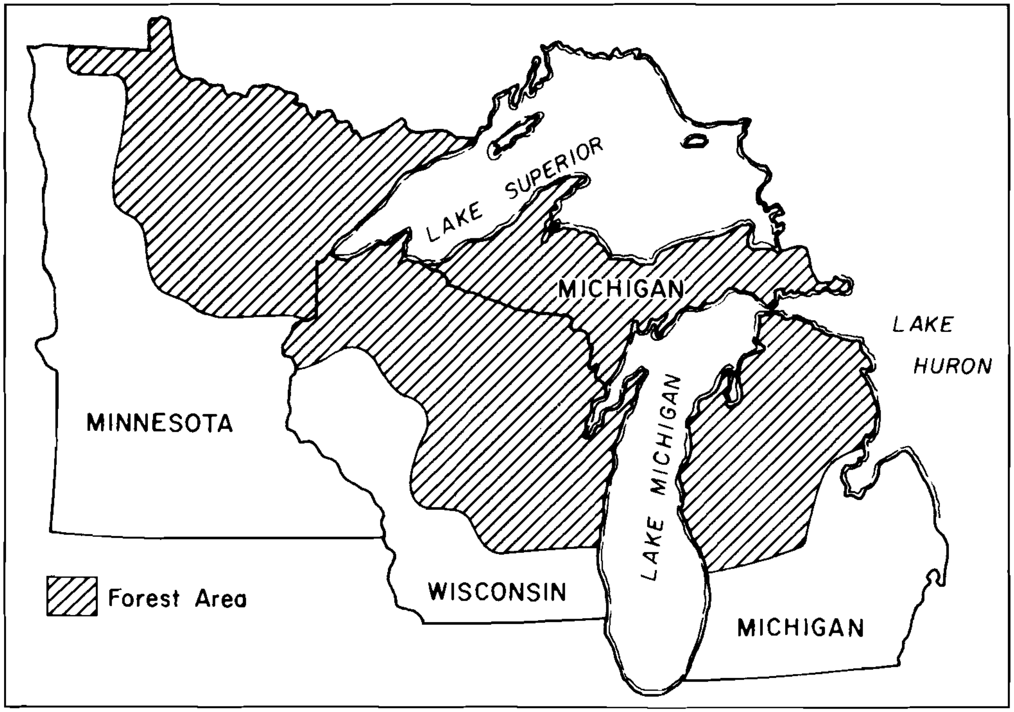

FIGURE 1. *Northern forest area of the midwestern United States.*

tained when there was a -2C temperature prior to 20 October. That is, counts conducted in the fall or spring following frosts in early autumn produced the best results.

McCaffery (1976) noted very little change in trail abundance from fall to spring. However, 65% of the trails marked in the spring were not visible in July. New and reopened trails began to appear in August.

Trail abundance was also positively related to the percentage of shade-intolerant forest types ($r = 0.79$, $P < 0.01$). Based on the experience in Wisconsin, the trail count seems to hold promise and further trials are warranted.

Track Counts

Work in Wisconsin, Michigan, and Minnesota indicates that deer tracks along roads correlate well with other indexes of deer abundance. McCaffery (pers. comm.) correlated track counts with the kill of bucks ($r = +0.85$) and Mooty (in prep.) and Moran in Michigan (pers. comm.) found significant correlations between populations estimated by track counts and populations estimated by pellet group counts ($r = +0.83$ and $+0.85$, respectively). Howe (1954), in comparing several census techniques (i.e. strip census, DeLury method [DeLury 1947], deer drives, mileage counts, sex and age ratios, shining counts, time area counts [Chiavetta 1952], and track counts) on the Rifle River Area of Michigan concluded that track counts gave a conservative estimate of the deer population.

Preparation of the surface for counting and elimination of old tracks is done the day before the count through rainfall, or by grading or dragging. Counts of fresh tracks are made the next day. I found while doing track counts in Minnesota that dragging, especially after a rain, was most convenient and produced a surface suitable for counting. In addition we took advantage of road grading when it was done, but could not rely on this as it occurred at irregular intervals and did not always fit our work schedule. I never felt comfortable with relying on rain alone to prepare the road because light rains might not eliminate some old tracks and heavy rains influence deer activity.

Variability of track count data is usually high because of the smaller sample size (the route is the sampling unit). For example, on a 842-km^2 study area in northeastern Minnesota, 10 years of track and pellet group count data had average 95% confidence intervals ± 30% and ± 20% of the means, respectively.

One of the critical limitations of the track count technique is that in most cases routes cannot be selected at random, introducing a possible source of bias. This bias should be reduced in direct porportion to the extent and distribution of countable roads in relation to deer habitat.

During the spring and fall, phenological changes and green vegetation attract deer to roadsides, and counts made at these times would probably be highly variable. Our counts in Minnesota were made between 1 July and 15 August. Earlier work in Minnesota (Kohn and Mooty 1971) indicated that deer do not avoid or prefer roadsides at this time.

Other problems associated with deer track counts include varying observer ability to see tracks, observer fatigue, erasure of tracks by vehicle traffic, and differences in judgment as to how many deer are represented when several sets of tracks occur together. Additional problems include the trend towards blacktopping of rural roads, and the attraction of deer to logged areas which are usually concentrated along roads.

Given proper distribution of roads, accurate counts, and correct timing, I believe this technique will accurately reflect deer numbers. The following papers provide more information on track counts: Schrader (1949), Tyson (1959), Brunett and Lambou (1962), Downing et al. (1965), Harlow and Downing (1967), and Daniel and Frels (1971).

Track counts may also lend themselves to measuring habitat selection by recording the vegetation adjacent to tracks, and production and survival by recording fawn tracks separately from adults (Moran 1978). In Minnesota we found a significant correlation ($r = +0.91$) between fawn tracks and the previous winter's severity, as measured by Verme's (1964) Winter Severity Index.

Pellet Group Counts

Any deer hunter "worth his salt" would leave an area where he consistently sees very little deer sign. When he does this he is in effect making a crude census. The pellet group count technique refines this evaluation through the use of an equation with "knowns" and an "unknown". The knowns (pellet groups, defecation rate, deposition period, and size of area searched) are used to determine the unknown deer density. Of course, the knowns must be accurately measured.

The first reported use of deer pellet group counts occurred around 1940 (Bennett et al. 1940, Interstate Deer Herd Committee 1946). At present it is the most accepted and used deer census method in the northern and western states. Surprisingly though, only 2 studies (Eberhardt and Van Etten 1956, Ryel 1971) have tested the technique on an area with a known population of white-tailed deer. They concluded that while the technique is subject to serious errors resulting from missed and incorrectly aged pellet groups, that these can be controlled sufficiently to give reliable results.

The pellet group count is at present the preferred method for censusing white-tailed deer in the northern forests of the Midwest. This is because the technique lends itself to unbiased random sampling, and appropriate statistical analysis. Several important assumptions implicit in the use of pellet group counts (Ryel 1971:16) are:

(1) Deer defecate at a rather constant frequency.
(2) Pellet groups persist long enough to be counted.
(3) Pellet groups can be found and counted in the field.
(4) An explicit deposition period can be delineated.
(5) The age of pellet groups, which are present, can be established relative to the deposition period.

As applied in Minnesota the procedure is roughly as follows:

(1) Define the area to be censused.
(2) Determine required sample size.
(3) Stratify the census area by expected deer density.
(4) Determine which areas are accessible such as those within 1.0 km of a driveable road. These form the population from which the sample is drawn.
(5) Allocate sample among strata using optimum allocation.
(6) Select a random sample for each strata.

Assuming a stratified sample, analysis consists of calculating a weighted mean by strata of pellet groups per course and then using the following formula:

$$\text{Deer population} = \frac{\bar{x}\text{ pellet groups per course} \times \dfrac{1}{\text{plot size}} \times \text{size of area}}{\text{deposition period} \times \text{defecation rate} \times \text{no. of plots}}$$

For more detail on design and calculations, see Neff (1968), Smith et al. (1969), and Ryel (1971).

The most serious problem associated with pellet group counts in the forested area of the Midwest is that of making accurate counts of the groups present on plots and distinguishing between old and new groups. Rechecks of plots indicate that large errors are possible. Van Etten and Bennett (1965) reported an undercount of 22% of the new groups actually present. Petraborg and Idstrom (1972) found that original counts were 17.8% lower than re-counts. More recent data from Minnesota suggest a trend towards undercounting equal to 15-20% (Mooty, unpubl.). Ryel (1971) stressed the importance of training and monitoring field crews and Van Etten and Bennett (1965) believed that errors would be reduced by using a plot shape that can be readily searched and by using 2 experienced observers to check each other's findings. As a result of this study Michigan went to a rectangular plot (21.8 × 3.6 m, 0.008 ha). Their second recommendation for reducing error is that the position of pellet groups upon the litter be used as the age criterion – i.e., all groups on top of the leaf litter should be counted as new. In areas without leaf litter, such as meadows and pine stands, criteria for aging of pellet groups need to be developed.

Population Modelling

While models are not an actual census technique, they can be used to estimate deer numbers provided some baseline data are available (Gross 1973). For most models in use the basic data needed are a population estimate, and estimates of age-specific natality and mortality. Models are "powerful" in that we can look at the effects of various rates of mortality or natality on the total population or a given segment (Walters and Gross 1972). However, the use of models will only be as good as the data that goes into them. One of the important benefits of using modelling is that it stimulates interest in getting good data. An update on the current status of big game population modelling is given by Pojar and Strikland (1979).

Sex-Age-Kill Estimates

This method is similar to those known in fisheries work as estimates of virtual populations (Ricker 1958) in which the annual catches of a given year class are summed until the class disappears from the catch. The method, when used for deer, involves 2 steps: (1) estimating the buck population, and (2) expanding the estimate to the total deer population. The necessary data are, according to Eberhardt (1960), age ratios, number of deer legally killed, hunting effort records, and an assumed specific rate of natural mortality. If there are large losses to sources other than legal harvest, then there are problems with this techique. However, in postseason dead deer surveys in Michigan (Eberhardt 1960, and D.A. Arnold, pers. comm.) and Wisconsin (Creed 1966) very few adult male deer were found. So, the assumption that legal harvest accounts for most of the hunting kill of adult males is apparently valid. Large, unaccounted-for poaching losses will also affect sex-age-kill calculations. Recent studies (Vilkitis 1968, 1971) indicate that such losses may be common. Wisconsin presently uses the sex-age-kill method to estimate deer populations, and assumes that 80% of the adult bucks are taken annually by legal hunting.

Additional references for this technique are Kelker (1940), Allen (1942), Lauckhart (1950), Dasmann (1952), Selleck (1957), and Hanson (1963).

METHODS OF LIMITED USE

Drive Counts

Briefly, drive counts are made on areas with a distinguishable boundary – usually roads. Observers (standers) are placed on the roads on 3 sides, and drivers begin on the fourth side and move through the area. Deer which leave are counted by the standers and those animals which cut back through the drive line are counted by the drivers. Theoretically, this results in a total or near total count of the deer on the area; and with a well-trained crew working on an area with good visibility on the boundaries and good interval marking of the drive area, this is probably the case.

In areas with a good road system distributed throughout the deer range, drive counts will work well. However, in most northern areas, forest roads are poorly distributed, leading to problems of a biased sample. The other major problem with drive counts is the requirement for 100 or more people for the census. A technique described by Morse (1943) greatly reduces the manpower required in the drive by using deer tracks in the snow instead of standers to tally the number of deer leaving the drive area. In a report on deer drives in Minnesota, Olson (1938), stated that the average drive area was 224 ha. Drives on areas larger than this were less successful and more difficult to manage. According to Adams (1938), the main disadvantages of the drive method are disorganized drive lines, exaggeration of the number of deer seen, heavy cover, and adverse weather.

These counts were used extensively during the 1930's when the Civilian Conservation Corps (CCC) provided large amounts of manpower. The longest continuous record of drive counts (1933-61) is from the George Reserve in Michigan (O'Roke and Hamerstrom 1948, Chase and Jenkins 1962).

In 1971 there was renewed interest in the deer drive census in Minnesota (Carter 1971). Twenty-three areas totalling 31.5 km^2 were driven by private citizens. On these fall counts an average of 4.7 deer/km^2 were counted. Pellet group counts the previous spring on 26,000 km^2 of northern deer range estimated an overwinter population of 5.3 deer/km^2 (Karns 1971).

Drive counts are of only limited value for censusing deer over large areas in heavily forested parts of the Midwest. They will probably work best on small areas where there is a good road system and a readily available manpower supply. The U.S. Forest Service (1935) and Trippensee (1948) provide more detail on setting up and conducting deer drives.

Strip Census

The strip census is dependent upon the number of animals flushed in a sample strip and an expansion of these numbers to the remaining unsampled area. As devised by King (Leopold 1933) the census consists of walking all the 16-ha lines and one-half of the boundary lines on a 10.4-km^2 area. All of the animals flushed are counted and the flushing distance is measured. The average flushing distance from the observer determines the width of the sample strip. Intuitively, the strip census has much appeal because it is easy to do and large areas can be covered in a short time with limited manpower.

This type of census was first used to census ruffed grouse *(Bonasa umbellus)* by King (Leopold 1933), and to census deer by Erickson (1940) in Minnesota. Krefting and Fletcher (1941) used the strip census on deer in Oklahoma. Hahn (1949) applied a variation of the strip method in censusing deer in the Edwards Plateau region of Texas.

However, there are some important unanswered questions in extrapolating data from the strips to the census area. For example, one does not know what proportion of the animals are seen at a given distance from the observer (visibility bias, Eberhardt 1968). Eberhardt (1968:22) stated: "For line transects, the major unknowns pertain to the behavior of individual animals. Very likely the most serious problem has to do with the prospect that some individuals will move before 'flushing'. Most of the methods for dealing with transect data assume some kind of frequency distribution model and are subject to bias if the assumed distribution does not apply." Eberhardt (1978) recommended using Hayne's method (Hayne 1949) when working with animals that flush, as it does not assume a specific model.

Recent improvements in correcting for the visibility bias (Anderson and Pospahala 1970) of this method make its use for censusing of immotile objects, such as dead deer, more feasible. Robinette et al. (1974) found that the method of Anderson and Pospahala (1970) and that of Kelker (1945) gave close estimates of a known population of inanimate objects.

King's method, while biased, was less so than other methods based on sighting distances. Anderson et al. (1979:72) stated that the following assumptions are critical for valid results:

(1) Points directly on the line are seen with probability 1.
(2) Points are fixed at the initial sighting position (they do not move before being sighted) and none are counted twice.
(3) There are no measurement errors and no rounding errors (distances are measured exactly).
(4) Sightings are independent events.

In addition, a minimum of 40 objects should be located.

While conducting strip counts, it is also possible to record data on habitat conditions, habitat selection, and herd composition. Other wildlife flushed may also be tallied. With these improvements in the strip census, this method should work well for estimating dead deer numbers. The most serious problems are finding the required minimum of 40 objects and the necessary manpower. For a comprehensive, current discussion of this technique, see Burnham et al. (1980).

Mark-Recapture

The mark-recapture method is one of a group of population estimators based on some change in the ratio of two identifiable characteristics of a population (Paulik and Robson 1969). Other approaches utilize changes in observed sex ratios and/or age composition (Kelker 1940, Rasmussen and Doman 1943).

This technique is not, to my knowledge, currently used as a regular census method for estimating deer numbers in the northern forests of the Midwest – the major problem being that when standard trapping methods are used, the assumption of equal probability of recapture is violated (Eberhardt 1969). For example, Strandgaard (1967), in a Petersen method (Petersen 1896) census of roe deer *(Capreolus capreolus)*, found this procedure unsatisfactory because deer observed (recaptured) did not constitute a truly random sample from the total population. Andersen (1962) found that 75% or more of the population of roe deer had to be trapped to get a reliable estimate of percent fawns. Petraborg and Idstrom (1972) found that spotlighting counts of marked and unmarked deer underestimated the population as determined by pellet group counts.

To overcome some of the difficulties with the mark-recapture technique, Martin (1970) presented a regression method of correction for unequal catchability, and Eberhardt (1969) recommended shifting traps at least once as a check on bias. Another way to overcome this problem is to "recapture" marked animals visually from aircraft. This method has been used successfully by Rice and Harder (1977) and Floyd et al. (1979). At best, the mark-recapture technique using aircraft seems suited for use on areas such as military reservations, wildlife management units, and research areas.

A considerable volume of literature is available regarding this technique. Several methods for analysis of mark-recapture data are presented by Parr et al. (1968), Paulik and Robson (1969), and Manly (1970). A bibliography of statistical methods was prepared by Tepper (1967). The following papers give more information on this technique: Petersen (1896), Lincoln (1930), Ricker (1958), DeLury (1958), Seber (1965), Jolly (1965), Edwards and Eberhardt (1967), Nixon et al. (1967), and Anderson (1975).

Aerial Counts

Direct Counts. Since the pioneering work of Saugstad (1942), aerial censusing of big game animals has increased and been refined. From the general survey approach (Morse 1946), efforts have progressed to transects of a determined width (Banfield et al. 1955, Bergerud 1963) to stratified sampling and optimum allocation (Siniff and Skogg 1964, Evans et al. 1966). Aerial counts have been most often used in the north to census caribou *(Rangifer tarandus)* and moose *(Alces alces)* in remote areas (Edwards 1954, Banfield et al. 1955, Bergerud 1963, Bergerud and Manuel 1969, and Timmermann 1973).

Aerial census of wildlife has much appeal. Flying is exciting, animals are seen, and large areas can be covered in a relatively short time. However, in reality the technique is no more problem-free than any other. Because of heavy forest cover, their more accessible range, and the availability of other census methods, aerial counts have not been used extensively for deer in northern forests of the Midwest. The problem of visibility bias is summed up by Caughley (1974:92) when he stated: "Aerial censuses of large mammals are inaccurate because the observer misses a significant number of animals on the transect. The accuracy deteriorates progressively with increasing width of transect, cruising speed and altitude". He suggested that the best strategy may be to measure the bias and correct the estimates accordingly. One recent study which attempts to measure this bias when counting deer is that of Floyd et al. (1979). In making counts of deer on sample areas in northeastern Minnesota where a known number of radio-marked deer were located, 42% of the radio-marked animals were visible from the aircraft. This observability factor was then used to estimate the deer population in a similar census of the larger area. Woolf and Harder (1979) saw an average of 32% of the marked deer in an aerial helicopter census of white-tailed deer in Pennsylvania. For mule deer *(Odocoileus hemionus)* on their winter range in Colorado, Gilbert and Grieb (1957) determined air observability to be 43% of the animals observed on the ground by deer drives. Jacobson and Weatherill (1975), using multiple regression analysis, determined a visibility bias of at least 46% for an aerial census of white-tailed deer in Manitoba. In Texas (Hahn 1949) reported that only 50% of the deer observed on cruise counts were seen from the air. LeResche and Rausch (1974) determined observability for moose to be 68% and 43% for experienced and inexperienced observers, respectively. These data suggest that about one-half of the animals are seen in an aerial census in forested areas.

In an attempt to improve the aerial census of deer in Manitoba's Interlake Region, Jacobson and Weatherill (1975) compared

2.6-km^2 quadrats and variable-sized strip plots flown at various air speeds and altitudes and recorded the deer observed by individual crew members. Based on costs, they recommended using strip plots (\$0.50/km^2), provided adjustments for visibility bias are possible, although the accuracy of the quadrat census (\$1.00/km^2) was improved by using 2 observers and overlapping strips. Quadrats are recommended in hilly or river valley terrain, and when a greater degree of accuracy and precision is required. As with strip plots, a correction for visibility bias, based on crew performance, is necessary. Caughley (1977) also concluded that transect sampling was more efficient than quadrat sampling, and anyone planning an aerial census should refer to this publication and that of Jolly (1969).

Although there are problems with an aerial census, this technique may be the only answer when large areas must be censused in a short time. Further improvements in aerial census will, no doubt, increase its use for deer. The "state of the art" will improve in direct proportion to experience and rigorous and disciplined approach to study design as suggested by Jacobson and Weatherill (1975).

Remote Sensing. Published trials on infrared or remote sensing for the census of wild ungulates are scarce. However, those that have been reported (Croon et al. 1968, McCullough et al. 1968, Graves et al. 1972, and Wride and Baker 1977), mention 2 serious problems with this technique:

(1) Inability of the equipment to detect animals under conifer or deciduous leaf cover; and
(2) Inability to distinguish between animals of similar size.

Until these problems are overcome, this method of census will be of limited usefulness in the northern forests of the Midwest.

MISCELLANEOUS METHODS

Two of the less well-known methods used in attempts to census deer are string counts, i.e., counts of breaks in a string strung through the woods (Morse and Burcalow 1942), and bed counts (Bartlett and Stephenson 1929). Neither of these methods seemed to work very well and received little attention beyond these initial efforts.

Deer seen while driving roads during a specified period were used as an index to deer numbers in Minnesota from 1942 to 1953 (Erickson et al. 1961). This type of census is subject to the vagaries of weather, phenological conditions, and varying work schedules, and was discontinued after 1953. Such counts are used in Wisconsin to determine sex and doe:fawn ratios during summer months. Michigan also uses deer seen by DNR employees per 100 hours of driving by county as a population trend indicator.

To overcome wartime restrictions on travel, and limited manpower, a variation on this observation technique was the Railroad Engineers' Deer Tally (Erickson et al. 1961). Engineers and firemen of 4 major railroads in Minnesota recorded all of the deer seen along the railroad rights-of-way between 15 September and 15 December. Because of wartime restrictions on the railroads, the census was discontinued after 1 year (1942).

Two published studies, both from Wisconsin, using highway mortality as an index to deer populations were reviewed. Jahn (1959) concluded that because of inconsistencies in recording, reporting, and traffic pressure, these data could not be used in an index to annual changes in the deer population. However, McCaffery (1973) found a highly significant correlation ($r = 0.97$, $P < 0.01$) between numbers of roadkills, adjusted for changes in traffic volume, and the antlered buck harvest.

VERIFIED CENSUS STUDIES

Let me return here to the census standards suggested by Bergerud (1968). Very few studies comparing a census with a known population are available. Most verified studies are based on 2 independent estimates of the population. In this section I want to concentrate on these "verified census" studies. While this will be repetitious I think it's important to bring these studies together in one part of this paper. This discussion will be limited to studies of white-tailed deer in the Midwest.

Ryel (1971) compared 10 years of pellet group counts with known populations based on the aging method (Jenkins 1964) for the George Reserve of southern Michigan. The results indicated poor agreement between the 2 methods. The 95% confidence limits for pellet group counts included the known population in only 2 of the 10 years. The linear correlation coefficient ($r = -0.62$) indicates an inverse relationship, but was not quite significant at the 0.05 level (0.6319 for 8 df). Ryel (1971) also reported on a similar comparison for the Cusino enclosure in the Upper Peninsula of Michigan. Here population estimates based on pellet group counts were compared with the known population. The known population was determined by removal of all animals each year. The Cusino results were somewhat better than at the George Reserve. Calculated confidence limits of 2 standard errors of the mean included the known population in 4 of the 5 years. However, the correlation coefficient for the data was not significant ($r = +0.45$, $P > 0.05$). Rechecks of plots on both areas indicated serious undercounting of the pellet groups actually present. Ryel (1959:18) stated: "Missing groups are by far the commonest source of error we can demonstrate with pellet group surveys. Other possible explanations for the differences include use of incorrect defecation rates and incorrect aging of pellet groups. The better performance of the pellet group count technique at Cusino may be related to the better compaction of the leaf litter and herbaceous vegetation by snow, and the absence of large grassy openings and abundant oak trees which are common in the George Reserve."

Petraborg and Idstrom (1972) estimated deer populations by track and pellet group counts and by the Lincoln Index in the Camp Ripley Military Reservation in Minnesota.

Pellet group and track count population estimate differences ranged from 11% to 30%. The 95% confidence limits for track counts included the mean deer per square mile estimate by pellet group counts for 3 of the 4 years. Lincoln Index population estimates based on recapture of collared deer by spotlighting averaged only 38% of the population estimates by pellet group counts for the 5 years. Roadside counts of deer tracks were significantly correlated with other population indexes in Minnesota (Mooty and Karns in prep.) (tracks and pellet group counts, $r = +0.83$), Michigan (R.J. Moran pers. comm.) (tracks and pellet group counts, $r = +0.85$), and Wisconsin (K.R. McCaffery pers. comm.) (tracks and buck kill, $r = +0.85$). In addition, Mooty and Karns (in prep.) found that the 95% confidence limits for the pellet group counts included the track count average population estimate in 7 of the 10 years. McCaffery (1976) found a highly significant correlation between deer trails and 3 other population indexes (buck harvest, pellet group counts, and sex-age-kill calculations).

Howe (1954) attempted to census deer on the Rifle River Area of Michigan using 8 different methods. The strip census (King variation by cover type) gave good results. DeLury's regression equation (DeLury 1947) of kill per unit of effort and total kill produced a good estimate of the buck population. Deer drives and mileage counts produced reasonably accurate population estimates. Shining and track counts tended to underestimate the population.

Kubisiak (1976) censused deer on the Sandhill Wildlife Area of Wisconsin using pellet group counts, mark-recapture, trail counts, aerial census, and sex-age-kill analysis. Population estimates from these methods were compared with a minimum reconstructed population estimate (mrpe) compiled by backdating harvest, mortality, and trapping records for the years 1963-72. The 95% confidence limits for the pellet group count included the mrpe estimate for 5 of the 7 years they were completed. However, the correlation coefficient for these 2 estimates ($r = +0.43$) was not significant. The pellet group counts were completed using a simple random sample design. Kubisiak (1976) believed that stratification would improve the accuracy of the estimate, because deer distribution changes with winter conditions. Lincoln Index population estimates were calculated for 5 years. These estimates exceeded the mrpe in 4 of the 5 years by 17-66%. The correlation coefficient for the 2 estimates ($r = +0.78$) was not significant. Trail count population estimates were close to the mrpe for the 4 years they were completed. In a later study, Kubisiak (1979) found a highly significant correlation ($r = +0.97$, $P < 0.01$) between 11 years of trail count and mrpe data. Aerial helicopter counts were completed in March of 1971 and 1972. These counts exceeded the mrpe by 37% and 24%, respectively. Sex-age-kill analyses were made for 2 years and resulted in close agreement with the mrpe.

CONCLUSION

It has been said before but bears repeating: select a census method which is valid, design the survey carefully for the best possible results and execute the same with a high degree of precision. Population data provide a base or starting point for many other approaches such as population modelling. These subsequent calculations will only be as good as the input data.

Generally, the greater the desired precision of a census, the more expensive it will be. So, take time beforehand to decide how precise the result must be to meet your needs. Also, consider the benefits of other information which can be recorded in conjunction with a deer census. While the cost of a deer census alone might be high, by getting information on other species at the same time, the cost per unit of information will be reduced. For example, on pellet group counts in Minnesota, record was also made of ruffed grouse flushes and roosts, snowshoe hare (*Lepus americanus*) pellets, moose pellets, timber wolf (*Canis lupus*) sign, dead deer, and habitat conditions. An additional benefit is that on the ground field surveys, such as pellet group counts, biologists are out in the woods on an annual basis, thereby keeping them in touch with what is happening in the woods. This is especially important for local wildlife managers and biologists.

As wildlife resource managers we have a responsibility to monitor deer populations using the best method that time, money, and manpower will permit. Our various publics are much too sophisticated today to settle for "seat of the pants" estimates. Intuition is no substitute for hard data and often leads to erroneous conclusions (Gross 1972).

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REPRODUCTION OF WHITE-TAILED DEER IN THE NORTH CENTRAL UNITED STATES

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Abstract: Natality is the most easily studied of all the major population parameters. Valid estimates of ovulation rates based on counts of corpora albicantia require careful examination of histological preparations; this approach is not recommended for general surveys. Conversely, gross examination of ovaries collected from deer after mid-December provides accurate information on current ovulation rates, and uterine examination of deer killed after early February yields valid estimates of pregnancy rate and the number and sex ratio of fawns born per doe the following June. Unfortunately, the relationship between gross natality and net natality, i.e., the fall fawn "crop," is often unknown because early postnatal mortality can be high and, in most cases, difficult to measure. Still, uterine examination is, by far, the most efficient and valid procedure for estimating reproductive performance, and is currently employed throughout the north central region. Since reproductive rates increase significantly during the first 2 or 3 years of life, estimates of the female age structure of populations, as well as adult sex ratios, are essential for calculating natality. Reported fetal rates of mature does (2½+ years) collected in 10 north central states ranged from 1.53 to 2.10, whereas the percentage of pregnant fawns varied from zero to over 60%. Agricultural regions produced does with higher reproductive performance than those from northern, wooded, or arid regions. Nutritional status is the major determinant of reproductive performance in white-tailed deer. Reported fetal rates in mature does increased with whole body weight, and pregnant fawns were observed only in populations in which the mean whole body weight of all doe fawns exceeded 38 kg. Computer simulation of deer population dynamics can be used to illustrate the effect of changes in fetal sex ratios, fetal rates of fawns, and fetal rates of mature does on natality and population growth. Use of computerized models for predicting population size and exploring the consequences of different hunting regulations and harvest strategies is encouraged.

Harder, John D. 1980. Reproduction of white-tailed deer in the north central United States. Pages 23-35 *in* Ruth L. Hine and Susan Nehls, eds. White-tailed deer population management in the north central states. Proc. 1979 Symp. North Cent. Sect. Wildl. Soc. 116 pp.

INTRODUCTION

Estimates of natality, mortality, immigration, emigration, and density are essential for understanding the dynamics of a population. Of these, natality is the most readily estimated and, perhaps, most useful of all. Estimates of the other parameters often require ambitious mark-recapture efforts or involve statistical models with unrealistic assumptions. Given unbiased sampling, natalities of deer populations can be obtained from does killed in sport hunts or in highway accidents. Furthermore, reproductive performance data, the basis of natality estimates, serve as convenient monitors of herd and range conditions.

Definitions and Terminology

Natality is defined as a rate, the number of new individuals added to a population by birth (N_n) per unit of time (t) per unit of population (N):

$$\Delta N_n / N \Delta t$$

Where Δ = change (Odum 1971). It is a population parameter that requires estimates of the sex and age structure of the population as well as estimates of the reproductive performance of the female. For example, data indicating that an average yearling doe (1-2 years old) will give birth to 1.20 fawns provide very little predictive capability regarding change in population size, if the number or relative proportion of yearling does in the population is unknown. Natality may be delineated in a number of ways, but an important distinction is made between gross and net natality. Gross natality is estimated for the moment of birth by projection of fetal rates, whereas net natality is a measure of the number of independent young added to the population each fall. This distinction recognizes the importance of postnatal mortality (death rate of fawns during the first 5 months of life) and the limited utility of simple measurements of reproductive performance.

The difference between reproductive performance and natality is important. Reproductive performance (or reproductive rate) is a measure, usually age specific, of fertility or fecundity. Deer biologists typically express it as the average number of ova shed (ovulation rate) or fetuses (fetal rate) or fawns produced per year by females in a given age class. These ratios are valuable biological measurements and essential components of natality estimates, but they are not in themselves parameters of population ecology.

Productivity is a popular term, particularly among wildlife biologists, generally meaning young produced per 100 females or the replacement rate of the population. Unfortunately, the term has a host of meanings in agriculture and industry, and it has been used classically in the biological sciences as the rate of carbon fixation, i.e., photosynthesis in primary production or assimilation in secondary productivity. Therefore, I choose not to use the term productivity in a technical sense, using instead, natality.

Objectives

This paper is concerned with reproductive performance and gross natality in white-tailed deer *(Odocoileus virginianus)*, and therefore the physiological events of the female reproductive cycle from ovulation to birth. Spermatogenesis and associated physiological events in the male are, of course, important but are not considered here. Estimates of population sex and age structure are essential for calculation of natality. However, such estimates depend on valid sampling schemes rather than an understanding of reproduction, and the technical aspects of sampling will not be treated here. Net natality is primarily a function of early fawn mortality, the subject of the paper by Porath in this symposium.

REPRODUCTIVE BIOLOGY AND NATALITY

Ovarian Analysis

Reproduction in the female begins with oogenesis and the associated events of follicular development, ovulation, and corpus luteum formation. These processes may be viewed histologically in specimens collected during the breeding season. The scars of corpora lutea of pregnancy regress slowly, after parturition, and can be used to assess ovarian activity many months afterward. For these reasons, examination of ovaries collected during the hunting season has been practiced for over 30 years.

Large follicles (>3 mm diameter) can be observed in the ovaries of deer collected at almost every month of the year. Most of these follicles do not ovulate but, rather become atretic. During the onset of the rut in early November, the percentage of large, atretic follicles decreased markedly, but yet only 1 or 2 follicles per ovary were in precisely the right stage of development to respond to the sequence of hormonal dynamics that culminate in ovulation (Harder and Moorhead 1980). The endocrine-ovarian-environmental mechanisms controlling the number of ova ready for ovulation in a given estrous cycle are not well understood for any species, but therein lie the keys to understanding much of the observed variation in reproductive performance of white-tailed deer.

After ovulation, the granulosa cells of the ruptured follicle begin to luteinize under the influence of luteinizing hormone (LH), and the corpus luteum (CL) begins to form. Thomas and Cowan (1975) reported that the first ovulation of the breeding season in black-tailed deer *(O. hemionus columbianus)* seldom led to conception or a lasting pregnancy. The resulting CL regressed quickly and a second ovulation occurred about 8 days later. Harder and Moorhead (1980) estimated the interval between the first and second ovulations of the season in white-tailed deer to be no more than 15 days and otherwise confirmed the observations of Thomas and Cowan (1975). Perhaps due to an incomplete hormonal regime, the first ovulation of the breeding season is not accompanied by estrus; the ovulation is "silent". The second ovulation of the season, apparently associated with estrus, results in fertilization and the resulting CL persist as CL of pregnancy.

After parturition, in early June, CL of pregnancy begin to regress. The resulting scars, the corpora albicantia (CA) or corpora rubra, accumulate a rust or reddish pigment that is grossly visible on razor-sectioned slices of Formalin-fixed ovary. Cheatum (1949*a*) estimated that CA persisted for 8 to 12 months after parturition, and thus, were a reliable indicator of the ovulation rate associated with the previous pregnancy. However, Golley (1957), Mansell (1971), and Teer et al. (1965) found that CA persisted for 2 or 3 years and that CA counts often exceeded the true ovulation rate, particularly in older does. Gibson (1957) demonstrated that a variety of ovarian structures, including luteinized follicles, regressing CL of estrus, and CA will form rust-colored scars.

Uterine Examination

Necropsy of pregnant deer is, by far, the most efficient and productive approach to the measurement of reproductive performance. *In utero* mortality of fetuses is apparently very low (Teer et al. 1965), and, unless does are severely undernourished, counts of fetuses can be projected to live births per doe. Uterine examinations also provide valid estimates of fetal sex ratios.

Reliable procedures for estimating early postnatal losses are needed; without them, estimates of gross natality are of diminished value, particularly if early postnatal mortality is potentially high. Verme (1962) observed that most fawns of undernourished does were born dead or died within 48 hours of birth. Langenau and Lerg (1976) described a maternal rejection syndrome in undernourished does that included neglect of the newborn fawn and refusal to nurse despite the presence of milk in the udder. Teer et al. (1965) estimated that about 11% of the fawns on the Llano Basin of Texas were lost shortly after birth.

In that a large portion of postnatal mortality apparently occurs within 1 or 2 days after birth, the ability to predict such early mortality on the basis of a fetal or maternal condition index would be most valuable. Verme (1977) developed fetal growth curves, which, when projected to term, indicated mean birth weights ranging from 3.24 to 2.27 kg. Based on weight-death relationships of newborn fawns in pen studies, projected fetal weights indicated probable mortality rates in fawns ranging from 10% to 70%. The relationship between projected natal mortality and the fawn:doe ratio in the fall harvest was significant, indicating that the technique was a potentially reliable indicator of early fawn losses.

Population Structure and Natality

Reproductive performance data have no direct application to population ecology unless they are used with estimates of population size and structure to calculate gross natality. The prefawning population size might be known from a census, or it could be set arbitrarily, e.g., as a multiple of an abundance index for a given management unit. Accurate estimates of sex and age structure are essential but difficult to obtain, particularly those concerning the size of the fawn component of a population.

Information on population sex and age structure is available from 3 sources: sport hunts, highway accidents, and field observations. Sex ratios obtained from hunter returns are usually biased in favor of bucks, but short seasons (2-3 days) might reduce hunter selectivity (Nixon 1971). Large samples from hunters probably provide reasonable estimates of the female age structure, excluding fawns. Large samples of deer killed on highways might provide useful data on population structure. Numbers of deer killed on Wisconsin highways correlated well with trends in buck harvests (McCaffery 1973). Numbers of fawns and yearlings killed on a section of Interstate 80 in Pennsylvania did not differ significantly between sexes, but among adults many more does than bucks were killed (Bellis and Graves 1971). Field observations could potentially yield useful data on adult sex ratios and fawn:doe ratios, but standardized, unbiased procedures are needed. Clues to the solutions of these and other sampling problems are the subject of other papers in this symposium (Ryel, Beattie et al., and Burgoyne).

Given accurate age-specific fetal rates, sex and age structure data, and negligible early postnatal mortality, calculation of gross natality is a relatively simple task. Fetal rates must be expressed as the average number of fetuses per all does examined in a given age class, rather than fetuses per pregnant doe. In many cases, small sample sizes and low variation between older age classes will justify the use of average fetal rates for does older than 3½ years or even 2½ years. The actual number of does used in calculation of natality should be obtained from the proportion of the total number in the population in each female age class. Then, the total number of fawns produced can be obtained by summing the products of doe number and fetal rate in each age class. These and more complex calculations involving early postnatal losses, net natality, and population growth over a series of simulated years can be done readily with relatively simple, computerized projection models.

REPRODUCTIVE PERFORMANCE OF DEER IN THE NORTH CENTRAL UNITED STATES

Reproductive performance of mature does (2½ + years) collected throughout the north central United States ranged from 1.53 to 2.10 fetuses per all does examined (Table 1). Variation in reproductive performance within some states was as large as variation between states. This was especially true of states with a wide range of habitat types and climatic conditions. The southern agricultural regions of Michigan, Minnesota, and Wisconsin produced does with higher performance than those of the northern, wooded regions. Does from the western, more arid sections (Black Hills) of South Dakota showed lower fetal rates than the East River Area of the same state. Fawns exhibited the most striking variation in reproductive performance of any age group. The percentage of fawns breeding ranged from 6% or less in the northern reaches of Michigan and Wisconsin to over 60% in the agricultural regions of some states.

Recent reproductive data contributed by biologists in Michigan and Minnesota revealed significant ($P < 0.05$) variation in fetal rates between years and between regions within those states (Table 2). Some variation in fetal rates might be related to yearly differences in sampling locations within regions or annual variation in weather. Higher fetal rates in the southern sections of both states probably reflected the higher nutritional plane of deer associated with agricultural land use patterns.

DETERMINANTS OF REPRODUCTIVE PERFORMANCE

Aside from variation in the percentage of does breeding, ovulation rate clearly accounts for most of the variation in reproductive performance of female white-tailed deer. That is, loss of ova and fetuses from a fertile estrous cycle normally totals less than 15%. Roseberry and Klimstra (1970) observed a 12.6% loss of ova in yearling and older does from Illinois, and estimates of ova loss in other areas ranged down to less than 5% (Ransom 1967, Haugen 1975). However, Ransom (1967) also found ova loss exceeded 20% when more than 2 ova were shed. *In utero* mortality, as evidenced in resorbing fetuses, has been low in most studies, typically involving less than 5% of the fetuses, often less than 1% (Teer et al. 1965, Ransom 1967, Woolf and Harder 1979). Thus, following ovulation, the next important adjustment of productivity apparently comes in the form of stillbirths or early postnatal mortality (Verme 1962).

Age of the Doe

Age and nutritional status are the 2 major factors affecting reproductive performance in white-tailed deer. The 2 are related, but regardless of nutrition, ovulation rate tends to increase with age, at least through the first 3 or 4 years of life. The ovulation rate and fetal rate of fawns are always significantly lower ($P < 0.05$) than those of older females. In some populations, does 2½+ years showed significantly higher ovulation and fetal rates than yearlings (Ransom 1967, Nixon 1971, Kirkpatrick et al. 1976), while in other areas, differences between yearlings and older deer were not significant (Ransom 1967). In general, differences between fetal rates of yearlings and older does were small in populations containing a large proportion (>40%) of pregnant fawns (Table 1). Increases in reproductive performance after the third year of life are generally small and nonsignificant.

Nutritional Status of the Doe

Cheatum and Severinghaus (1950) were among the first to clearly demonstrate the relationship between range conditions and fertility of white-tailed deer. During the last 30 years overwhelming evidence has accumulated indicating that nutrition is the major factor controlling reproductive performance in white-tailed deer. Poor nutrition can stem from a variety of sources ranging from a negative energy balance during severe winter weather in Manitoba (Ransom 1967) to drought-induced range deterioration in Texas (Teer et al. 1965). Sileo (1973) divided the eastern United States into 6 major deer "fertility regions" based on a forest type by soil type classification. These factors were related to the percentage of land farmed which was, in itself, a reliable indicator of reproductive performance in deer.

Conclusions from field studies regarding nutrition and reproduction have been confirmed in pen studies where short-term reduction in rations caused reduced fawn production (Verme 1969) and delayed maturity in female fawns (Abler et al. 1976). Conversely, Robinette et al. (1973) found that litter size in penned mule deer (*O. hemionus*) increased when their nutritional level was raised.

Ovulation rate is probably most strongly influenced by the nutritional status of the doe in late summer and early fall. Although

TABLE 1. *Comparison of reproductive performance of white-tailed deer in the north central United States*.*

State and Region	Fawns Percent Pregnant	Yearlings Percent Pregnant	Yearlings Fetal Rate	Mature Does (2½ + years) Percent Pregnant	Mature Does (2½ + years) Fetal Rate	Year of Deer Collection	Reference
ILLINOIS							
Crab Orchard Refuge	41 (160)	96 (110)	1.68	98 (278)	1.88	1966	Roseberry and Klimstra (1970)
INDIANA							
NAD Crane Depot	20 (45)	100 (34)	1.53	100 (93)	1.94	1964-71	Kirkpatrick et al. (1976)
IOWA							
Statewide and Desoto Range	74 (240)	85 (472)	1.66	100 (655)	2.10	1957-66	Haugen (1975)
Statewide	68 (83)	96 (22)	1.82	90 (30)	1.63	1978	Gladfelter (1978)
MICHIGAN							
Region I (U.P.)	6 (489)	91 (626)	1.25	96 (2,350)	1.75	1951-79	Friedrich (1979)
Region III (Southern)	52 (966)	96 (412)	1.83	96 (665)	1.94	1952-79	J. Vogt (1979, pc)
MINNESOTA							
North Forest	11 (822)	88 (110)	1.34	85 (421)	1.53	1971-79	P. Karns (1979, pc)
South Agricultural	31 (179)	92 47)	1.49	94 (161)	1.85	1979	J Ludwig (1979, pc)
MISSOURI							
N.E., Agricultural	56 (9)	89 (9)	1.89	100 (12)	1.92	1978	W. Porath (1979, pc)
E. Central Hills	48 (23)	91 (11)	1.73	100 (15)	1.93	1978	W. Porath (1979, pc)
NEBRASKA							
Statewide	63 (295)	94 (143)	1.74	99 (182)	1.95	1961-73	K. Menzel (1979, pc)
OHIO							
Statewide	77** (335)	99 (180)	1.87	100 (215)	2.04	1962-67	Nixon (1971)
SOUTH DAKOTA							
East River	57 (21)			97 (39)[1]	1.85	1978	L. Rice (1978, pc)
Black Hills				96 (28)	1.54		L. Rice (1978, pc)
WISCONSIN							
Northern	3 (203)						Hale (1959)
Statewide		74 (230)	1.20	86 (538)	1.56	1956-58	Sileo (1973, from Hale 1959)
South and East Central	29 (147)						Sileo (1973), Hale (1959)

* States with a 1978 or 1979 collection date estimated reproductive rates on a yearly basis. Fetal rate indicates the number of fetuses from all does examined in a given age class. Sample sizes are given in parentheses. Reference date with pc indicates personal communication.

**Percentage that ovulated.

[1] Yearlings included with does 2½ + years.

forage availability in late summer is undoubtedly important to the pre-ovulatory condition of the doe, maternal obligations during the preceding 6 months might also be a factor, particularly in northern regions. That is, if spring is delayed or if the doe is in poor condition at the onset of lactation, low nutritional status might be maintained throughout much of the summer. Verme (1969) suggested that the undernourished does cannot recover from the stress of lactation in time to be in prime condition for ovulation during the rut and are, therefore, less productive.

Numerous measurements can be made of the bodies of female white-tailed deer that reflect nutritional status and history, but they vary considerably in reliability, sensitivity, and convenience. Body weight reflects growth as well as seasonal accumulation and depletion of fat reserves. As such it is an old, reliable index of nutritional status and, when measured during the fall hunting season, it is particularly relevant to puberty in fawns and the breeding condition of mature does. Body weight is also well suited for use in comparisons of deer from large geographic areas or animals taken over long time spans. Unfortunately, body weights are difficult to measure in the field and are normally only recorded at selected check stations. Indexes of fat reserves are valuable because they reflect the energy balance of an animal, the most popular being those of kidney (Riney 1955) and bone marrow fat (Cheatum 1949*b*, Verme and Holland 1973). In recent years, Michigan biologists have collected mandibles of all deer killed on the highways in winter for age determination and fat analysis (Friedrich and Fay 1978). Ozoga and Verme (1978) found that the growth and involution of the thymus gland in fawns varied with dietary plane, and they encouraged use of thymus gland weights as an index of nutritional status. An informative review of measurements commonly used to estimate physical condition was provided by Hesselton and Sauer (1973).

TABLE 2. *Examples of geographical and chronological variation in fetal rates in does from Michigan and Minnesota, 1972-79*.*

	Michigan[1] Fetuses per Mature Doe (2½ + years)				Minnesota[2] Fetuses per Pregnant Doe			
	Food Shortage Area of Region II		Region III		Itasca Rainy River (Northern Region)		Mille Lacs Big Woods (South & Central Region)	
Year	N	$\bar{x} \pm$ SD**	N	$\bar{x} \pm$ SD	N	$\bar{x} \pm$ SD	N	$\bar{x} \pm$ SD
1972	63	1.88 ± 0.54		(No Data)	45	1.64 ± 0.47	51	1.63 ± 0.51g
1973	42	1.83 ± 0.49	58	1.95 ± 0.63	18	1.56 ± 0.33	38	1.68 ± 0.60
1974	26	1.96 ± 0.20a	12	2.00 ± 0.43	27	1.70 ± 0.50	47	1.57 ± 0.44h,i,j
1975	24	1.83 ± 0.48	19	2.10 ± 0.57b	49	1.55 ± 0.49e,f	53	1.81 ± 0.50f,h
1976	41	1.88 ± 0.51	21	1.67 ± 0.66b	22	1.77 ± 0.61	63	1.81 ± 0.43i
1977	14	1.79 ± 0.58	15	2.06 ± 0.46	16	1.69 ± 0.48	64	1.70 ± 0.40
1978	51	1.78 ± 0.54c	40	2.10 ± 0.50c	14	1.64 ± 0.63	28	1.89 ± 0.57g,j
1979	44	1.54 ± 0.62a,d	47	1.94 ± 0.53d	63	1.81 ± 0.50e	46	1.78 ± 0.51

* Data from Region II (northern one-half of the Lower Peninsula) and Region III (southern agricultural one-half of the Lower Peninsula) represent only the 8 most recent years of a continuous series of annual data sets dating back to 1951.

** Data are presented as the mean ± standard deviation ($\bar{x} \pm$ SD). Column means bearing the same alpha superscript are significantly different ($P < 0.05$).

1 Means and *t*-tests calculated from age-specific fetal counts given in Ryel and Youatt (1972), Burgoyne and Youatt (1973), Youatt et al. (1974, 1975), Purol et al. (1976), Friedrich et al. (1977), Friedrich and Fay (1978), and Friedrich (1979). Means include nonpregnant does; 95-100% of the does were pregnant.

2 Data were presented as fetuses per pregnant doe and notation of significant differences ($P <$ 0.05) was provided by P. Karns (pers. comm.).

During the last 15 years, blood chemistry and hematology have attracted interest as indicators of nutritional condition of deer. Blood parameters reflect vital processes and should be sensitive to subtle or recent changes in nutrition. Measurements of red blood cells, hemoglobin, cholesterol, serum urea, lactic dehydrogenase, thyroxine, and nonesterified fatty acids reflected differences between populations relevant to habitat and nutritional status (Seal et al. 1978). Unfortunately, biochemical parameters can be affected by factors unrelated to ongoing nutritional status, and thus their interpretation is generally more difficult than analysis of physical measurements. LeResche et al. (1974) evaluated a number of blood parameters relative to nutritional assessment.

Female Body Weight and Reproductive Performance

Populations with high female body weights tended to have high reproductive rates (Table 3). Crab Orchard deer, the apparent exception, had a relatively high fetal rate despite low body weight. However, these deer from the southern tip of Illinois were not undernourished, but were smaller because they probably belonged to the inherently smaller subspecies, *O. v. virginianus*, while other populations in Table 3 belonged to the larger *O. v. borealis* (J. Roseberry, pers. comm.). Excluding Crab Orchard data, fetal rates of mature does in Table 3 were closely correlated with body weight ($r = 0.982$, $y = -1.23 + 0.049X$). Gill (1956) found does in the West Region of West Virginia to be larger (mean dressed weight = 41.3 kg) and to have a higher ovulation rate (1.90) than does in the East Region which averaged 32.7 kg and 1.51 corpora lutea per doe.

The Age of Puberty

Reproductive performance of yearling and mature does was higher in populations that showed a high percentage (>30%) of pregnant fawns (Table 1). This might simply reflect a higher overall nutritional plane for these populations, or it might indicate that rapid growth and sexual development as a fawn enhance reproductive performance throughout life. Some of the physiological mechanisms involved in puberty might also be active during the transition from seasonal anestrus to the rut and thus explain the absence of breeding in some older animals.

Attainment of puberty is closely related to nutritional and physical development. The amount of growth achieved by fawns before the onset of winter and decline of natural forage in December probably determines whether or not a fawn participates in the rut. Robinette et al. (1973) concluded that the minimum whole body weight for first estrus in mule deer fawns was 41 kg; Hesselton and Sauer (1973) thought that this threshold weight for white-tailed deer was 38-40 kg (30-32 kg, dressed). Data from the several northern locations seem to support the critical weight hypothesis (Table 3). However, the threshold weight might be lower in smaller subspecies. Crab Orchard fawns were well nourished and productive but inherently small, being approximately 21% lighter than fawns from northern Illinois (J. Roseberry pers. comm.).

TABLE 3. *Relationship between whole body weights and reproductive performance of female white-tailed deer from northern United States.*

	Fawns		Mature Does (2½ + years)		
Location and Reference	Mean Weight (kg)	Percent Pregnant	Mean Weight (kg)	Percent Pregnant	Fetuses per All Does Examined
IOWA Kline (1967)* Haugen (1975)	41.2 (288)**	65-74 (240)	68.9 (244)	100 (655)	2.10
SENECA ARMY DEPOT[1] (New York) Hesselton (1967)	42.4 (23)	36 (22)	62.7 (29)	100 (29)	1.93
CRANE NAD DEPOT[1] (Indiana) Kirkpatrick et al. (1976)	38.0 (1,146)	36 (45)	63.2 (1,145)	100 (93)	1.94
CRAB ORCHARD NATIONAL WILDLIFE REFUGE (Illinois) Roseberry and Klimstra (1970, 1975)	29.5 (178)	41.6 (160)	53.2 (266)	98 (278)	1.88
PLUM BROOK STATION (Ohio) Harder and Peterle (1974) Bell and Peterle (1975)	32.7 (35)	0 (35)	59.3 (197)	95 (197)	1.67
RACHELWOOD WILDLIFE[1] RESEARCH PRESERVE (Pennsylvania) Woolf and Harder (1979)	30.9 (187)	0 (35)	52.3 (314)	94 (46)	1.32

* Kline (1967) and Roseberry and Klimstra (1975) were cited for weight data only. All data for Plum Brook Station represent weighted averages of values presented in Harder and Peterle (1974) and Bell and Peterle (1975).

** Sample sizes given in parentheses.

1 Whole body weight calculated: dressed weight × 1.28.

Fawns normally comprise the single largest age class in a population. Thus, even though fawns seldom, if ever, carry more than 1 fetus and even if 1-year-olds are less successful in raising their young, small changes in the percentage of pregnant fawns could lead to large changes in gross natality. Unfortunately, despite the fact that reproductive performance of fawns is highly variable (Tables 1 and 3) and sensitive to environmental changes, this age class has received relatively little attention in reproductive studies.

Population Density and Reproductive Performance

Low fecundity in deer is usually attributed to a low nutritional plane. However, this relationship is often associated with high population density (Teer et al. 1965), and the potential effect of density of social stress alone (Christian and Davis 1964) should be considered. Data are available from 2 populations that apparently had good-to-adequate nutrition during the time of high population density, i.e., more than 20/km². Deer numbers on the Crab Orchard National Wildlife Refuge had reached an estimated density of about 30/km² (Autry 1967) in 1965, just prior to the data collection of Roseberry and Klimstra (1970) (Table 1). Rice and Harder (1977) documented the presence of 2,499 ± 94 (± 2 SE) deer on the 2,176-ha Plum Brook Station in 1975 for a density of 115 per km², the highest density ever reported for white-tailed deer. Computer simulations indicated that the deer density on Plum Brook Station was at least 80/km² during the period that reproductive data were collected (Table 3). Although Plum Brook fawns did not breed, reproductive performance for adults taken from these high density herds was well within the range of values reported for deer from low density herds (Table 1).

High density has had no discernible effect on reproductive performance of penned deer. Mature does held in pens at a high nutritional plane produced an average of 1.80 fawns (Verme 1969). Mule deer held in 1.2-ha enclosures at densities ranging from 20-30/ha, equivalent to densities of over 2,000/km², produced an average of 1.97 fawns per doe when maintained at a high dietary plane (Robinette et al. 1973). Thus, I believe it may be safely stated that population density *per se* has little or no influence on the reproductive performance of mature does. Whether density influences the initiation of breeding in fawns, postnatal mortality, or other determinants of net natality is another question.

COMPUTER SIMULATION IN THE STUDY OF NATALITY AND POPULATION GROWTH

A computerized version of the Leslie-Lewis matrix model (Pennyquick et al. 1968) developed by Rice (1976) was used to simulate the dynamics of the deer population on Plum Brook Station in northern Ohio (Fig. 1). A 2.44 m fence enclosed the Station and eliminated significant immigration or emigration.

The parameters required by the model were: (1) initial population size, (2) sex and age structure of the initial population, (3) fetal sex ratios, (4) age-specific reproductive rates (fetuses/doe), (5) number of animals removed each year, e.g., from hunting and trapping, and (6) natural mortality, or the reciprocal, survival. The first 5 parameters were estimated directly from samples taken from the Station. Natural mortality or survival of deer on the Station, independent of removals, was unknown, so estimates from similar herds were assigned to each age class, beginning with fetuses to the first 6 months after birth (0.775 survival). High annual survival after the first 6 months (0.90-0.95) was assigned to females. Male survival ranged from 0.90 to 0.70 for the first 3 years of life and then declined steadily to 0.40 at 7 years of age.

States are typically divided into management units based on topography, climate, agricultural land use, and other factors relevant to deer biology. Sampling effort within a given management unit, ideally, should be commensurate with temporal and spacial variation in reproductive rates. That is, units that show high performance with little variation within or between years could be sampled less intensely than units exhibiting depressed or variable rates. Once a desired level of discrimination or precision has been selected, the variance of previous estimates can be used to determine the required sample size (Ostle 1963).

Practical considerations regarding sampling effort are frequently as important as statistical determinations. In areas of low deer density, it might be necessary to take whatever samples are available and then pool data over several years. Shortages of funds, trained personnel, or opinions of administrators can present obstacles. Therefore, biologists should be able to clearly justify collections, define the level of precision necessary to meet objectives, and then determine appropriate sample size for each management unit.

How often should reproductive rates be measured? This is an important question involving the time and efforts of many people. About one-half of the 10 states surveyed (Table 1) took statewide observations of fetal rates on a yearly basis. The remainder conducted special studies of deer natality on selected localities or statewide on an unscheduled basis, perhaps every 5 or 10 years.

Objective answers to questions regarding sampling frequency must be based on some knowledge of annual variation in reproductive rates for the management units in question. Significant differences in fetal rates occurred between units and between years (Table 2). Annual differences in fetal rates of 0.2 to 0.3 were common, and they occasionally approached 0.5. Differences of the latter magnitude could lead to marked variation in natality and population growth (Fig. 5).

It is recommended that annual statewide surveys of reproductive rates be conducted over a sufficient number of years to cover the range of annual variation in winter severity, precipitation, or other factors known to influence reproductive rates. Data from at least 5 years would be required in most cases, and sample sizes would have to be large enough (probably >40) to support statistical comparisons between years and management units.

Collection and Analysis of of Biological Material

Examination of ovaries collected during

the hunting season is recommended for states or management units with low numbers of deer killed on the highways in winter or early spring. Hunters can be encouraged, through instructions and advertisements, to save the reproductive tract when dressing the carcass; biologists have used this approach with varying degrees of success for several decades (Cheatum and Severinghaus 1950, Haugen 1975).

For reasons outlined previously, CA counts from gross ovarian examination (Cheatum 1949*a*) should not be used to estimate the ovulation rate associated with the previous pregnancy in mature does. Careful histological examination of ovaries by trained technicians could produce useful indexes of ovulation rate in older does (Mansell 1971), but this approach probably would not be practical in most cases. More emphasis should be placed on gross ovarian analysis of yearling does and carefully developed criteria of CA indicating pregnancy rates in fawns. If estimates of pregnancy rates in fawns are not forthcoming from winter necropsies, then they should be obtained from the occurrence of CA in yearling does or from the proportion of yearlings in the fall harvest that show enlarged teats, a reliable indicator of lactation and prior pregnancy (Sauer and Severinghaus 1977).

Assigned annual survival values used in the simulation model were confirmed with a combination of simulation and field observations. Rice and Harder (1977) estimated the population at 2,499 ± 94 (± 2 SE) deer in January 1975; approximately 90 more were present in October 1974. Sport hunting and removal by trapping reduced the population to low levels by the fall of 1977 (Fig. 2), and removals thereafter, mostly fawns and does (67-84%), maintained the low density. Fifty-one deer were counted on the Station in October 1979 (Edward Butler pers. comm.). Not all deer were seen, and the total number present was probably at least 2-4 times the number counted. Thus, the computer simulation using high female survival (0.90-0.95) agreed with field observations in that at least

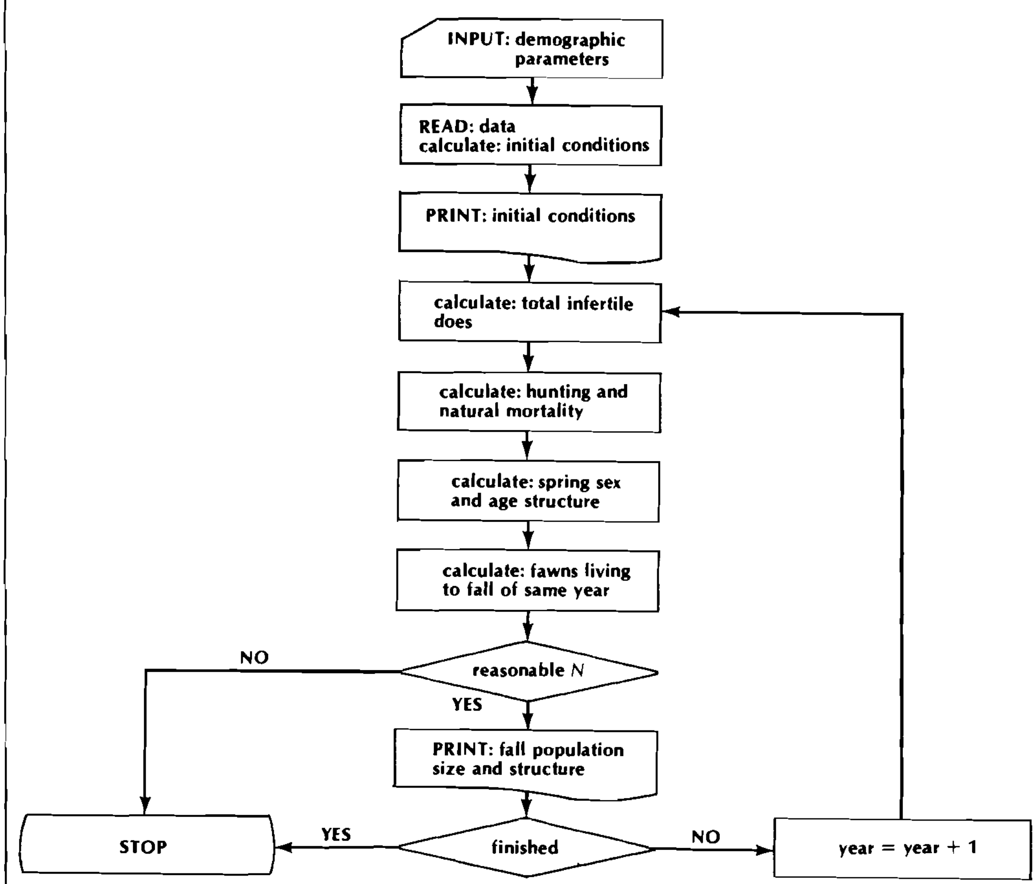

FIGURE 1. *Flow diagram of the computerized projection model of the Plum Brook deer population (Rice 1976).*

100-200 were known to be on the Station in the fall of 1979. However, when a slightly lower female survival (0.85-0.90) was used in the data set, the simulation terminated in 1978, when the simulated population was reduced to zero (Fig. 2), indicating that the estimate of 0.90-0.95 annual female survival used in the model was not too high.

In addition to confirming assumptions regarding natural mortality, the projection or simulation model has been applied in 3 general ways: (1) year-by-year projection of population size (Fig. 2) based on known removals and reproductive parameters; (2) exploration of management strategies, e.g., hunting, trap-removal, and the application of antifertility agents (Rice 1976); and (3) simulation of population dynamics with varied reproductive rates and sex ratios (Figs. 3, 4, and 5).

Fetal sex ratios normally range between 45% and 50% female, but extremes of 60% female fetuses (Woolf and Harder 1979) and 30% female fawns (Verme 1969) have been recorded. The causes and theoretical or evolutionary implications of shifts in fetal sex ratios are controversial and have been discussed elsewhere (Verme 1969, Trivers and Willard 1973, Woolf and Harder 1979). Of importance to this discussion, however, are the results of simulations indicating that a wide range of fetal sex ratios might have a relatively small impact on natality as evidenced in population growth (Fig. 3).

Does that produce a viable fawn on their first birthday could have a tremendous impact on natality (Haugen 1975). Computer simulations showed that populations differing only in the proportion of breeding fawns would respond quite differently to exploitation (Fig. 4).

Different fetal rates, covering the range observed in mature does from across the north central United States (Tables 1, 2, and 3) led to substantial differences during a 5-year projection of population size (Fig. 5). The high fetal-rate population (A) grew to be 3 times larger than the low fetal-rate population (C). Equal numbers were removed from the 3 populations, and during the first 3 simulated years, the percentage removed from each population was approximately equal (22-28%). Nevertheless, population A grew steadily, so that the numbers removed during the last 2 simulated years represented only about 21% of the fall population levels. Population C declined gradually at first and then, steeply during the last 2 years when the numbers removed represented 32-42% of the fall populations. Population B maintained the initial size while supporting annual removals of 23-29%.

RECOMMENDATIONS FOR STUDIES OF NATALITY

Sampling Procedures

In most populations, ovaries of mature does collected after late November will contain active CL of pregnancy, which provide a reliable indication of ovulation rate and have a predictable relationship to fetal rate. CL of pregnancy can be easily identified and measured in razor-sectioned ovaries. However, care must be given to the collection dates relative to timing of the rut, and size criteria for CL of pregnancy should be established (Trauger and Haugen 1965).

All states that made annual surveys of reproduction in deer (Table 1) did so by uterine analysis, i.e., by counting fetuses in does killed on highways. This is, by far, the most efficient and meaningful measurement of reproductive performance. Michigan and other states concentrate their efforts in March, April, and May, but collections made any time after the first of February would give reliable estimates of the percentage of breeding does in all age classes, the number of fetuses per doe, and fetal sex ratios.

Uterine analysis is advantageous because data can be collected during field necropsies without the need to collect or preserve tissues. At the very least, age of the doe and the sex and number of fetuses should be recorded. Measurements of forehead-rump length and body weight can be used to age healthy fetuses (Armstrong 1950) or possibly to predict early postnatal mortality (Verme 1977). Interested personnel can be easily trained to collect data, but dead deer can be widely distributed over time and space. Biologists often must depend on a large number of cooperators willing to work over a period of 2-4 months, and inconsistency in procedures and effort could be a source of biased data. Thus, ovaries should be collected from a subsample of does killed on highways in order to confirm reported fetal rates and to determine the relationship between ovulation rate and fetal rate of does in a given area.

APPLICATION OF REPRODUCTIVE DATA TO DEER MANAGEMENT

Estimates of natality and reproductive data are applicable to 2 major areas of deer management: (1) prediction of population size and setting harvest quotas, and (2) evaluation of the general vitality of a deer population and the condition of the habitat or range. State game agencies spend a large amount of time in setting and enforcing hunting regulations and in evaluating the harvest. Clearly, estimates of abundance are essential to this process, but natality estimates can be particularly useful in calculating antlerless permit quotas for management units (J. Ludwig pers. comm. 1979). Setting regulations is, in many cases, an unavoidable process of reacting to prevailing conditions on a year-to-year basis. Land acquisition or habitat alterations may be planned years in advance, but populations are typically viewed in retrospect. This need not be true.

Computerized projections or simulation models offer predictive capability, and biologists in several states are currently using this tool. Population modelling can be used to predict population size (Fig. 2), explore the impact of various hunting regulations on sex and age classes, and determine optimum yield (Walters and Bandy 1972). Realism of the projections will depend on the nature of

FIG. 2

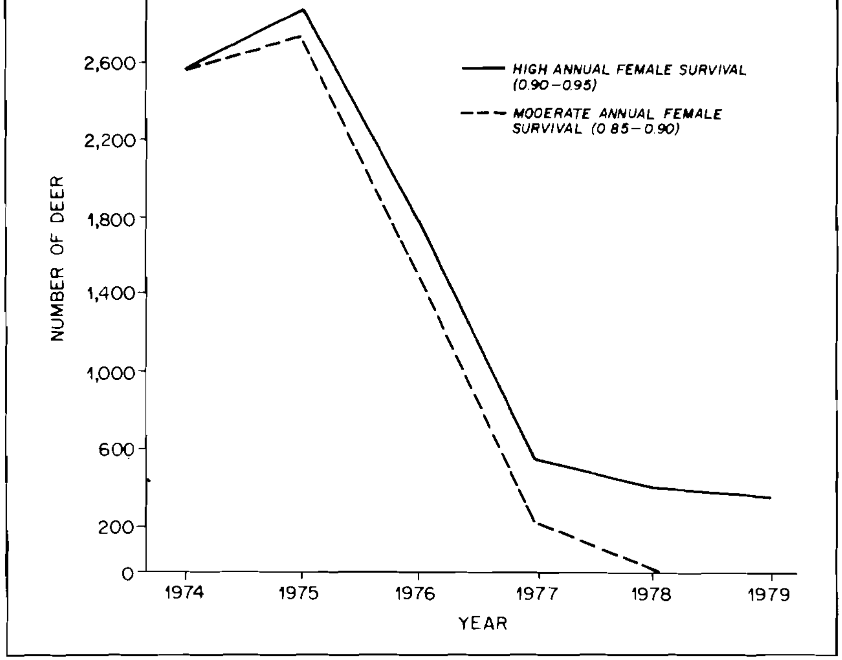

FIG. 3

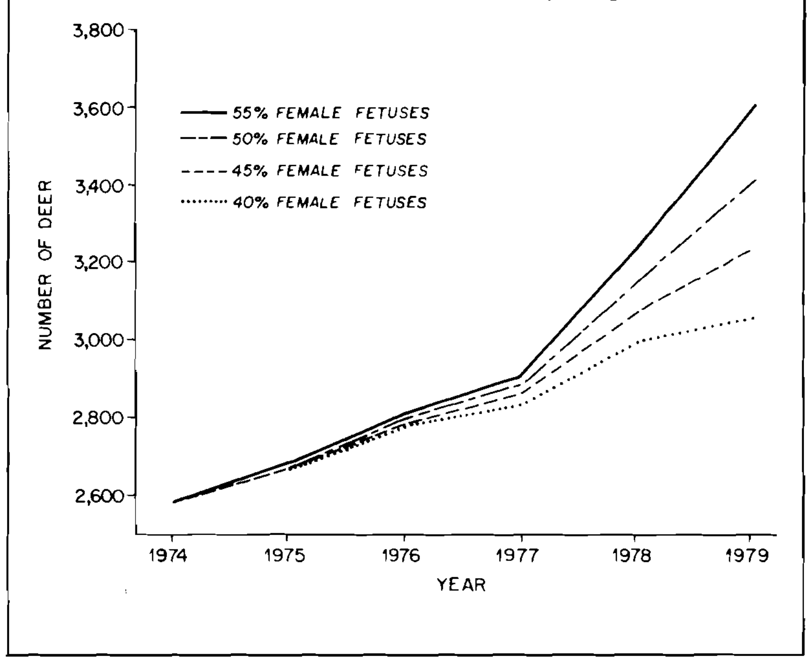

FIG. 4

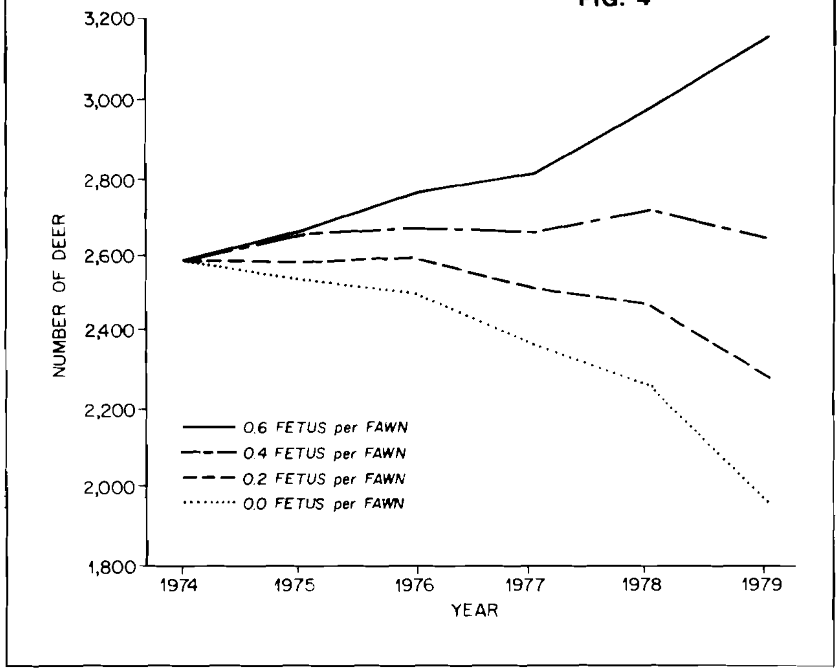

FIG. 5

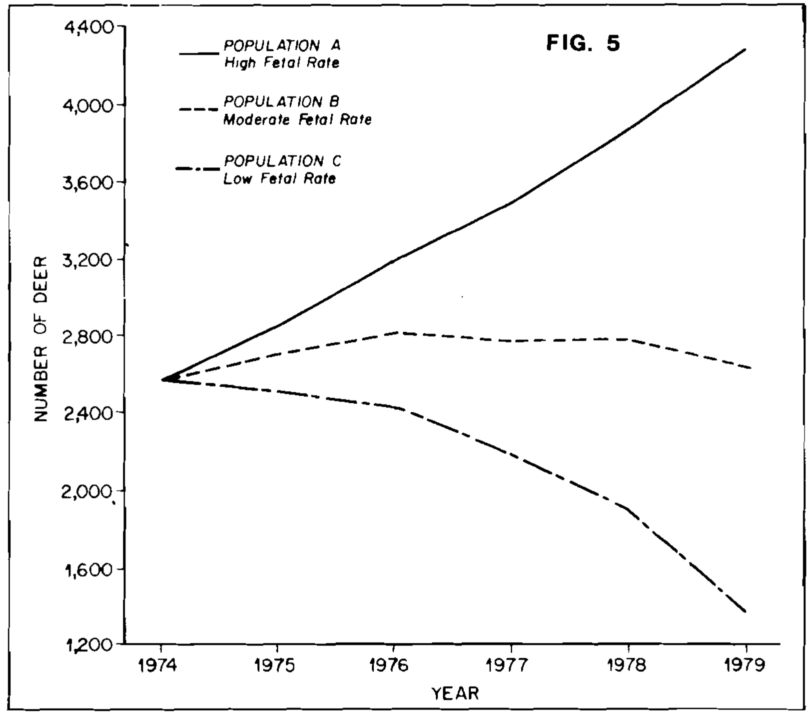

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FIGURE 2. *Computer projection of the fall deer population on Plum Brook Station, based on the 1975 census (Rice and Harder 1977) and known removals of 384, 1,603, 1,292, 171, and 90 deer from 1975 through 1979, respectively. With the high female survival, the computer simulation projected the population to be about 300 deer in the fall of 1979, a reasonable estimate relative to minimum numbers known to be on the Station at that time.*

FIGURE 3. *Computer simulations of fall deer populations differing only in fetal sex ratios (percentage of female fetuses). Simulated annual removals were proportional to the sex and age structure of the population and totaled 500, 500, 600, 600, and 700 deer from 1975 through 1979, respectively.*

FIGURE 4. *Computer simulations of fall deer populations differing only in the proportions of fawns breeding (equal to fetal rates of 0.0-0.6 because pregnant fawns carry one fetus only). Simulated annual removals were proportional to the sex and age structure of the population and totaled 600, 600, 700, 700, and 800 deer from 1975 through 1979, respectively.*

FIGURE 5. *Computer simulations of fall deer populations differing only in adult fetal rates. Population A produced 0.20 fetuses/fawn, 1.50 fetuses/yearling, and 2.00 fetuses/doe 2½ years or older. Population B produced 0.2 fetuses/fawn, 1.20 fetuses/yearling, and 1.65 fetuses/doe 2½ years or older. Population C produced 0.20 fetuses/fawn, 1.00 fetuses/yearling, and 1.30 fetuses/doe 2½ years or older. Simulated removals were the same as in Figure 4.*

the model and the accuracy of the data used in the simulations. Nevertheless, modelling can provide reasonable answers to the "what if" questions and could contribute to enlightened management decisions (Walters and Gross 1972).

The second major use of reproductive data, that of evaluating the general vitality of deer or range condition in a given area, is well established, dating from the classic publication of Cheatum and Severinghaus (1950). Fetal rate, yearling antler development, and body weight were the criteria for assignment of Pennsylvania counties into 1 of 5 deer-quality classes (Lang and Wood 1976). Indices of population size, and recruitment and harvest quotas were then calculated for each county class. Reproductive parameters, e.g., percentage of fawns breeding, might be more reliable or even more sensitive indicators of nutritional plane or habitat change than body weight. Reproductive parameters are of greatest value, however, because they integrate the effects of nutrition over the entire year and probably over the life of the individual. All things considered, the study of reproduction and natality is one of the most efficient, practical, and meaningful ways to monitor a deer population.

Acknowledgments. Information in Tables 1 and 2 came as generous contributions from deer biologists from throughout the north central states and their time and effort is sincerely appreciated. Ted Bookhout, Tony Peterle, John Roseberry, and Lou Verme made valuable suggestions for improving the manuscript.

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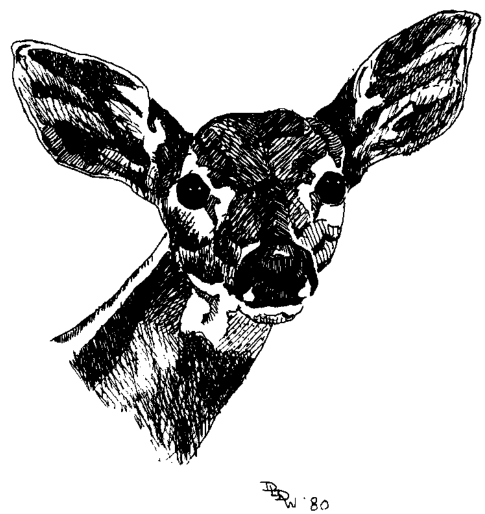

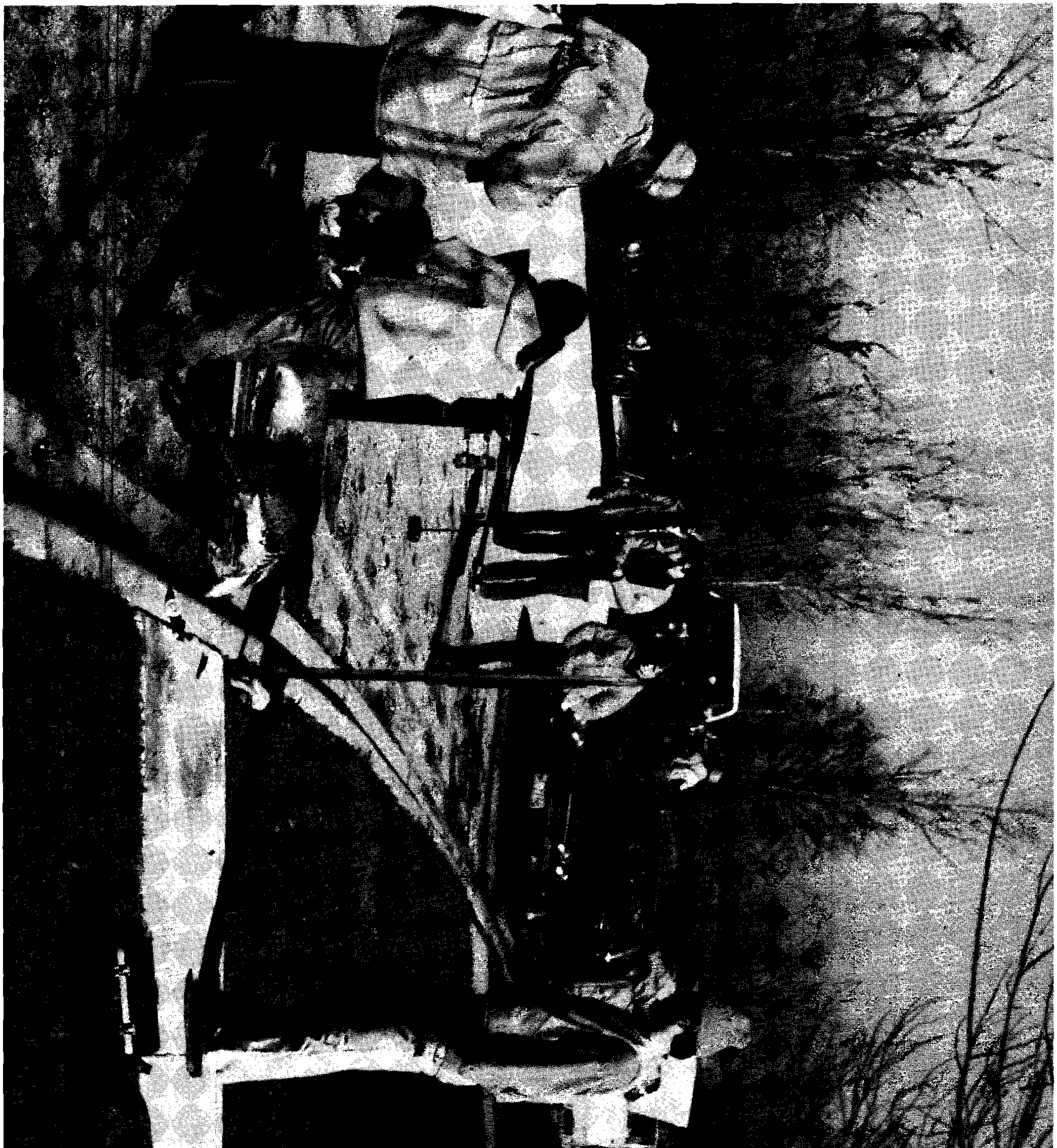

Wisconsin DNR

THE LEGAL DEER KILL - HOW IT'S MEASURED

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Abstract: The size of the legal deer harvest in a state or province is not only of great interest to sportsmen, but it also provides necessary information for wildlife managers. Measuring the legal harvest is much easier to do than estimating values for other mortality factors. Basically only 3 techniques are used by midwestern states and provinces: compulsory deer registration, compulsory hunter report cards, and mail out-mail back questionnaires. Some states use 2 systems. Registration provides the most detailed, the most timely, and the most acceptable harvest figures to sportsmen. Mail surveys can produce much additional information such as hunter success, hunting pressure, origin-destination, and opinions on regulations. Report cards combine advantages and disadvantages of both of these systems. Mail surveys are generally less expensive than registering deer or using report cards; however, care must be taken to insure precision and accuracy in the estimates. Deer registration generally underestimates the true legal harvest since accuracy depends entirely on the degree of compliance. Report cards are more difficult to assess, depending on return rates and how estimates are produced. All methods can be made to perform satisfactorily.

INTRODUCTION

The white-tailed deer *(Odocoileus virginianus)* is the most heavily hunted big game species in the Midwest. In Michigan it has been the most hunted game species since 1963, with some 760,000 individual deer hunters afield in 1978 with gun and bow. Many Michiganians believe that the opening of the firearm deer season is the second most significant day of the year next to Christmas. Many northern schools close, hundreds of thousands of people begin their vacations, and factories and offices report high absenteeism. In 1968, over one-quarter of the resident males in Michigan between the ages of 25 and 44 hunted deer (Ryel et al. 1970). The deer season is news. If the Michigan Department of Natural Resources does not provide deer harvest information, the news media will fabricate it.

The legal harvest is potentially the most accurate, precise and easily obtainable life history component for deer. Estimates of other mortality factors such as predation, malnutrition, disease, crippling loss, or poaching are not likely to be anywhere near as precise or accurate. Obtaining good population estimates of most wild animal species, including deer, is notoriously difficult. Still, great care must be taken in obtaining deer harvest information because all sorts of errors can be present which will produce misleading results.

Over the years in the United States and Canada, a number of approaches have been employed to obtain deer harvest data – some good and some not so good. Trial and error has weeded out most of these until today only a few are in use. Bennett et al. (1966) have chronicled the various systems used in Michigan.

In all of these systems the primary objective is to estimate the total legal harvest; however, much related information is also desirable and useful in developing deer management strategies. For example:

(1) Determine the sex and age of the deer killed.
(2) Determine the distribution of the harvest over time and by geographic areas.
(3) Determine the number of hunters, their distribution, hunting effort, and relative success over time and by geographic areas.
(4) Determine the harvest by traditional firearms as well as by primitive weapons such as long bow, cross bow, and muzzle loaders.
(5) Obtain information on hunter attitudes concerning management practices and regulations.
(6) Obtain economic data on deer hunting.
(7) Obtain demographic information on hunters.

The information given in this paper is based in large part on the experiences of workers in Michigan where deer harvest estimates have been calculated by various methods since 1880. In addition, information was supplied by the other 13 states and provinces making up the Midwest Fish and Wildlife Conference. Finally, much material was also obtained from literature searches.

In the Midwest, 3 main deer harvest estimate methods are currently in use: registration, mail out-mail back surveys, and hunter report cards. These will be described and evaluated in some detail, along with brief presentations of certain other methods.

Ryel, Lawrence A. 1980. The legal deer kill – how it's measured. Pages 37-45 *in* Ruth L. Hine and Susan Nehls, eds. White-tailed deer population management in the north central states. Proc. 1979 Symp. North Cent. Sect. Wildl. Soc. 116 pp.

NOTES ON SAMPLING

Before discoursing on harvest surveys, some general comments on sampling seem in order. Kill surveys are really sampling problems and anyone involved in producing deer harvest estimates by whatever means should be at least somewhat knowledgable about proper sampling methods. Fortunately there are several excellent sampling texts which can be consulted: for example, Cochran (1977), Kish (1965), and Jessen (1978).

The population is the central concept in sampling. It can be defined as a set of elements having at least one characteristic in common. A sample, then, is some subset of a population. Ideally, a sample will be a representative portion which will allow an accurate characterization of the entire population for the items of interest. One cannot say whether a given sample is "good" or "bad" without knowing population values. Samples can only be rated on the basis of the selection process used and on long-term probabilities. That is, representativeness is inherent in the sampling plan and not necessarily in the sample at hand.

In most "real world" situations, one cannot usually sample the entire population of interest, or target population, for one reason or another. Instead we settle for something less, called the sampled population, which can be covered by something called a sampling frame. A frame is a device, real or implied, which allows us to take hold of the population piece by piece. At times one must work with a very incomplete frame. In a sample survey one can really only estimate the characteristics of that part of the target population covered by the frame.

Probability sampling is the highest ranked form of sampling. A probability sample is one selected by a chance mechanism where the chance of selection for each population element entering the sample is known. In effect this means that population elements are selected through the use of random numbers (Rand Corporation 1955) at one or more steps of the selection process. Whatever the details of the sampling method used, the essential feature is randomness which insures the absence of subjectiveness in the selection process. Virtually all statistical methods presuppose randomly selected samples.

For various reasons, probability sampling is not employed in all deer harvest surveys. In many cases there is no way of assigning a probability of selection to any population element. Statistics such as means and variances can be calculated for nonprobability samples, but these can really apply only to the sample itself. There is no theoretical basis for arguing from such a sample to some population. The sort of nonprobability samples dealt with in deer harvest surveys are commonly called "handy" samples.

Estimates derived from surveys can be evaluated in 2 ways, accuracy and precision. To the layman these 2 terms are synonymous. To the statistician they are quite different. Precision is a measure of the inherent variability of the data collected during a survey and can be expressed in terms of range, standard deviation, variance or confidence intervals. Accuracy refers to the closeness of the estimate to the true population value. Precision can be calculated from the results of a survey, while accuracy can be determined only in rare instances where the true population value is known. Precision and accuracy are not necessarily related. For example, a subjective sampling procedure may produce an estimate with high precision but low accuracy.

Bias is another term which has several meanings. In the context of sample surveys, it commonly means systematic distortions due to subjectiveness or nonrandomness in sampling procedures.

DEER HARVEST ESTIMATING SYSTEMS

Registration

Deer registration, as used here, means a procedure whereby hunters who kill a deer must present it to an authorized registration or deer checking station. They may be required to answer certain questions concerning where and when the animal was taken, and perhaps have a confirming seal attached to the deer. In some states and provinces, registration stations are operated exclusively by the natural resource agency's personnel. In others, private business establishments such as gasoline service stations, motels, restaurants, sporting goods stores, and grocery stores are authorized to register deer for a fee.

In a nationwide survey, Guynn et al. (1977) reported that some 25 states used a statewide compulsory deer registration system in the 1976-77 hunting seasons, although in 4 of these the hunter had to stop only if he encountered a checking station on his travel route. Some states registered deer only on certain management areas. In the Midwest, 6 states and provinces now use compulsory registration: Illinois, Minnesota, Missouri, Nebraska, Ohio, and Wisconsin.

In a deer registration system, the target population is made up of all deer legally killed by hunters. The sampling frame of necessity consists of the successful hunters. In theory, a 100% sample is used. The accuracy of a deer registration system depends entirely on relative compliance, which may vary from area to area. Harvest figures will always be equal to, or less than, the true kill. No statistical basis exists for estimating the total harvest from an incomplete count, which amount to a nonprobability sample. Appraisal of the accuracy is necessarily subjective, largely based on prosecution reports and rumors of noncompliance. Very likely those choosing not to register their deer will be different in some respects from those who do. Accurate harvest estimates under this system depend on such things as aggressive law enforcement and judicial support, the backing of hunters and biologists, an adequate number and distribution of registration stations, and tradition. Without all of these ingredients in the recipe, the cake will likely be a failure. Almost certainly the early years of a registration system will produce serious underestimates of the harvest.

Michigan registered antlerless deer in 2 counties in its northern Lower Peninsula (Lake and Newaygo) during the 1956, 1957, and 1958 seasons. At the same time, mail surveys were also conducted of hunters who received permits to kill an antlerless deer. In 1956, 2,028 antlerless deer were registered while the mail survey estimate was 2,076. Following the season, conservation officers contacted 602 of the 2,463 apparently unsuccessful permit holders (not a random sample) and found 16 (2.7%) who admitted they failed to register an antlerless deer. Similarly, in 1957, 1,999 antlerless deer were registered, 2,016 were estimated by the mail survey, and officers queried 414 of the 2,055 apparently unsuccessful (not a random sample) and found 6 (1.4%) who did not register an antlerless deer (Hawn and Ryel 1969). In 1958, no postseason checks were conducted.

By and large, deer registration is well liked by wildlife managers in those states and provinces where it has been used for several years. Illinois, Missouri, and Wisconsin have all registered deer for over 20 years and Ohio has for 18 years. They all report high compliance and satisfaction with the system (Lynch and Carr 1974). Registration provides harvest information for small areas which is often difficult to obtain with mail surveys. The hunters and the public generally seem to accept the figures as valid, and registration records can be easily checked by the skeptical. Hand counts of kill data are available soon after the season. Final summaries of registration data, however, may require significant amounts of data processing compared to mail surveys. For example, in 1978, about 145,000 deer were estimated to have been harvested in Michigan's firearm season based on a sample of some 33,000 hunters (Ryel 1979*a*). Registration would have required over 4 times the data entry without yielding one iota of information about the 600,000 hunters who did not kill a deer that year.

Other phases of registration systems are also expensive. A large number of stations must be used, several in each county or management unit open to deer hunting. Wisconsin used 417 in 1978. Stations must be adequately staffed and should be open during some portion of the evening hours. It requires a great deal of preseason effort to line up enough registration stations in the proper places to provide adequate coverage of the state. It also requires a great deal of careful planning to insure that biologists are assigned to stations in the most efficient manner. If private businesses are included in the network, then contracts must be signed, liability coverage provided, and instructional programs conducted. Normally the businesses receive a small fee for registering each deer, except that there is generally a minimum payment. Records must be audited prior to issuance of checks.

Regardless of whether the stations are manned by private citizens or natural resource agency personnel, they must be supplied with signs, reporting forms, confirming seals, and maps. Stations require continual servicing during the season. Following the season, all records must be promptly retrieved.

Sex and age composition of the harvest must be based on the deer examined by competent biologists. Such data when recorded by lay workers are not reliable and their records are useful only as "body counts". Agencies will have little control over who registers deer at privately run stations. Some states, such as Michigan, can examine large numbers of hunter-killed deer by using a few checking stations (4 in Michigan) during peak periods of hunter traffic on major highways. With a registration system, an overall appraisal of the physical condition and composition of the harvest will require that biologists be sent to a large number of registration stations. Wisconsin regularly mans about 70 during the early part of their firearm deer season. On the other hand, if detailed information is desired for specific areas, then it is a simple matter to send biologists to registration stations in these localities.

The accuracy of kill locations will depend basically on the hunters' knowledge of local geography, although registrars may be able to help identify colloquial place names.

Successful hunters are a captive audience while registering deer. All sorts of collateral information can be gleaned from them: animal sightings, hours of hunting, number in party, kind of lodging used, land ownership, crippling loss, other hunters seen, kind of gun, number of shots fired, costs of hunting trips, miles driven, violations observed, type of vehicle, opinion on regulations, and so on.

But there are 2 serious problems with this approach. First of all, to be meaningful, personal interviews need to be carefully conducted by trained interviewers. With the large number of people involved in a registration system, there is little hope that this can be accomplished. Secondly, only successful hunters are seen. They do not constitute a probability sample of all hunters nor in all likelihood are they a representative sample. Successful hunters are not distributed uniformly but tend to be concentrated where the deer herd is largest. It would be unwise to expand such information to all hunters. Because of this, the midwestern states of Minnesota, Missouri, and Wisconsin also utilize mail surveys to provide information on relative hunter success, hunting pressure, and other information.

Finally, it is important to realize that in a period of oil shortages, registration forces many hunters to drive extra miles to register their deer since there are only a few stations per county. While this may not amount to a large distance for an individual hunter, in the aggregate it could amount to millions of miles if appreciable numbers of deer are killed. Rain and snow can also make deer registration an uncomfortable or even dangerous experience.

Mail out-Mail back Surveys

Mail out-mail back surveys, called mail

surveys hereafter, are used by about 26 states to estimate deer harvests (Guynn et al. 1977). In the Midwest, 7 states and provinces employ this method for gathering harvest data: Indiana, Iowa, Kansas, Manitoba, Michigan, North Dakota, and Ontario. In addition, Minnesota, Missouri, and Wisconsin use mail surveys to obtain supplemental hunting information.

Basically this method involves sending questionnaires to a sample of hunters and asking them questions about their hunting experiences in the recent season.

Mail surveys have several distinct advantages. When statistically valid sampling designs are used, the precision of the estimates can be estimated from the survey results themselves. Mail surveys are the most economical of the several methods and costs and precision can be easily controlled by manipulating sample size. Both successful and unsuccessful hunters can be contacted. Questions can be asked about success, hunting locations, days hunted, and weapons used, as well as information on economics, attitudes, and sex and age of the hunters themselves. The work is generally all carried out at a central location with much of the effort done by clerical personnel.

The target population is licensed deer hunters. The ideal sampling frame is a central file of copies of all licenses. Although even with a central license file the frame used may not exactly correspond to the entire population of licensed deer hunters. For example, in Michigan not all carbon copies of hunting licenses are available for sampling. Some license agents go bankrupt each year and their records are tied up in litigation. Some agents experience fires. Some license copies apparently become lost in transit, and some are returned too late to be included. Furthermore, Michigan and some other states sell various combination of sportsman's licenses which enable sportsmen to hunt or fish for several species. Hence, not all people purchasing one of these licenses are deer hunters.

Other frames that might be considered are those receiving special permits to harvest antlerless deer. Michigan regularly conducts a separate survey in each of its hunter's choice permit areas – some 113 in 1978 (Ryel 1979a). Here variable sampling rates are used to obtain the most precise information for a given overall sample size. Each area is in effect a stratum in a stratified sampling plan (Cochran 1977).

Variable sampling rates can also be employed. A more accurate assessment of the hunting effort and deer harvest for a particular county can be accomplished by increasing the sampling rate for the residents of those counties who do the bulk of the hunting there. Or one could study the hunting experiences of the hunters from Detroit by sampling licensees with certain ZIP codes.

Licenses can be sampled in 2 main ways: by a systematic sample with a random start or completely at random using random numbers. If the file is small or if all names and addresses are on the computer, a random selection is preferred. If a large file is sampled by hand, systematic sampling is the more practical approach. Two kinds of systematic samples can be used: a straight systematic sample of every nth name or randomly selected terminal license digits. Since there should be no correlation between license position or license number and hunting success, such systematic samples should approximate true random samples and can be treated as such for most analyses. An alternative is to use the technique of replicated or interpenetrating sampling which allows valid computations of means and variances from a series of systematic samples (Deming 1960).

The accuracy of harvest estimates derived from mail surveys depends on the magnitude of sampling error, response biases, and nonresponse biases (Hayne and Eberhardt 1954). The probable magnitude of chance sampling error (precision) can be estimated from the results of the sample itself and can be manipulated by sample size, assuming a random sample is used (Cochran 1977, Turner 1970). For a simple random sample, halving the confidence limits requires 4 times the sample size. In a management context, a sample is considered too small if its results are not precise enough to make appreciable contributions to decisions (Kish 1965). In practical situations, sample sizes are often determined by costs.

Response biases are caused by false reporting. This may involve only the kind of deer killed or whether or not a deer was killed at all. There is ample evidence that some hunters upgrade the kind of deer killed in their questionnaire response. Doe fawns become does, buck fawns become does or bucks, etc. The magnitude of this depends partly on the hunting traditions of the state or province. In a 1950's Michigan study, handy samples of deer were examined at locker plants, seal numbers were recorded, and later these hunters were sent a questionnaire. Compared to the deer actually observed, mail survey results in general indicated a small increase in the number of adult bucks reported, a relatively larger increase in adult does, and a large decrease in fawns, especially doe fawns. Most surprising, however, were a few that reported they did not kill a deer (Ryel 1960). MacDonald and Dillman (1968) reported similar results from a study in New Mexico.

In Michigan, there is a long, historical tradition for members of a party to help each other fill their tags, even though this is not strictly legal. Hence, we have modified our questionnaire in recent years to find out if a sampled hunter's tag has been placed on a deer rather than whether he or she killed a deer. In Michigan, data from deer checking stations are used to determine the composition of the deer killed by hunter's choice permittees. There is also a tendency for casual hunters, for instance some wives or youths, to have the husband or father fill out any questionnaire sent to them. The average person seems to have an uncomfortable feeling about not being able to provide something positive. Questionnaires and cover letters need to emphasize that the experience of the sampled person is what should be reported.

Finally, it is widely supposed that some hunters report killing a deer when in reality they do not. MacDonald and Dillman (1968) reported about 9% in their study did so. The difficulty here, however, is to contact a random sample of truly unsuccessful hunters whose kill tags were not placed on a deer without them being aware that such a list was being assembled. Similar criticisms can be leveled at locker plant or checking station studies which are certainly not random samples of the deer harvest.

It is important to conduct mail surveys as close to the end of the hunting season as possible. In South Carolina, Webb and Loadholt (1971) sent questionnaires to the same sample of archers 4-5 months apart and found both inflated kill and hunting effort estimates from the later survey. In a related study Johnston and Webb (1975) found that mail survey estimates of hunting effort and deer harvest on South Carolina game management areas were lower than those produced by a subsequent personal interview survey of a random sample of 6% of the respondents to the mail survey. The harvest estimate for the identical subsample of hunters was 23.3% higher for the interview.

Finally, since seemingly minor changes in the wording of questions may cause dramatic changes in response, it is important to pretest questionnaires. As in all professions, wildlife biologists have developed a unique jargon which is not necessarily understood by hunters.

Nonresponse bias refers to possible differential results by different classes of hunters. In a mail survey those responding to the original mailing tend to be more successful than those responding to reminder mailings (Eberhardt and Murray 1960). Hence, it is important to obtain a high response through the use of several reminders. In general, the lower the response rate, the higher the inflation of the estimates. Michigan currently uses an original and 4 reminder mailings to achieve return rates of about 90% of delivered questionnaires (Ryel 1979*a*). Delivered questionnaires are those believed to have been received and do not include those where the addressee moved without leaving a forwarding address, died after the season, gave a ficticious name and/or address, or wrote illegibly on the carbon copy of the license (phone directories will often help decipher some of these). Normally, a 2-week period between mailings seems about ideal based on the usual pattern of returns.

For a small annual survey of about 500 firearm deer hunters to obtain license purchase information, Michigan regularly achieves about a 98% response on delivered questionnaires through a combination of 4 reminder mailings followed by telephone calls and finally personal contacts (Ryel 1979*b*).

Questionnaires should be attractive, short, unambiguous in wording and easily filled out with the questions in a logical order. A cover letter is very important to both explain the reason for the survey and provide instructions for filling out the questionnaire. Filion (1974, 1978) has described a number of methods for increasing return rates on Canadian Wildlife Service surveys. Experiences in Michigan suggest that response rates are inversely related to time delays in sending questionnaires to the hunters. Ideally, forms should be mailed near the end of the hunting season; however, waiting for license agents to return carbon copies may mean a delay of 2 months before initial mailing.

Mitigating the effects of nonresponse bias can be done in a variety of ways. In Michigan, the approach is to obtain response rates near 90% and assume the remaining 10% have similar experiences. To use this same approach with low response rates seems quite risky. The effect of even relatively low nonresponse on confidence limits for the mean success can be quite serious (Cochran 1977). Substituting new individuals for nonrespondents is of little use and may make matters worse. It has the effect of replacing nonrespondents with other people who closely resemble those who have already responded (Kish 1965). Some states apply correction factors based on the results of years when special efforts are made to obtain high response rates. Correction factors can also be developed by contacting a high proportion of a random subsample of the nonrespondents through telephone or personal contact (Hansen and Hurwitz 1946).

Correction factors have also been developed from comparisons of mail survey estimates with checking station data for special management areas. This approach has a high potential for trouble. First of all, hunters using such areas are not a random sample of all hunters, nor are they necessarily representative of all hunters. Secondly, it is extremely difficult to obtain a 100% kill estimate for a given area unless there are limited access points and all vehicles are searched as they leave. Otherwise an underestimate will almost certainly occur. Quality control checks made at Michigan's Mackinac Bridge suggest that the accuracy of the deer count there varies with the length of the lineups to pay tolls, the individual booth operators, and the mood of returning hunters. Probably less than 85% of the true total is counted in most years. Finally, results from poorly conducted mail surveys are typically used for comparison, i.e., one having a very incomplete sampling frame, or a poor response rate, or both. As Deming (1960) stated: "Good agreement or poor agreement between the results of a sample and of a complete census taken at about the same time does not of itself establish or disprove the precision of the sample, nor the quality of the complete census."

Some workers seem to feel that an increased sample size by itself will somehow improve the quality of mail survey results. Deming (1960) spoke to this point very succinctly: "One cannot offset the hazard of nonprobability sampling by increasing the size of the sample." Rather than increasing initial sample sizes in order to obtain some stated number of returns, it is far better to spend extra money increasing the response rate of a smaller sample. Similarly, a valid sampling plan should be substituted for a poor one even if the former is more expensive and the sample size must be smaller.

Various mathematical approaches have been used to estimate true hunter success. For example, the relation between cumulative returns and cumulative success can be projected by regression techniques to estimate the 100% point. Others have fitted a second degree polynomial to these data and projected the tangent to this curve at the last point and to the total sample size (Legler and Hayne 1967). A very conservative approach is to assume that none of the nonrespondents killed a deer.

Besides introducing biases, the problem of nonresponse on mail surveys also affects the time when data are available. If an agency must make 4 or 5 mailings at 2-week intervals, then a minimum of 2 to 2½ months is spent in just obtaining returns. To this must be added the time preceding contacts for sample selection and the time following contacts required for analyses and report writing. When the start of the survey is delayed because lists of hunters are unavailable for sampling immediately after the season, harvest estimates may not be available until several months following the season.

A mail survey of deer licensees was first conducted by Michigan in 1925, but since only 50% responded to the single mailing, the workers at the time felt the survey wasn't accurate enough. Had they followed through with reminder mailings, Michigan could have had a 27-year head-start on their current system.

Hunter Report Cards

Hunter report cards are considered here to be questionnaires supplied to all hunters, usually at the time of license purchase, which are to be returned by mail at the end of the season. Some states require only successful deer hunters to report. Guynn et al. (1977) indicate 11 states used hunter report cards in 1976. In the Midwest, South Dakota and Illinois (bowhunters only) are currently using this method.

The basic advantages of hunter report cards are that the hunters receive them generally at the time of license purchase, thus saving postage and insuring receipt. In addition, the hunters are aware of the information which is desired prior to the season. Both the target population and associated sampling frame are all of the licensed hunters. In theory, memory bias should not be a problem since all hunters are aware at the outset of the season that they must supply their hunting results.

The chief disadvantages include the high costs involved with supplying all hunters with cards and, more importantly, the problems associated with incomplete returns. As with mail surveys, successful hunters are more apt to respond than unsuccessful, causing inflated estimates. The degree of inflation is inversely related to the response rate (Hayne and Eberhardt 1954). As with deer registration, accuracy depends on achieving near 100% compliance. Here the logical approach would be to use several reminder mailings and/or to treat nonrespondents as a separate stratum and subsample them. This approach must also be followed where only successfuls are asked to report, since there is no way of knowing who is successful.

Michigan used compulsory report cards, which were attached to all hunting licenses, from 1937 through 1954; however, the reporting regulation was never enforced. Returns declined from 66% in 1937 to 18% in 1951 (Bennett et al. 1972). Numerically, even the low returns tended to overwhelm the available staff and subsampling of returns was used in some years to produce harvest estimates. During this period, firearm deer license sales ranged from a low of 158,720 in 1937 to a high of 386,400 in 1951. Hence the 18% return in 1951 amounted to some 69,500 cards. Because of the need for labor saving, the old Michigan Conservation Department turned at an early date to punched cards and performed analyses with the forerunners of today's sophisticated electronic data processing hardware. Attempts to use a report card system today in Michigan with sales of over 820,000 deer licenses of various types (Ryel 1979a) would be a massive and expensive undertaking even in the computer age.

A compulsory report card system can be thought of as a hybrid between mail surveys and deer registration, but it lacks the major advantages of either system. The problem of obtaining the necessary high return rates is akin to that in mail surveys except on a much larger scale. The idea of obtaining data from all hunters, or all successful hunters, is not unlike examining all deer in a registration system.

Some states have attempted to adjust for incomplete returns in calculating deer harvest estimates by employing a Lincoln-Index-type estimator. The idea here being that in the population of hunter-killed deer, a sample would be "marked" *(m)* when deer were examined at roadside deer checking stations by recording seal numbers. The second sample would be the returns of hunter report cards *(n)* which contain $\bar{x}$ of the "marked" deer. Then an estimate of the total kill can be calculated according to Overton and Davis (1969) by:

$$\hat{N} = \frac{nm}{\bar{x}}$$

In practice, there are some serious problems with this system. The following discussion follows Ryel (1965):

(1) All tag numbers must be accurately recorded and properly matched against the mail sample. Mistakes would mostly cause $\bar{x}$ to be smaller than actual and cause an overestimate of the kill.

(2) The proportion of hunters who have their deer checked and also report by mail must be the same as the proportion of hunters who did not have their deer checked and reported by mail. In other words, the fact that a hunter has his deer examined at a biological checking station must not influence his decision whether or not to send in his voluntary report card by mail. Furthermore, this must be true at all geographic levels in order that estimates

will be valid for counties or groups of counties. If hunters are more likely to reply by mail after having their deer checked, the kill estimate is deflated; if less likely, the kill estimate is inflated. This has a high potential as a source of trouble. For instance, a good share of the hunters whose deer are being examined are likely to inquire if they should also send in their deer report. By answering, the examiner has influenced the hunter's decision.

In New York, comparisons between hunters whose deer were checked only once and those checked more than once (i.e. at a locker and a checking station), disclosed that a higher proportion of those undergoing multiple checks mailed in their reports (Hesselton 1964). This suggests that a higher proportion of contacted hunters would report compared with those not contacted at all. If true, this would result in a deflated kill estimate.

(3) The deer examined on roadside checking stations must be a random sample of the kill, and hunters who report killing a deer on their report cards must be a random sample of all hunters who shot a deer. This latter condition does not hold in Michigan since placement of deer checking stations depends on the fact that most deer are killed in northern Michigan and most hunters live in southern Michigan. Such an unbalanced sample would cause $\bar{x}$ to be small relative to n and would result in an inflated estimate.

Other Methods

Deer Traffic Survey. To provide a kill figure right after the season for the news media and the winter "hot-stove" league, Michigan developed the so-called deer "traffic survey" in 1952 (Hayne and Eberhardt 1956). Actually, traffic isn't surveyed at all. Rather, observations of deer going south on hunters' vehicles are used. These are conducted entirely separate from roadside deer checking stations. In Michigan most hunters live in the southern Lower Peninsula but hunt in the northern two-thirds of the state. Hence, counts are made at the Straits of Mackinac and across the middle of the Lower Peninsula on major north-south highways. At the Mackinac Bridge, ticket booth operators make a continuous tally for the entire season. At all other locations deer counts are made during samples of time periods. These counts are for 30 minutes and are distributed roughly proportioned to expected deer flow. Observations from these samples are first expanded to total southbound visible deer, then, using the proportion of visible deer among those examined at roadside checking stations, to an estimate of the total southbound deer. Multiple regression prediction equations, calculated from the relationship between adjusted deer observations and the mail survey harvest estimates for prior years, are used to predict what the mail survey estimate will be for the just completed season. Estimates are available about a day or two after the season and provide a total kill estimate which has been quite accurate in the past, averaging within 6.9% of the mail survey for the 25-year period 1954 to 1978. The kill is also apportioned into bucks and antlerless deer by region of the state using preliminary summaries of checking station data and a subjective appraisal by field wildlife biologists in the southern Lower Peninsula.

License Stub Survey. Hawn and Ryel (1969) reported on a system imposed on the Michigan Department of Natural Resources by the Michigan Legislature in 1967 wherein hunters purchasing a deer hunting license were queried about their hunting during the previous year, 1966. The advantages of this system were similar to those of the hunter report card, as were the disadvantages. In addition, there were some unique problems:

(1) Estimates were not obtainable until 15 months after the season.
(2) Not all hunters in 1967 hunted in 1966. Michigan has found that 75-80% of firearm licensees and 60% of bow and arrow licensees in a given year will purchase a license the following year (Ryel 1967).
(3) Hunters hunting 2 consecutive years were more successful than those that didn't (Ryel 1968), hence, expanding the results over the license sales for the previous year produced inflated harvest figures.
(4) License agents neglected to ask the required questions of many hunters and some hunters refused to answer the questions.

Michigan had also employed a similar system from 1932 to 1936 with the same poor results.

Telephone Surveys. Telephone surveys have been used to estimate game harvests, particularly in the Southeast, with some success (Stern et al. 1962). The chief advantage of telephone surveys is the ability to quickly contact a sample of people. However, the sampling frame is typically very incomplete. Not all people have telephones and for those who do, some numbers are unlisted or not up-to-date. Generally, it is not easy to trace someone who has moved. Michigan workers have used telephone surveys to reach chronic nonrespondents on certain mail surveys to deer hunters. With a nearly complete set of current Michigan phone directories, one can obtain phone numbers for about 70% of the deer hunters (Ryel 1971). Our feeling is that those with listed telephone numbers are probably different in some respects from those for whom we cannot obtain numbers; however, no real evaluation has been made.

Telephone company records of residential phone numbers provide a more complete and up-to-date sampling frame, including unlisted numbers, for the much smaller target population of hunters. Even so, hunters without telephones are not included in the frame at all and some phone numbers will include several hunters in the same household. In spite of these deficiencies, where no central license file exists and/or where there are large numbers of unlicensed hunters, telephone surveys provide virtually the only approach.

In Michigan a year-long telephone survey of recreation participation was carried out in 1976 with telephone interviews – some 17,781 in all (Kennedy 1977*a*, 1977*b*). Compared to the regular mail survey of 1976 firearm deer hunters, estimates of hunter-days from the telephone survey were 26.3% higher.

DISCUSSION

The ideal system for determining the deer harvest should produce accurate, meaningful, timely, and acceptable information on harvests, hunting and hunters at minimum costs. Unfortunately, no such system exists. Whichever methodology is employed will be a compromise in one or more respects. Regardless of the system (or systems) used, however, it should be carried out in a careful and thorough fashion. Too often data are collected in a manner not consistent with good statistical practices. Furthermore, it is easy for procedures to become routine and for inherent biases to creep in and become perpetuated. Workers should be aware of potential problems and take great pains to avoid them. Where possible, independent quality control checks should be built in.

In conclusion, I hesitate to make specific recommendations. The methods described in this paper can all be made to perform satisfactorily. The choice depends on many factors. The important thing is for an agency to adopt a harvest-estimating system with their eyes open – to be aware of the pluses and minuses. Caveat emptor!

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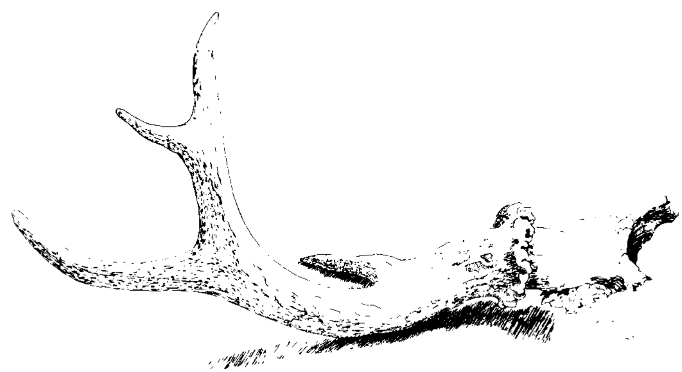

Wisconsin DNR

WINTER – THE GRIM REAPER

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Abstract: White-tailed deer are considered recent invaders in the northern portion of their range, and as such their physiological adaptation is incomplete. This is manifested by overwinter mortality of deer when winter severity exceeds the deer's physiological limits. Fawns require the greatest amount of nutrition through the winter, and are hence the first to feel the effects of undernourishment. Various means of assessing winter severity and effects on overwintering deer are reviewed.

HISTORICAL PERSPECTIVE

The energy crunch is nothing new for our whitetails. Ever since they've "moved north" there have been winters too severe for them to keep the fuel tank full. As a result of these severe winters, deer have died in large numbers.

Historical evidence places the major portion of the presettlement white-tailed deer populations of the upper Great Lakes region south of 45°N latitude (Bartlett 1938, 1950; Dahlberg and Guettinger 1956; and Erickson et al. 1961; Ontario Deer Technical Committee 1978) (Fig. 1). As whitetails are basically grazers (Cook and Hamilton 1942, Mooty 1976), the vegetational changes brought about by logging, fires, and settlement created a considerable amount of suitable habitat north of the 45°N latitude that was rapidly filled by deer from existing stock, as was the case in Michigan (Bartlett 1938, 1950), Wisconsin (Dahlberg and Guettinger 1956) and parts of Minnesota (Erickson et al. 1961, Petraborg and Burcalow 1965). The extreme northern portion of Minnesota and northwestern Ontario was occupied by moose and caribou and was devoid of deer until the late 1800's. The logging operations that created this habitat began in eastern Ontario in the 1830's and proceeded westward into Minnesota, ending here about 1920, thence proceeding into northwestern Ontario where deer reached their maximum northward extension at Sioux Lookout in the 1950's (Ontario Deer Technical Committee 1978).

Along with the new habitat came control of major deer predators, the timber wolf *(Canis lupus)*, cougar *(Felis concolor)*, and man *(Homo sapiens)*; and a conservation conscience that led to a very protectionist attitude towards deer (Flader 1974). Michigan

FIGURE 1. *Approximate northern limits of major white-tailed deer populations prior to logging and settlement (from Bartlett 1938, Dahlberg and Guettinger 1956, Erickson et al. 1961).*

Karns, Patrick D. 1980. Winter – the grim reaper. Pages 47-53 *in* Ruth L. Hine and Susan Nehls, eds. White-tailed deer population management in the north central states. Proc. 1979 Symp. North Cent. Wildl. Soc. 116 pp.

implemented the buck law for deer hunting in 1921, and "by 1936 starvation was rampant . . ." in the northern lower peninsula (Bartlett 1950:11). Similar losses were also occurring in Wisconsin, which had enacted the buck law in 1915 (Swift 1946:30). The buck law was not adopted by Minnesota, but alternate year seasons were adopted from 1922 to 1932, after which annual any-deer seasons have been the rule until 1970. As a result deer populations erupted (Leopold et al. 1947), as did the controversies over proper herd management. All of this took place north of the traditional deer range, an area where winter weather entered the arena as "the Grim Reaper".

Wisconsin, in response to the wintering problem, began an artificial feeding program in 1934, which lasted until 1956 (Haberland pers. comm.). This practice was avoided on a large scale by Michigan and Minnesota.

From the 1930's on, losses of deer to starvation were documented as a result of severe winters throughout the area, and biologists fought with almost everyone regarding deer population management. In severe winters the deer population occupied less than 10% of the total range in "deer yards". Population problems were more apparent in these yarding areas than on other areas of the range. It was during this period that the concept of carrying capacity for deer was developed as ". . . the number of deer a unit of range can support for a full year without serious damage to the plants that provide deer food and cover or to the deer themselves" (Dahlberg and Guettinger 1956:192). This became dogma in the field of wildlife management.

Early research efforts were focused on deer winter concentration areas, referred to as deer yards (i.e., Bartlett and Stephenson 1929), food habits, feeding trials, and carrying capacity of deer yards (Davenport 1939, Davenport et al. 1944, Davenport et al. 1953, Kabat et al. 1953, Dahlberg and Guettinger 1956:196). From the work of Davenport et al. (1953), it was determined that cedar deer yards, in the peak of production, could support 2-3 deer/acre/year, and less than 1 deer/acre/year after being browsed out. The carrying ability of unbrowsed cedar areas deteriorated almost as fast as the browsed areas through natural events of self-pruning and decreased plant reproduction. The carrying capacity of hardwood yards was determined to be less than 1 deer/acre/year (Davenport 1939).

A similar study in a "typical" Wisconsin deer yard indicated this type could withstand approximately 60 "deer browse days"/acre/year and remain productive. It is interesting to note there was recovery of plants in the pens 2 years after all deer were removed, but in unbrowsed control areas the number of stems decreased 73% (Dahlberg and Guettinger 1956:197).

All of this, and that reported by many other workers, dwelt on the theme that because there were overwinter losses, deer exceeded the carrying capacity of the range, as, by definition, there should be no overwinter losses if the herd was "in balance" with the range. This would imply then that no overwinter losses would occur, regardless of any extrinsic factors.

Studies by Aldous (1952), Krefting (1941), and Krefting et al. (1966) demonstrated that browsed plants such as willow, dogwood, and mountain maple actually produced more foods than unbrowsed stems, and were very tolerant to the annual removal by deer. Krefting concluded that what had been referred to in the past as "overbrowsing" should have been termed "heavy browsing" and had the beneficial effect of producing more browse over a longer period of time than unbrowsed plants. In a 25-year study of forest development in Minnesota, Krefting could find no effects of deer browsing (1975). Perhaps a better definition of carrying capacity would be that density at which deer can attain their full optimum biotic potential, realizing in some winters there will be mortality, and in some areas deer may control vegetation to their advantage.

Severe winters, in terms of deer survival, are more frequent in the recently occupied deer range north of the 45th parallel, and literally hundreds of thousands of deer have died as a result of these severe winters since the 1930's, and yet, throughout most of the area the deer population persists.

The exception to this persistence is in the most northerly expansion in northwestern Ontario, from Lake Nipigon to Sioux Lookout, where deer, as plentiful as they were in the 1950's and 1960's, now only occur as scattered individuals throughout the area. The same applies to northeastern Minnesota, and overall the combination of changing habitat, weather, wolves, and hunting has been responsible for such population declines (Mech and Karns 1977).

PHYSIOLOGICAL CONSIDERATIONS

A considerable amount of research effort has been expended over the past 3 decades in attempting to understand more about the nature of wintering deer. It wasn't until the pioneering work of Helenette Silver's group (Silver et al. 1969, 1971) that we began to grasp the adaptations the deer had to surviving the winter months. The basic fact that the physiological mechanisms of deer resulted in a reduced fasting metabolic rate during winter months, which in turn would allow them to exist on reduced rations, was a real breakthrough in our understanding of deer survival. Moen (1978) has added significantly to this basic framework in describing the seasonal nutrient requirements as a smooth flowing sine wave, reaching its nadir in winter and apex in summer. Expressed as multiples of basal metabolism:

$$BMR = 70W^{0.75}$$

where BMR = basal metabolic rate and W = weight of the deer in kilograms, these multiples range from 1.5 in the winter to 3.5 in summer. The multiples during winter months also increased with increasing snow depths.

Quite simply, in the northern environment, there are winters that extend beyond the deer's physiological limits, either in total length of the winter or snow depth, that result in mortality. This is not a function of deer population density, as length of winter and snow depths are independent of deer populations, but is a basic physiological property of white-tailed deer. The deer are unable, under certain conditions, to meet their nutrient needs, and die. Even on white cedar *(Thuja occidentalis),* the most "complete" deer food, Ullrey et al. (1970) concluded pregnant adult does would lose approximately 23% of their fall weight over a 90-day wintering period. This is close to the critical 30% overwinter weight loss, the point at which deer die. The length of winter has its effects by reducing the nutrients available to deer while their metabolic demands are still high in the fall and spring. Snow depth increases the nutrient expenditure for obtaining food. Moen (1968) demonstrated that deer can withstand the rigors of our northern winters with little or no overhead canopy if they maintain a high plane of nutrition. Again, we have an animal that, while it is adapted to seasonal changes in nutrient availability in its traditional range, is not completely adapted to life in the northern forests. Hence, environmental extremes have more of an effect on deer in the more northerly areas of their range.

WINTER SEVERITY ASSESSMENT

Several schemes have been devised to assess winter severity in terms of deer mortality. The simplest is merely the rule of thumb used in Minnesota that "46 cm or more of snow for 13 weeks" results in deer mortality. The 13 weeks means early snows that leave late, thus imposing a restriction on nutrient intake at times (late fall and early spring) when metabolic demands are not down to winter levels, and also increases the amount of energy required to obtain the foods available during the winter.

The Ontario snow rating system (Passmore 1953) uses basically the same criteria as the "46 cm for 13 weeks", but adds to it a factor for evaluating crust conditions by the ability of the snowpack to support a man on snowshoes. Crust on the snowpack can act in a positive manner by elevating deer to new food supplies, making travel beyond yard limits possible, and decreasing the amount of energy required for travel (Moen and Evans 1971, Moen 1978). A crust can also be a negative factor by enabling predators to move advantageously over the snowpack or sealing off herbaceous food supplies. Crust formation is variable across the area, depending on climatic factors. In the more eastern areas, and near the Great Lakes, crusts may form at almost anytime during the winter. In Minnesota and northwestern Ontario, the snowpack usually stays loose and fluffy all winter, with crust formation usually limited to late winter and early spring. When crusts form in late winter in the more northerly areas, they have resulted in overkill by timber wolves (Mech et al. 1971) and provide an advantage for coyotes, bobcats, and domestic dogs in preying on deer.

Kohn (1978), working in Wisconsin, has developed an index to winter severity using Climatological Records. The number of days with 46 cm or more of snow is added to the number of days the minimum temperature goes below −18 C. The resulting index correlates well with dead deer found on intensive dead deer searches in northern Wisconsin.

Verme (1968), working in Michigan, developed a rating scheme for winters taking into account snow depth, snow support, and the cooling power of the environment. The cumulative index for the winter is taken as an index of winter severity as it relates to deer and fetal development (Verme 1977). From the Winter Severity Index, under Michigan conditions, Verme states that weather in December and April is the determinant of overwinter and newborn fawn survival, respectively. This accounts for how long the deer are on a winter diet (does it meet or exceed their physiological limits?), and the increased nutrient demands placed on pregnant does in the last trimester of pregnancy, beginning in mid-March. No attempt has been made under Michigan conditions to relate the Winter Severity Index of Verme to total overwinter mortality (Vogt pers. comm.).

EFFECTS OF WINTER ON DEER

Minnesota has employed Verme's Index since 1967. Despite the fact that it is only a crude approximation of winter severity (Moen 1978), an analysis of the data has revealed significant correlation between the Index and the dead deer found on spring deer pellet count courses conducted since 1973 ($r = 0.98$, $N = 7$ years) and with the rate of femur fat depletion in adult does and fawns.

Although there is a good correlation between dead deer and the Winter Severity Index, we have been unable to arrive at a satisfactory means of going from dead deer found to total overwinter losses. For 4 years the fat loss in the femur shows strong correlations with the total Winter Severity Index for fawns ($r = -0.83$) and adult does ($r = -0.94$) (Fig. 2). Data for bucks are too limited for similar analysis. Although these relationships are apparent, it is not presently possible to extrapolate them to survival, but they are another index of winter severity. Based on findings in dead deer, 30% fat in the bone marrow has been described as the starvation level. No one has performed serial marrow biopsies to see if surviving deer reach a similar plane and recover.

Stepwise multiple regression between percent of femur fat loss in fawns and monthly Winter Severity Index values revealed that February and March were the critical months. The March Index was critical to fat depletion in does. As the onset of fat depletion in the femur is rapid (Harris 1945), and represents loss of the last vestiges of stored fat, the weather preceding February in the case of fawns is what sets the stage for this depletion. Similarly for adult does, while condition of

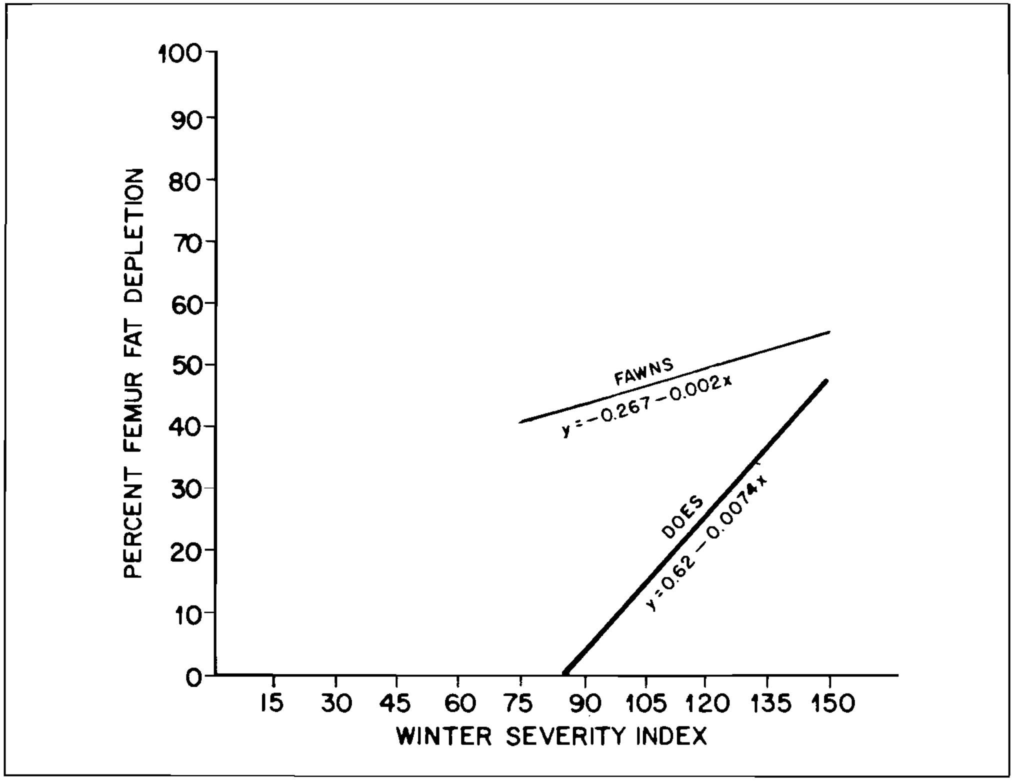

FIGURE 2. *Percent femur fat depletion in fawns and does as related to the total Winter Severity Index in northern Minnesota.*

the marrow may decline rapidly in March, depending on March weather, the winter up to that point will largely determine if fat stores are mobilized. Additional field measures of stress are needed to fully assess the environmental effects on deer survival. Stepwise multiple regression of monthly Winter Severity Index values to fetus development indicated March as having the most significance.

Thus, in accord with the physiological demands of deer, months when the metabolic rate is above the mid-winter nadir have the most bearing on fat depletion in does and fetal development. For fawns, which continue tissue growth throughout the winter (Thompson et al. 1973), the critical time in determining their survival begins in February.

ESTIMATING OVERWINTER DEER LOSSES

Most large-scale dead deer searches generally conclude that insufficient numbers of deer were found to arrive at any sex and age distribution of the overwinter losses. Despite these limitations of data, it has been almost universal experience of the deer managers that losses are largely apparent in the fawns, those deer entering their first winter. Bartlett (1950) reported 90% of the overwinter losses to be fawns in Michigan, whereas Swift (1946) reported 76% in Wisconsin. Fawns comprise about 85% of the deer found dead by wildlife managers as a result of winter weather in recent years. This disproportionate loss of fawns has its explanation, at least in part, in the fact that they have physiological demands imposed on them for continued growth during the winter months (Thompson et al. 1973).

As overwinter losses are primarily restricted to young of the year in the population, the principal effect is a reduction in the next year's sport harvest, as a proportion of the yearlings which make up a large share of the harvest, particularly in bucks-only hunting situations, are absent. Prior to 1973, Minnesota seasons were for deer of either sex and any age, and as a result approximately 1/3 of the deer harvested were fawns. Thus, larger-scale overwinter losses were averted because a large share of this cohort had already been removed by hunters.

Estimating the overwinter losses is a herculean task. Large-scale dead deer searches, as described by Whitlock and Eberhardt (1956) have been applied in Michigan following severe winters (e.g., Burgoyne and Moss 1978, Ryel 1959 and others) and in Wisconsin (e.g., Thompson 1979). The searches require a large amount of manpower and generally lack in the precision of their estimate. The winter of 1978-79 was described as "the worst winter east of the rockies". Overwinter losses estimated for Michigan's lower peninsula were approximately 83,000 deer (Burgoyne and Moss 1978) and were estimated as 30,000 ± 20,000 in the northern area of Wisconsin (Thompson 1979) based on statistically designed dead deer searches. Haberland (pers. comm.) placed Wisconsin's total overwinter losses at 100,000 animals.

Techniques currently used to estimate overwinter losses rely on a large number of people searching for dead deer in the spring. Techniques to reduce the amount of manpower, and improve the precision of the estimates are needed. Recent developments in the mathematical treatment of strip count data may allow their use for estimating the losses (Eberhardt 1968, 1978; Anderson et al. 1979, and Burnham et al. 1980).

Recent developments in treating strip count data should permit their use in estimating overwinter losses (Eberhardt 1978, Anderson et al. 1979). Although in Minnesota the number of dead deer found on spring pellet counts has a strong correlation with the Winter Severity Index, this number (from 3 to 25 deer/year) may not be sufficient for a good estimate. Anderson et al. (1979) stated that a minimum of 40 "objects" must be found before estimates from strip counts are valid. Perhaps with additional research, the strip count can become a valid technique for estimating overwinter losses.

DEER POPULATION MANAGEMENT

"Managing" the overwinter losses has provided the battleground between wildlife managers and the populace since the deer moved north. Winter feeding programs were strongly advocated by a large segment of the public to "save the deer". Wildlife managers denounced the program for many reasons; for example, winter feeding doesn't solve the problem of overpopulation, costs too much, can't get to all the deer, can't be a sustained effort, causes concentration of deer with an adverse effect on the remaining browse, promotes the likelihood of spreading parasites and disease, increases predation, provides indigestible artificial food, etc. All of these arguments were developed under a superabundance of deer, deer that could have been harvested before they got into this predicament but weren't, so that they starved and the high populations persisted. Artificial feeding may be, as one manager put it, the lowest form of deer management known. Yet, deer can be fed successfully if provided a complete diet. Feeding may be justified in some situations, such as trying to maintain or increase a low population in face of a severe winter, or to avert crop damage. It is a difficult decision to make, and each situation must be judged on its own merits.

A management scheme for cedar deer yards was outlined by Verme (1965), and for mixed conifer swamps by Krefting and Phillips (1970). Silvicultural practices to assure perpetration of cover in conjunction with food-producing areas is stressed by these investigators. Cutting practices that assure a continuum of cover and food are to be favored over a strict preservationist attitude towards a yarding area. Allowed to mature, a yarding area will die in its ability to winter deer.

While I have dwelt largely on what happens during the winter months, the rest of the year cannot be ignored. What of the nutrient content of the plants during the summer months, and those left for the winter? Einarsen (1946) was able to predict overwinter survival based on the crude protein content of key browse species in Washington. McCullough (1978:175) described the quality and quantity of the late summer fattening period, which is dependent upon precipitation, as critical for overwinter survival in Tule elk *(Cervus elaphus nannodes)* of California. Stewart et al. (1976) presented a model for overwinter losses of moose in Saskatchewan based on the growing season. In Minnesota, as elsewhere, we have demonstrated the seasonal cycle of nutrient availability, and are now into a long-term project to determine what the differences may be between years. Differences in crude protein are apparent over the past 4 years, and we expect other differences to manifest themselves as the analysis continues. Indeed, the whole aspect of overwinter mortality is a combination of factors that are present throughout the year. To this end, the Great Lakes Deer Group Committee stated that factors other than winter alone must be considered in determining carrying capacity (Krefting 1964).

SUMMARY

Physiological adaptation of white-tailed deer to the seasonal weather pattern is an annual metabolic rhythm that assures survival through most years. Occasional severe winters exceed these physiological limits, resulting in overwinter mortality. Fawns have higher metabolic demands during winter months, due to their continued demands for growth, therefore winter weather is a large determinant in their survival.

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Michigan DNR

FAWN MORTALITY ESTIMATES IN FARMLAND DEER RANGE

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Abstract: Reproduction and mortality are the essential components of deer population dynamics. Estimates of preseason mortality are important to deer harvest strategies. Fawn mortality rates are most critical because they typically are higher than those of older age classes. Age composition in the harvest and preseason doe:fawn ratios may provide indexes to production and mortality, but fail to identify temporal distribution, causes, or magnitude of fawn mortality. Mortality-sensing transmitters attached to fawns allow continuous observation and rapid retrieval of dead animals, thus are preferred over visual tagging systems. Fawn capture methods have included walk and horseback searches, use of gill nets, tracking with trained dogs, aerial surveillance with helicopter and fixed-wing aircraft, ground surveillance with spotting scope from fixed position, monitoring radio-equipped does at parturition, and landowner contacts. During the period 1977-79 in Missouri, 62 fawns averaging 8 days old were captured through landowner-cooperator contacts (34), walk searches (10), aerial surveillance with helicopter (7), doe observations (8), and tracking with trained dogs (3). Observed mortality rates in 1978 were 35.5% and 53.3% during 0-90 and 91-180 day postpartum periods, respectively. In 1979, mortality was 28.6% within 90 days postcapture. No specific mortality source was identified as most important in Missouri. White-tailed deer fawn mortality rates have been reported between 8 and 96% in other studies. High rates in these areas have usually been associated with a low nutritional plane of pregnant and lactating does and/or predation, neither of which should constitute a significant factor in farmland deer range. Application of principles of mortality assessment to farmland deer populations is discussed.

Porath, Wayne R. 1980. Fawn mortality estimates in farmland deer range. Pages 55-63 *in* Ruth L. Hine and Susan Nehls, eds. White-tailed deer population management in the north central states. Proc. 1979 Symp. North Cent. Sect. Wildl. Soc. 116 pp.

INTRODUCTION

Minimum information needed to understand the dynamics of a population are production and mortality rates, rate of increase or decrease and number of animals within that population. Knowledge of these parameters is extremely elusive and wildlife biologists usually are forced to make gross estimates or educated guesses about them. The quality of estimates may be dictated as much by personnel and dollar availability, habitat and weather conditions as it is by logic.

The parameter being addressed in this paper is mortality between ages 0-6 months for quantifying recruitment into prehunt populations of white-tailed deer *(Odocoileus virginianus)*. Mortality patterns for most mammals, including ungulates, typically follow a "U"-shaped pattern (Caughley 1966). Mortality is highest in the youngest age class, declines rapidly, then increases in older age classes.

It is important to recognize how mortality patterns change in response to environmental fluctuations. The weakest link in the life history will be the first to be affected, either positively or negatively, by environmental change. Reducing mortality rates of the youngest age class may not be possible, but identification of causes and rates of mortality will at least facilitate more informed decisions on harvest management. This knowledge becomes increasingly important as biologists begin to use population modelling in their management programs. Age-specific mortality rates are important components in most models; and although knowledge of all age-specific rates is necessary, mortality rates for the age class comprising the "weakest link" have the greatest effect on simulations.

Obtaining reliable mortality estimates has been and continues to be one of the most difficult problems facing deer managers. Historically, data have been limited and have been derived largely from reproductive rates and harvest sex ratios (Eberhardt 1960). Biases such as variation among age classes in harvest vulnerability and inaccurate check station sampling may render such data invalid. Usually herd dynamics have been assessed and harvest recommendations made without identification of preseason fawn mortality (Lang and Wood 1976). Some assessment systems, however, require such data.

The nutritional plane of does during pregnancy has substantial effect on prenatal and early postnatal mortality rates. Does experimentally fed a high or moderate quality diet in winter plus a high quality spring ration produced large, healthy fawns, and early fawn mortality from nutritional deficiencies was only 7%. Early postnatal mortality increased to 90% when both winter and spring diets of does were of low quality (Verme 1962). Low levels of protein in the diet of penned, pregnant females had more effect on early postnatal mortality of fawns than on production of fawns in Missouri. Forty-two percent of fawns produced by females on a 7% protein diet died of malnutrition within a few days after birth, while none on a 13% protein control ration died (Murphy and Coats 1966). Weekly patterns of black-tailed deer *(O. hemionus columbianus)* fawn remains in coyote scats supported the hypothesis that early fawn loss is a function of inadequate nutrition of the pregnant doe (Salwasser 1974). Verme (1977) described a method of assessing the annual magnitude of natal mortality in white-tailed deer due to inadequate maternal nutrition. Based on birth weights predicted from indexes of road-killed pregnant does, early postnatal mortality varied from 10% following years with low winter severity indexes to 70% following winters with high severity indexes. Thus, winter and spring nutritional planes of pregnant females may have a pronounced effect on early postpartum mortality. This mortality factor must be considered in design of fawn mortality studies.

Three types of data have been used to assess fawn recruitment into prehunt populations – fall sex and age ratio counts, sex-age structure of the harvest, and fawn capture-radio tagging studies. Discussion of the applicability of each to farmland deer populations follows.

FALL SEX AND AGE RATIO COUNTS

Fall sex-age ratio counts have been used widely within the range of white-tailed deer. Typically the ratios have been based on spotlight counts, counts along established survey routes, or random daytime observations. There is no doubt that fawn:doe ratios decline through time and by fall are substantially lower than spring production estimates. Hall (1972) estimated mortality at Camp Wainwright, Alberta, by comparing spring fetus:doe counts to fall fawn:doe counts made via helicopters. Mortality estimates following a hard winter were 64% and a mild winter were 39%. Chronology of California mule deer *(O. hemionus californicus)* mortality was estimated by field observation of changes in sex and age composition, and by noting temporal pattern of fawn remains in coyote scats (Salwasser 1974, Salwasser et al. 1978). O'Pezio (1978) collared females in winter and recorded observations of marked females and their subsequent families to estimate mortality of fawns.

Fall fawn:doe ratios do not identify causes or indicate temporal distribution of fawn mortality, important considerations in understanding herd dynamics. Also, observability of fawns was significantly less than does during fall months in Virginia (Downing et al. 1977). December was the only month when observability was equal, but fawns had shed their spotted coats by then and ages were not discernible. Observed fall fawn:doe ratios, therefore, would be below the real values and would bias prehunt fawn mortality estimates.

Fall fawn:doe ratio counts are used to assess recruitment in several midwestern states. Daytime fawn:doe ratio counts were not significantly different from spotlight ratio counts in Wisconsin (McCaffery pers. comm. 1979) and were used to estimate an annual net production index, which is incorporated into the sex-age-kill method of herd assessment (Rusch 1978). Research is underway in South Dakota to evaluate 2 methods of fawn:doe ratio counts–random daylight counts and spotlight counts (Rice 1978). Random daylight counts appear to represent actual conditions and are preferred over spotlight counts. Random daytime ratio counts are also used in the fall in Nebraska, Michigan, Ohio, and Indiana (Table 1).

The reliability of fall fawn:doe ratio counts is a function of ability to correctly identify and classify animals, sufficient numbers of observations from a representative sample of the population, and differential observability of sex-age classes of deer. Correction factors for differential observability must be established for estimating net production through ratio counts.

HARVEST SEX-AGE STRUCTURE

Harvest sex and age data collected at checking stations and life tables derived from these data have commonly been used as descriptors of population phenomena. Special emphasis has concentrated on measurement of those parameters which identify the success or failure of a particular harvest strategy as a tool for population control.

Methods of estimating total populations from sex, age and kill data were described by Eberhardt (1960). These methods, or slight modifications of them, are currently used by biologists in several midwestern states to describe herd dynamics and formulate allowable harvest figures (Table 1). Fawn mortality is important to these methods only as it affects net production indexes, while adult buck populations, adult sex ratios, and fawn:doe ratios are the more critical parameters of the system (Creed et al. 1978). Lang and Wood (1976) indicated that equations based on harvest reports, sex ratios, attrition rates, and recruitment rates adequately described deer population dynamics in Pennsylvania. Weaknesses of this population estimation technique were described as underestimation of mortality rates, and failure to delineate specific causes of mortality.

The usual life table unfortunately lacks reproductive data and assumes births balance deaths and all rates are constant over the history of the population tabled (Eberhart 1969). More importantly, harvest sex and age data do not describe the magnitude, causes, or temporal distribution of prehunt fawn mortality. If knowledge of those parameters is necessary in a particular population analysis procedure, whether simulation is used or not, other methods must be used to obtain the information. While the importance of harvest sex and age data can-

TABLE 1. *Status of fawn mortality assessment in midwestern states.*

State and Source*	Need for Mortality Estimates	Techniques Currently Used	Prehunt Mortality Rate (%)	Causes of Mortality	Potentially Applicable Techniques
Illinois (F. Loomis)	Modelling	Harvest sex-age ratios	Unknown	Variety	Fawn capture - radio tracking
Indiana (J. Olson)	Modelling	Daytime fawn:doe ratio counts	Unknown	Variety	–
Iowa (L. Gladfelter)	Modelling	Harvest sex-age ratios	Unknown	Variety, proportions unknown	Fawn capture - radio tracking
Michigan (J. Vogt and R. Aho)	Modelling, regional life tables, antlerless quotas	Daytime fawn:doe ratio counts, track counts	20-30	Variety, proportions unknown	Field collection of lactating does, fawn capture, radio tracking
Minnesota (J. Ludwig)	Assess turn-over, population trends, antlerless quotas	Harvest sex-age ratios	10	Variety, proportions unknown	Sex-age-kill, fawn:doe ratio counts, fawn capture - radio tracking
Missouri (W. Porath)	Modelling	Harvest sex-age ratios, fawn capture - radio tracking	35	Variety	Fawn capture - radio tracking
Nebraska (K. Menzel)	Modelling, allowable harvest	Daytime fawn:doe ratio counts	Unknown	Variety, assume predation highest	Production indexes
Ohio (R. Stoll)	Modelling (planned)	Daytime fawn:doe ratio counts, harvest sex-age ratios	20	Variety	Fawn:doe ratio counts
South Dakota (L. Rice)	Calculate allowable harvest	Daytime fawn:doe ratio counts, harvest sex-age ratios	35	Variety, predation may be high	Fawn:doe ratio counts
Wisconsin (K. McCaffery and W. Creed)	None, use sex-age-kill	Daytime fawn:doe ratio counts, harvest sex-age ratios	Unknown	Early post-natal, winter stress on doe	Net production index as component of sex-age-kill

* Persons responding to questionnaire sent July 5, 1979. Responses on file at Missouri Department of Conservation, Columbia, MO 65201.

not be discounted, their applicability in quantifying prehunt fawn losses is limited.

FAWN CAPTURE-RADIO TAGGING

Radio telemetry may prove to be the best system for assessing fawn mortality in farmland deer populations. Causes, rates, and temporal distribution of mortality can be identified by continually monitoring instrumented fawns. Fawn capture-tagging studies only recently have been attempted on deer in the Midwest and elsewhere. There are several reasons for this, but primary causes are difficulties encountered in capturing an adequate sample of fawns and the absence of reliable tagging systems. Precision biotelemetry equipment with mortality-sensing components is now available and has been adapted for use on young ungulates (Cook et al. 1967, Long 1977, Masters 1978).

Fawn Capture Methods

Several methods have been employed to capture white-tailed and mule deer fawns (Table 2). Some considerations in selecting methodology include deer density, terrain, vegetative cover, availability of personnel, and land ownership. However, in any method it is important to consider abandonment-related mortality. Handling fawns may cause abandonment, especially if it occurs before parental bonds are established (White et al. 1972). Hesitant, but eventual, acceptance of radio-collared and ear-tagged mule deer newborn fawns has been reported (Goldberg and Haas 1978). Mortality related to capture and tagging can be minimized by following certain guidelines – allowing time for maternal bonds to develop (about 2 days postpartum), handling fawns as little as possible, wearing sterile gloves, and avoiding conspicuous markers.

One of the first capture techniques described was that by Downing and McGinnes (1969) who found that searching by vehicle followed by a noisy, fast-run ap-

TABLE 2. *Capture and marking techniques used in fawn mortality studies.*

State (Reference)	Deer Species	Capture Technique	Marking Technique
Virginia –Bradford Army Depot (McGinnes and Downing 1969)	w.t.*	Vehicle search followed by tracking with trained dogs and fast, noisy chase on foot	ear tag and streamer, tattoo
Texas –Welder Wildlife Refuge (Cook et al. 1971)	w.t.	Same as Virginia	Radio
Texas –Lavaca and Gonzales cos. (Carroll and Brown 1977)	w.t.	Night search with spotlights and nets	Radio
Texas –eastern (Veteto and Hart 1976)	w.t.	Night – vehicles with spotlights	Radio
Oklahoma –Cookson Hills (Bolte et al. 1970, Logan 1972)	w.t.	Walk and horseback searches with throw net and ½-mile gill net	Radio
Oklahoma –Wichita Mts. (Garner et al. 1976, Bartush 1978)	w.t.	Ground surveillance with spotting scope from fixed position, night search with spotlight, and aerial surveillance with helicopter followed by fast, noisy chase on foot	Radio and ear streamer
New York –Seneca Army Depot (O'Pezio 1978)	w.t.	Tranquilize	Observation of family groups, radio
Arkansas –Sylamore Forest enclosure (Cartwright and Rogers 1977)	w.t.	Walk search; 100+ persons	Radio
New Jersey –west central (Lund 1975)	w.t.	Walk search with 2-4 man teams, throw net and recording of fawn bleating	Ear tag and streamer
Missouri –east central (Bryan 1980)	w.t.	Walk search, aerial surveillance with helicopter, landowner-cooperator contacts, and tracking with trained dogs	Radio
Oregon –Steens Mt. (Trainer 1975)	mule**	Ground surveillance with spotting scope from fixed position, and tracking with trained dogs	Radio
Colorado –north central (Anderson 1975)	mule	Ground surveillance with spotting scope from fixed position	Radio
Montana –Missouri River Breaks (Dood 1978)	mule	Ground surveillance with spotting scope from fixed position, and aerial surveillance with fixed-wing aircraft	Radio, ear streamer

* White-tailed deer.
** Mule deer.

proach to observed fawns was successful in pastureland with occasional wooded areas. They suggested concentrating the search for a single doe, not leaving the vehicle until the fawn is sighted, and using a noisy, fast approach to encourage the fawn to drop.

Night searches aided by spotlights and dip nets have been used in southern (Carroll and Brown 1977) and eastern Texas (Veteto and Hart 1976). Sites in southern Texas were gently rolling coastal prairies with timber adjacent to major creeks and gently sloping upland with scattered trees and wooded bottomlands. Eastern Texas habitat was primarily post-oak *(Quercus stellata)* savanna.

Understanding and concentrating on the behavior of the doe can facilitate capture of hidden young fawns (White et al. 1972). Observation platforms were used to study mannerisms of the doe to alert observers to possible locations of fawns. The most helpful cues of the doe to locate fawns were long solitary walk, close approach to the fawn, searching, nursing, watching, and aggression. This observation technique has been used successfully in Colorado (Anderson 1975), Oklahoma (Garner et al. 1976, Bartush 1978), Oregon (Trainer 1975), Missouri (Bryan 1980), and Montana (Dood 1978).

Searches on foot or horseback have been used by several investigators. Phenomonal success with this technique was reported by Lund (1975) in New Jersey. During a 5-year period, 496 fawns were captured by 2-4 man teams walking hay meadows. Density estimates were not presented, but either-sex harvest was 4.74 per km^2. Capture success increased each year and was 3.1 man-hours per captured fawn during the final year of the study. A recorded bleating of a fawn was sometimes played before searching a field in an attempt to trick does into giving away the locations of their fawns. Occasionally, a doe would emerge from cover and walk toward its hidden young. Lund (1975) suggested further experimentation with high quality recording and amplifying equipment.

Others who have used walk searches include Bolte et al. (1970) and Logan (1972), both on Cookson Hills Wildlife Refuge in Oklahoma. Horseback riders and persons afoot directed fawns into a 0.8 km long, 1.2 m high gill net. Walk searches using up to 15 persons were used during the period, 1977-79, to capture 10 of 62 fawns marked on a 131-km² study area in Missouri (Bryan 1980). Effort required for this method was high (34-176 hours/capture). Small crews of 2-4 persons have been most effective. Deer densities should be very high for walk searches to be effective in farmland deer range.

Aerial search and surveillance with air-ground communications have been successfully used to locate and capture fawns in Oklahoma (Bartush 1978), Montana (Dood 1978), and Missouri (Bryan 1980). Both fixed-wing aircraft and helicopters have been used. Helicopters are more versatile, allow for continuous surveillance, and can be used to guide running fawns toward strategically placed ground personnel. Fawns up to 2 weeks of age typically occupy grass or hay fields and field border cover types in farmland range and are visible from an altitude of 25-75 m. It is important to note that some negative reaction by private landowners occurred in Missouri because of their feelings about cost (too expensive) and worry of frightening livestock or flattening hay or cereal grain with downdraft. All landowners in an area should be contacted prior to helicopter usage.

Cooperating landowners were extremely helpful in locating and capturing fawns in Missouri. All land within the study area was in private ownership, and approximately 50% was comprised of agricultural crops, with hay being a primary component. Cooperating landowners were provided nylon laundry bags and were asked to capture fawns, place the fawn in a bag, lay the bag in a shady place and contact study personnel. Of 62 fawns averaging 8 days old captured between 1977-79, 34 (55%) were caught as a direct result of cooperating landowners. Walking crews captured 10 (16%), helicopter surveillance resulted in 7 (11%) captures, 8 (13%) by observing postpartum does, and 3 (5%) were captured with the aid of a trained labrador retriever (Bryan 1980).

Fawn Tagging Methods

Choice of appropriate tagging methods depends on research objectives. Visible markers would be preferred for observation of family groups to document changing fawn:doe ratios. Ear tags, ear streamers, ear streamers combined with tattoos, and leg streamers have been used as permanent, visual tagging systems (Queal and Hlavachick 1968, Downing and McGinnes 1969, Lund 1975, Bartush 1978, Dood 1978). These techniques have the disadvantage of not allowing continuous monitoring of marked animals, thus removing the possibility for determination of time and cause of mortality. Ear streamers have been shown to increase mortality by predation (White et al. 1972) possibly because of accentuated, more visible ear movements (Queal and Hlavachick 1968), although mortality was not increased due to attachment of ear streamers on fawns in Virginia (Downing and McGinnes 1969).

Use of radio telemetry to identify early mortality of white-tailed deer fawns on Welder Wildlife Refuge in southern Texas was described by Cook et al. (1967). Expandable collars containing mortality sensing, lithium-battery-powered transmitters were successfully used by Flock et al. (1975) on mule deer fawns. Telemetry has proved to be a very useful tool in identifying causes and rates of prehunting season fawn mortality because fawns can be continuously monitored. It has been employed for white-tailed deer in Texas (Cook et al. 1971, Veteto and Hart 1976, Carroll and Brown 1977), Oklahoma (Bolte et al. 1970, Logan 1972, Garner et al. 1976, Bartush 1978), Arkansas (Cartwright and Rogers 1977), and Missouri (Bryan 1980). Mule deer fawns have been radio-tagged in Oregon (Trainer 1975), Colorado (Anderson 1975, Anderson and Bowden 1975), and Montana (Dood 1978).

Several collar designs have been described for use on fawns. The "Oregon-Trainer" type (Trainer 1975) has been used extensively in western states and was used in Missouri. Transmitters and batteries were mounted on an oval-shaped collar with inside dimensions of 8.9 by 10.2 cm formed by preheating a 42.3 by 1.3 by 0.2 cm strip of Kydex plastic (Rohm and Haas, Philadelphia, Penn.*). Growth of fawn necks was accommodated by 1.3 cm strips of polyurethane foam glued to the inside of the collar. A strip of amber latex tubing (4.76 mm inside diameter and 2.38 mm wall thickness) was anchored near each end of the collar to fasten the ends together. Exposure to sunlight caused the tubing to rot allowing the collar to drop after about 9 months. Transmitters and batteries were encapsulated in dental acrylic or a urethane resin to provide protection from shock and moisture. The completed transmitter collar weighed 220 g.

This collar design with some modifications is now available commercially (Telonics, Mesa, Arizona*). The transmitter and lithium batteries are hermetically sealed in a metal housing. Operational life is 10 to 20 months depending on pulse rate chosen. Typical pulse rates are 60-80 pulses per minute (ppm) during the "alive period" and 120-160 ppm during the "dead period". The mortality sensor is a mercury switch which responds to movement. The sensor can be calibrated to switch to the "dead period" according to the user's specifications, usually 3-6 hours following cessation of movement. The transmitter collar weighs 220-30 g.

Radio-tracking of instrumented fawns can be accomplished with either portable or base-station receivers, the former preferred because of maneuverability. Available antenna systems include variable-element hand-held yagi, hand-held loop, vehicle-roof mounted, or fixed-site designs. Fawn bearings are determined by the strongest signal and/or

*Mention of trade names or manufacturer names does not constitute endorsement by the Missouri Department of Conservation.

the null-average methods. An excellent discussion of bias and sampling error involved in telemetric location fixing by triangulation has been presented by Springer (1979). Ability to obtain an accurate location is important in rapid retrieval of dead fawns.

A recent innovation in mortality research has been the use of heat-sensitive, vaginally implanted transmitters. (B. Lange, New Mexico Department of Game and Fish, Las Cruces, pers. comm. 1979). Radios are inserted in the vagina of pregnant females and retained in position by suturing the lip of the vulva. When parturition occurs, the transmitter is expelled with the fawn and the pulse frequency changes. Continuous monitoring of females must occur near parturition so newborn fawns can be found before they move from the birth site. Approximately 200 vaginal transmitters have been implanted in mule deer and elk in New Mexico. Results of this work will soon be published.

FAWN MORTALITY ESTIMATES

Published data have shown great variability in fawn mortality estimates, ranging from 8 to 96% (Table 3). Primary causes were predation by coyotes, starvation, disease, winter nutritional stress on pregnant females and blood loss and subsequent infection due to high infestation of ticks. Less important causes of mortality of instrumented fawns included dog or bobcat predation, highway kills, illegal and hunter kills and accidents caused by fences or other factors. During the summers of 1977 and 1978 in Missouri, 29 nontagged dead fawns were found by landowners and search crews, of which 20 were killed by hay mowing machines. This may be a significant mortality factor in areas where hay crops are an important component of agricultural operations.

Predation by coyotes has been the primary cause of white-tailed deer fawn deaths in several areas, including Texas, Oklahoma, and Arkansas (Table 3). This type of mortality typically occurred within 30 days postpartum. The predator/prey relationships between

TABLE 3. *Percentage estimates and primary causes of early mortality of deer fawns.*

Location (Reference)	Deer Species	Percent Mortality	Primary Causes of Mortality	Sample Size	Days of Observation
Virginia –Bradford Army Depot (McGinnes & Downing 1969)	w.t.*	8	–	258	60
Texas –Welder Wildl. Ref. (Cook et al. 1971)	w.t.	72	Coyote predation, starvation/disease	81	60
Texas –Lavaca and Gonzales cos. (Carroll and Brown 1977)	w.t.	47	Coyote predation, starvation/disease	120	60
Texas –eastern (Veteto and Hart 1976)	w.t.	37	Coyote predation, starvation/disease	65	90
Oklahoma –Cookson Hills Wildlife Refuge (1968-69) (Bolte et al. 1970)	w.t.	34	–	18	–
Oklahoma –Cookson Hills Wildlife Refuge (1970-72) (Logan 1972)	w.t.	18-64	Blood loss and infection from ticks	33	60
Oklahoma –Wichita Mts. (1974-75) (Garner et al. 1976)	w.t.	88	Coyote predation	35	365+
Oklahoma –Wichita Mts. (1976-77) (Bartush 1978)	w.t.	90	Coyote predation	48	49
New York –Seneca Army Depot (O'Pezio 1978)	w.t.	24	Early postnatal	46 **	90
Arkansas –Sylamore enclosure (Cartwright and Rogers 1977)	w.t.	100	Coyote predation	23	Until death
Missouri –east central (Bryan 1980)	w.t.	33	Variety	39	90
Missouri –penned deer (Murphy and Coats 1966)	w.t.	0-42	Nutrition stress on doe	12 [1]	Until death
Michigan –penned deer (Verme 1962)	w.t.	7-90	Winter/nutrition stress on doe	215	Until death
South Dakota (Rice 1978)	w.t.	35	Predation suspected	– [2]	– [2]
Oregon –Steens Mt. (Trainer 1975)	mule[3]	27	Coyote predation, starvation/disease	106	90
Colorado –north central (Anderson 1975)	mule	43	Unknown	23	127
Montana –Missouri River Breaks (Dood 1978)	mule	34	Coyote predation	32	90

*white-tailed deer.
**marked adult does.
[1] does.
[2] fall fawn:doe ratio counts.
[3] mule deer.

deer and coyotes are complex and not easily interpreted. Knowlton (1976) described the relationship of weather factors and deer/coyote interactions in western ranges. Following years of below average precipitation, conception of fawns was delayed, and parturition occurred midway between spring and summer fruiting periods. In the absence of fruit as a food source, coyotes actively searched for fawns which were likely to be weaker than in years of adequate rainfall. Conversely, when rainfall was abundant, a major portion of parturition occurred while coyotes were feeding on fruits, and fawns were healthier and more viable.

Nutritional stresses placed on females in northern portions of the Midwest during severe winters (Verme 1977) may result in mortality of malnourished fawns, and these losses may be accentuated by coyotes or other predators taking advantage of these weakened animals. This topic merits additional investigation for farmland deer, although it is unlikely that most farmland deer are often subjected to food shortages in winter or spring.

No particular cause of death was outstanding in Missouri. Of 32 fawns averaging 8 days of age at capture in 1978, mortality rates were 35.5 and 53.3% during 0-90 and 91-180 days postpartum, respectively. In 1979, mortality totaled 28.6% of 7 radio-equipped deer monitored 90 days postpartum (Bryan 1980).

Causes of death within 30 days postpartum were primarily starvation and bobcat predation; those after 30 days were exclusively man-related (highway, illegal, hunter, dog, and fence kills). Although man-related mortality has not been a primary source in other mortality studies, mortality has been highest during the first 30 days postpartum. At Welder Wildlife Refuge in southern Texas, 93% of the mortality, which was primarily coyote predation, occurred within 30 days (Cook et al. 1971). Garner et al. (1976) reported that 83% of the mortality occurred within 60 days postpartum in 1974-75 while Bartush (1978) reported 91% of the total mortality occurred within 30 days in 1976-77 for deer on a Wichita Mountains, Oklahoma study area. Losses of mule deer fawns were confined to about 45 days postpartum in Oregon (Trainer 1975). Since the majority of deaths typically occur early postpartum, it is important to capture and instrument fawns as soon as possible following development of maternal bonds.

It may be important to categorize causes of death as predation-excluded or predation-involved (Cook et al. 1971). White (1973) described remains of deer fawns killed by coyotes and Garner et al. (1976) provided a detailed description of criteria used to determine predator species in predator-involved mortalities. Necropsies of carcasses should be performed to aid in establishing cause of death, especially when disease, parasites or starvation are suspected. Salmonellosis (*Salmonella* sp.) was diagnosed as the cause of mortality of one fawn in Texas (Cook et al. 1971). Rectal swabs made at time of capture can be helpful in identifying the role of *Salmonella* or other bacteria in fawn mortality. Blood loss and infection from the feeding of lone star ticks (*Amblyomma americanum*) were associated with the deaths of 71% of instrumented fawns in eastern Oklahoma (Logan 1972).

DISCUSSION

Although fawn mortality research is in its infancy in the Midwest, sufficient work has been done elsewhere to suggest needs of farmland deer population management. The first and most important consideration is whether quantification of early fawn mortality is critical to understanding herd dynamics and whether such information is needed to develop harvest strategies. This information is of minor importance to some analysis systems, notably the sex-age-kill method. Energies would be better directed toward the weak links of these systems such as estimation of the proportion of the adult buck cohort not recovered through legal harvest and observed net production (McCaffery pers. comm. 1979).

Fall fawn:doe ratio counts when coupled with spring productivity data provide net production indexes and the magnitude of fawn losses. However, biases of observability among various sex-age groups must be overcome for accurate estimates. Also, it is impossible to determine causes or temporal distribution of mortalities with ratio counts. Legal harvest sex-age data have similar deficiencies.

Radio telemetry has provided a method for daily observation of young fawns and rapid detection of mortality. Lightweight, durable transmitters with mortality-sensing components and life expectancies of 1 year or more have been developed and are available commercially. Scanning receivers are available which enable simultaneous monitoring of many individuals.

Capture techniques which have potential in farmland areas include walk searches, aerial surveillance, ground surveillance with a spotting scope from a fixed position, and landowner contacts. Vaginally implanted transmitters for monitoring activities of does nearing parturition have not been used on white-tailed deer, but they have proved successful in mule deer and elk. Plans are underway for use of these devices in white-tailed deer in Missouri and Illinois (Loomis pers. comm. 1979).

Mortality estimates for fawns 1-90 days of age have been reported between 8 and 96%. High incidences of mortality have usually been caused by either early postnatal losses associated with winter nutritional stress on pregnant females in northern regions or coyote mortality in southern and western areas. A study is planned in Illinois to investigate the contribution of deer, especially fawns, to the overall diet of coyotes (Loomis pers. comm. 1979). A population study of bobcats is in progress in Missouri which may better define the role of this predator in deer mortality (Hamilton et al. 1979). Fritts and Sealander (1978) suggested that bobcat predation of fawns may be common in areas of high deer and bobcat densities. The complexity of predator/prey relationships as described by Knowlton (1976) indicates that subtle factors are involved and these factors are not easily quantified.

Wide variations in fawn mortality estimates have been reported within the range of white-tailed deer. Although preliminary work has been done in Missouri, studies should be done elsewhere within farmland deer range to identify probable regional differences in fawn mortality.

Reducing or eliminating major causes of mortality in young fawns would not be practical. However, identification of mortality rates caused by those factors will fill a significant gap in the knowledge of deer herd dynamics and will improve predictive capabilities of deer herd managers.

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ESTIMATING ILLEGAL KILL OF DEER

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Abstract: Methods presented for estimating in-season illegal deer kill involve: (1) extrapolating statistics from dead deer surveys during and/or following a hunting season, (2) making a simple count of the number of illegally killed deer discovered by enforcement officers, (3) determining an index to illegal deer kill based on the number of violation reports received by enforcement officers, and (4) using McCormick's compliance rate technique. The latter method assumes that total violations detected by wardens are related to the total number of hunters checked in the same way that total violations occurring are related to the total number of persons hunting. The only known technique for estimated closed-season illegal deer kill is a violation simulation technique. The rationale is that the total number of violations for a study period is related to the total detected violations in that time approximately the same way that violation simulations are related to total simulations reported by enforcement personnel. Two major drawbacks to the use of the violation simulation technique are presented. An untested procedure for estimating the number of individuals killing deer illegally during a specified period is presented.

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INTRODUCTION

Illegal kill of North American deer (*Odocoileus* spp.) is of vital interest to wildlife managers, deer hunters, and nonhunting observers of deer. Managers of the deer resource are charged with providing benefits to the American public via management of deer. Since many of the benefits derived from deer management accrue to hunters, maintaining a harvestable surplus of deer is normally a paramount objective of wildlife management agencies (subject to constraints such as big game crop damage, deer-vehicle accidents, disease outbreaks, etc.). Desired harvest levels for deer populations are established by estimating preseason deer populations and subtracting from these acceptable postseason populations. By knowing probable success rates for hunters, a fixed number of hunting licenses or permits may be issued (or, as is often the case, season lengths may be regulated). Illegally killed deer may result in the desired harvest being exceeded. If the likely number of illegally killed deer is overestimated in preseason computations of desired harvest, resource waste and agricultural damage may result. Thus, lack of good estimates of mortality from illegal causes may compromise scientific management of the deer resource.

Public hunting in America is based on the principle of equal opportunity. Many hunters do not harvest a deer in any 1 year, other hunters may legally harvest as many as 30 deer/year (e.g., in Alabama). Although success per hunter varies, each hunter has the same legal opportunity to harvest the same number of deer as other hunters. Kill of deer out of season decreases the opportunity of in-season hunters to harvest deer because of a reduced number of deer available, and violates the principle of equal opportunity. This results in hunter frustration, anger, and reduced quality of the overall hunting experience.

Out-of-season illegal kill of deer also irritates or disgusts nonhunting observers of deer through their knowledge that illegal kill is occurring, by reducing the number of deer available for observation, by driving deer away from easily observed areas near public roads, and, more importantly, by intruding on otherwise tranquil and safe experiences afield. In 1975, 2 districts of the Shenandoah National Park in Virginia were closed to after-dark travel for 2 weeks to combat deer poaching. The closure was extended to 3 weeks in 1976.

Assessing the magnitude of loss due to illegal deer kill is important for at least 3 reasons: (1) to allow deer managers to incorporate loss figures into deer harvest strategies; (2) to provide an indication of the magnitude of the deer poaching "problem" to wildlife law enforcement divisions (and subsequent measures of effectiveness of enforcement effort); and (3) to provide the potential for transfer of an illegal deer kill estimate methodology to illegal kill of other game animals.

However, many of the techniques for estimating illegal game kill require a sizable commitment of time and money to obtain unbiased statistics. Therefore, it is of primary concern prior to embarking on any research aimed at estimating illegal harvest to consider: (1) the degree to which the accuracy and precision of the illegal kill estimator is compatible with the population estimator; (2) the need to ascertain absolute or relative estimates of illegal kill; and (3) the potential for translation of research findings to management decisions.

From the standpoint of the deer manager, the first consideration is of importance. If the manager bases his estimate of total game population on information of low accuracy such as that obtained at public hearings, then it would be wasteful to attempt an intensive field study to try to obtain an accurate or precise estimate of illegal harvest.

The second consideration is of importance when contemplating estimation of illegal kill from the standpoint of law enforcement. Several of the more sophisticated approaches of estimating illegal kill have been employed by various state enforcement divisions once and never repeated. It could be asked why so much interest is expressed by enforcement officials in the absolute illegal kill since no one knows yet how to relate empirically the benefits of enforcement manpower to the costs of illegal kill. If it was known how many enforcement agents were required to effect a desired change in illegal kill, then an unbiased estimate of absolute illegal kill *would* be of value. However, the present state of knowledge regarding manpower requirements in wildlife law enforcement is so primitive that it would be wiser to learn more about *relative* rates of violations between regions and over time. This implies little need for unbiased absolute estimates of illegal kill and more need for consistent application, over time and between regions, of economical and less sophisticated indicators. Information thus obtained would be useful in enforcement decision making such as determining optimal distributions of a usually fixed supply of manpower.

Since the techniques of estimating illegal harvest have been developed in response to management needs, it can be assumed that the potential for use of the illegal kill estimate in management decisions is high. However, this does not negate the need for attention to the third consideration upon each planned application of an illegal kill estimator.

ESTIMATING IN-SEASON ILLEGAL DEER KILL

One method involves systematically searching a hunting area during and/or following a hunting season and counting the number of deer known to be killed illegally or thought to have been killed illegally. Hardin and Roseberry (1975) systematically searched 5,200 acres on Crab Orchard National Wildlife Refuge (Illinois) following the deer hunting season to assess unreported losses of deer. They examined various circumstances surrounding located dead deer and inferred intentional abandonment of deer (illegal) on the basis of these circumstances. Their estimates showed that at least 13 (20%) of the 64 carcasses located had been intentionally abandoned. One fawn had been hidden in a brush pile, 3 deer had been field-dressed, and 3 adult males had been decapitated and their carcasses left in the field. Hardin and Roseberry suggested that the remaining 6 deer had been intentionally abandoned because they had apparently sustained instantly fatal wounds.

The drawbacks accompanying this method of estimating illegal deer kill are probably sufficient to preclude its use as a standard estimation procedure. The estimate obtained is obviously an underestimate of actual loss because many deer will have been removed and failure to discover all carcasses is probable. Unless the illegality of the discovered carcasses is obvious (e.g., female in a bucks-only hunting season, decapitated carcass), much depends on the inference of the observer. Finally, and most importantly, time, manpower, and budgets are not sufficient to allow the method to be employed on a statewide basis.

Another method of estimating illegal deer kill also provides an underestimate of actual loss. This method involves simply counting the number of illegally killed deer discovered by enforcement officers. For example, Michigan conservation officers discovered 330 deer killed illegally during the bow season in Michigan in 1972 and 1,112 during the regular firearm season (Michigan Law Enforcement Division 1973).

The third method, developed by Kaminsky and Giles (1974), involved determining an index to illegal deer kill based on the number of violation reports received by enforcement officers. In a survey of all Virginia game wardens in the fall of 1969 the number of actual and casual complaints of spotlighting received by each warden was recorded, although some of the spotlighting reports were probably not related to deer poaching. Each of the 109 agents received an average of 3.94 actual spotlighting complaints per week from 1 October to 31 December. Based on these figures, the authors estimated that 5,153 spotlighting complaints occurred during this 12-week period. This period contained an average of 86.3% of all spotlighting arrests in the 3 years from 1968 to 1970 and the authors assumed that arrests were made in proportion to the total amount of illegal spotlighting activity occurring. During the remaining 40 weeks of the year, 13.7% of the total spotlighting arrests were made. By assuming that the same proportion of the 5,153 complaints would be reported during the 40-week period, the authors estimated that 5,895 spotlighting violations occurred during 1969. This figure was an overestimate to the degree that duplication in reports of spotlighting and reports of legitimate hunting (e.g., raccoon hunting) as spotlighting occurred. However, the figure is probably severely underinflated because only a portion of spotlighting violations were reported (based on similar studies). Kaminsky and Giles' procedure does not estimate the number of deer lost to illegal spotlighting activity nor does it accurately estimate the magnitude of spotlighting activity. However, under proper administration, the technique may be valuable as a relative index to the extent of illegal spotlighting activity.

A fourth method of estimating in-season illegal deer kill, developed by James McCormick of the California Wildlife Resources Agency (McCormick 1968, 1970), has received the widest acclaim and, with proper implementation, probably shows more promise than other methods developed. The procedure assumes the proportionality:

$$\frac{\text{total violations}}{\text{total hunters}} = \frac{\text{violations among those checked}}{\text{total hunters checked}}$$

Thus an estimate ($\wedge$) is possible:

$$\widehat{\text{total violations}} = \frac{(\text{total hunters})\ (\text{violations among those checked})}{\text{total hunters checked}}$$

Since the above formula assumes that each hunter hunts only one day of the year, "total hunters" is replaced by "total days of hunting" to adjust for the number of days spent in the field by all deer hunters:

$$\widehat{\text{total violations}} = \frac{(\text{total days of hunting})\ (\text{violations among those checked})}{\text{total hunters checked}}$$

An example of this compliance rate procedure is provided by the Michigan Law Enforcement Division (1974). During the 1971-72 deer hunting season, Michigan conservation officers inspected 77,450 deer hunters, made 2,438 arrests, and issued 3,765 warnings. Mail surveys for 1971 estimated there were 605,740 big game hunters in Michigan and they spent a total of 4,520,340 days hunting. The total number of deer law-related violations was estimated by:

$$\widehat{\text{total violations}} = \frac{(4{,}520{,}340)\ (2{,}438 + 3{,}765)}{77{,}450}$$

$$\widehat{\text{total violations}} = 362{,}034$$

Not all of these violations were related to illegal deer kill. Many were related to failure to post a camp registration permit. Separating those violations related solely to illegal deer kill would allow an uncontaminated estimate of illegal deer kill.

Cowles et al. (1979) listed 7 assumptions for compliance estimates based on the ratio of detected violations to total resource users sampled:

(1) Wildlife law enforcement agents contact resource users at random.
(2) Resource users contacted are representative of the entire user population being studied.
(3) Resource users commit a known average number of violations per day in the field.
(4) Contact of a specific user is not duplicated on the same day.
(5) All wildlife law enforcement agents are consistent in defining user behaviors.
(6) Wildlife law enforcement agent reports of inspections or violations are accurate or, if inaccurate, error does not change over time.
(7) If needed for computational purposes, the estimated days-afield per user is accurate.

Assumption number two is probably the most critical in attempts to estimate in-season deer violations by the compliance rate method. It seems intuitive that those persons who know they are in violation of a deer law or regulation will take steps to evade detection by law enforcement agents. If violators are more evasive than the average person who unknowingly commits a deer crime or a nonviolator, random inspection of hunters will result in the violation estimate being an underestimate of the actual number of violations occurring.

Cowles et al. (1979) suggested that the following procedures are minimal requirements for estimating compliance with wildlife laws from arrest data:

(1) Comprehensive definition of the problem with sufficient justification of why compliance should be estimated for a specific resource user group.
(2) Specific definition of the resource user group whose behavior is being studied. This would require a detailed analysis of the distribution of the population of users being sampled in both time and area.
(3) Specific definition of behaviors which will be considered violations and the role of officer discretion. If warnings are issued, they should be consistently included or excluded from compliance estimation.
(4) Design and implementation of sampling that will maintain randomness and representativeness.
(5) Attention to changes in administrative policy, technology, or legislative action which would affect reports of arrests and inspections.
(6) Concomitant studies of violators within each resource user type to establish an estimate of the mean number of violations expected per violator day. Self-report or spy-blind techniques may be applicable.
(7) Familiarity with, and critical appraisal of, surveys providing supporting data, such as hunter-use surveys. The analyst should be aware of major changes in such surveys and how they may affect his conclusions.

Use of the compliance rate procedure for estimating illegal deer kill is restricted to hunting seasons because the technique is based on random inspections of hunters. Inspections made during nonhunting seasons are not normally random and are instigated by probable cause (e.g., a person carrying a firearm in a hunting area).

ESTIMATING CLOSED-SEASON ILLEGAL DEER KILL

The only known technique for estimating closed-season illegal deer kill was developed by Vilkitis (1968) who studied closed-season big game poaching in Idaho and then retested his methods in Maine. First he defined: (1) violation as an offense against existing fish and game law; (2) arrest as an act of seizing or taking into custody when enough information is available to prosecute an alleged violator; (3) incident as a situation in which positive evidence of a violation is available, but information is insufficient for an arrest; and (4) violation simulation as an act performed by a specially authorized agent of the state to duplicate, in every way possible, a violation.

The violation simulation technique employed the rationale that the total number of violations *(I)* for a study period was related to the number of violations detected in that time (either arrests *Ma* or incidents *Mb*) approximately the same way that the total number of violation simulations performed *(C)* was related to the number of violation simulations detected and reported by enforcement personnel *(R)*. That is,

$$\frac{I}{Ma \text{ (or } Mb)} = \frac{C}{R}$$

and

$$\hat{I} = \frac{Ma\,(C)}{R} \quad \text{or} \quad \hat{I} = \frac{Mb\,(C)}{R}$$

An unbiased estimate is achieved by (Bailey 1951, Chapman 1951):

$$\hat{I} = \frac{(Ma+1)(C+1)}{(R+1)} - 1$$

The estimate is unbiased provided that the product of *Ma* times C is 3 or 4 times as large as the estimate *(I)* and guarantees that the rediscovery sample *(R)* includes at least one previously noted event. If *Ma* times C is not 3 or 4 times larger than *I*, the estimate is biased downward by a factor equal to the probability of getting no repeats or rediscoveries (Robson and Regier 1964:216):

$$100\, e^{\frac{-(Ma+1)(C+1)}{R}}$$

In Maine, Vilkitis (1971) simulated 81 closed-season kills from 27 November 1970 to 2 April 1971 using parts of 15 collected animals. Vilkitis dressed as a woods worker, drove a Scout, and used a .30-.30 rifle or 12-gauge shotgun. Shots were fired and evidence of blood, hair, hides, and drag trails was left. Simulations were performed only during daylight hours in areas where big game was known to be concentrated. Vilkitis performed simulations in all enforcement divisions in Maine in relative proportion to the mean number of convicted prosecutions from 1962 to 1965. In Idaho, Vilkitis simply displayed a legal collecting permit to the arresting officer. In Maine the lower court trial was waived and the superior court hearing postponed until after field research was to be completed. During the study period, 1 of the 81 closed-season simulations *(C)* was reported as an incident *(R)*. Based on the fact that enforcement agents reported 136 closed-season arrests and 249 incidents, illegal closed-season kill for the state of Maine for the study period was estimated as:

$$\hat{I} = \frac{(136+249+1)(81+1)}{(1+1)} - 1 = 15{,}825$$

This figure was underestimated by 13.95% since: (1) no arrests were made for simulated acts; (2) recording of incidents was a new procedure and some agents did not record all illegal kills; and (3) the product of *M* times C was not at least 3 times the estimate of *I*. The unbiased estimate of *I* was calculated as 15,825 + (0.1395 × 15,825) = 18,033. This estimate does not apply solely to deer because Vilkitis also collected moose *(Alces alces)* and black bear *(Ursus americanus)*. The low value of *R* suggests: (1) the error may be quite large, and (2) Poissonal or other distributions of events and detections.

Vilkitis also simulated 49 night-hunting violations from 15 September to 2 December 1970. None of the 49 simulations *(C)* resulted in an arrest (*R* = 0). Based on 403 night-hunting arrests made by agents during the period, night-hunting violations for the state of Maine during the hunting season were estimated to be:

$$\hat{I} = \frac{(403+1)(49+1)}{(0+1)} - 1 = 20{,}199$$

The unbiased estimate of *I* was 27,780. Field detection of violations was almost identical in both Idaho (1.1%) and Maine (1.2%). Thus, Vilkitis developed the following equation for estimating illegal kill:

$$\widehat{\text{Illegal kill}} = 122.9 \times \text{closed-season arrests}$$

The New Mexico Game and Fish Department replicated Vilkitis' closed-season violation simulation technique during 1975 (Pursley 1977). The simulator hired by the department was described as a "very good poacher." During the deer hunting season of 1975, the simulator raided dumps, trash cans, and abandoned camps to obtain deer carcasses. Nineteen animals were killed by the simulator but were apparently not counted as simulations. In contrast to Vilkitis' studies (Vilkitis 1968, Vilkitis and Giles 1970), the locations and times in which simulations were performed were selected randomly. Simulations (discards) were staged over a period of several months and their locations recorded. By checking incoming reports from agents, matches could be made. One of the 144 simulations was reported as an incident. Based on 236 violations reported by New

Mexico agents during the 50-week closed season in 1975, the following estimate was made:

$$\hat{N} = \frac{n\,M}{X}$$

$$\hat{N} = \frac{(144)\,(236)}{1}$$

$$\hat{N} = 33{,}984$$

where $\hat{N}$ = total estimated number of deer lost during closed season, n = total number of simulated violations, M = total number of reported violations, and X = total number of simulated violations reported. The 95% confidence limit was given as 2,447-662,314. The figure of 662,314 is almost 20 times the number of deer harvested annually in New Mexico. Due to a breakdown in officer reporting, Pursley discovered that one of the agents had discovered a simulation but had not reported it. Using this figure of 2 detections, a revised estimate was given as:

$$\hat{N} = \frac{(144)\,(236)}{2} = 16{,}992$$

with a 95% confidence limit of 1,303-47,934. The method of unbiased estimation was not employed.

There are 2 major drawbacks to the use of the violation simulation technique as a valid means of estimating closed-season illegal deer kill. First, in the 3 deer violation simulation studies reported previously, confidence limits on estimates of illegal kill were unacceptably large. Although Vilkitis did not report confidence limits in his studies, his estimates must have been similar to Pursley's confidence limits of 2,447-662,314 animals. The upper limit seems unrealistic based on biological carrying capacity and hunting activity required to harvest the animals. Clearly the distribution is not distributed normally. A low number of detections could be overcome by employing more than 1 simulator and/or by increasing the frequency of simulations performed by each simulator. The difference between 1 and 3 detections is the difference between a reasonable and an unreasonable estimate (i.e., 2,447-662,314 with 1 detection and 834-13,993 with 3 detections in Pursley's study).

The New Mexico researchers described the second drawback (Pursley 1977:1): "Our agent was armed with a substantial supply of dismembered deer. He was faced with the problem of deciding what the typical poacher does with his refuse. We do not know if 'typical' is casually tossing it by the side of the road or if it is carefully hiding the unwanted remains under a log. The only solution was to try to produce a spectrum, which would range from easy to detect, through possible, through improbable, in hopes of closely reproducing the real situation."

The researchers attempted to overcome this drawback, not knowing the habits of a "typical" poacher, by staging simulations randomly in space and time. However, there are indications from 2 previous studies that deer-related violations do not occur randomly in time or space.

Sawhill and Winkel (1974) interviewed 148 admitted illegal deer hunters from 9 counties of New Jersey. According to self reports of the violators, the majority of illegal deer activity occurred on any given day of the week between 12 and 2 a.m. during the winter months. Eighty-four percent of the time, the violation was committed by 2-3 men. (Note that past violation simulation studies employed 1 simulator.)

Kaminsky and Giles (1974) reported that spotlighting in Virginia was most frequent between 10 and 11 p.m. on Saturdays in November near cornfields surrounded by a mixture of oaks and pines. Spotlighting violations did not occur randomly.

Since no typology has been constructed for the "typical" deer poacher, violation simulation studies should probably be implemented by several people. To improve on the representativeness of the simulation, attempts should be made to select simulators with different characteristics. The simulated act (hide, trails, blood) is continuous over some time (several days), not instantaneous as the poaching act, therefore presenting additional problems in computing the probability of an agent encountering evidence.

Beattie et al. (1978) presented an untested procedure for estimating the number of individuals illegally killing deer during a specified period. The Lincoln-Petersen mark-recapture method with apprehended violators would employ the following formula:

$$\hat{N} = \frac{(A+1)(C+1)}{R+1} - 1$$

where $\hat{N}$ = estimated number of individuals violating, at least once, a deer-related wildlife statute during the period for which R is measured; A = number of individuals issued a verbal or written warning or citation for committing 1 or more violations of a deer-related statute during a specified period; C = number of individuals apprehended for violating a deer-related statute during the period for which measurement of C occurs; and R = number of A individuals apprehended during a period equal to but following the period for which A was measured. Roughly the same assumptions of the Lincoln-Petersen formula application to wild animal populations would have to be made (e.g., emigration from violator population equals immigration, A's keep violating and do not change behavior patterns). One advantage of this procedure is that previous arrest records could be employed to explore its suitability.

RELATIVE VERSUS ABSOLUTE ESTIMATES OF ILLEGAL DEER KILL

All of the techniques discussed for estimating illegal deer kill or number of deer-law violations produce absolute rather than relative measures. Absolute measures are useful for justifying increases in enforcement manpower levels to produce and document a reduction in absolute levels of violations. However, relative measures of the level of violation occurrence may be more desirable since manpower levels are normally static, and since information necessary to compute indexes of the level of violation activity will probably be less costly to acquire than absolute levels of violation activity. Indexes of the level of deer-law violations may be developed using: (1) a Harris Poll-type observation panel for wildlife violations, (2) a general probability survey of observed wildlife violations, (3) standardized violation reporting rates by agents and the public, or (4) self-reported violations by hunters (Beattie et al. 1978).

A Harris Poll-type observation panel would involve selecting randomly a sample of residents, probably in rural areas, and requesting them to supply periodic written reports of the deer-law violations they observe and/or hear about during the course of normal activities. Panel responses would provide an index to the change in frequency of deer-law violations over time.

A general probability survey would be similar to using a Harris Poll-type panel. A random sample of hunters and/or state residents would be contacted periodically and respondents requested to provide information about the type and frequency of violations they observed over a period of time.

Many state wildlife law enforcement divisions collect information enabling a comparison of violation reporting rates over time. Attempting to standardize report recording in conjunction with improved agency/public communication (increased reporting of violations) would allow such comparisons. Cowles et al. (1978) found that the nationwide probability of a citizen-observed violation being recorded by a state wildlife law enforcement division may be as low as 5.6%. This probability was computed under the assumption that most citizen reports of violations would be made by telephone. Since only 20 of 50 state wildlife law enforcement divisions were found to have standard record-keeping of citizen violation reports, and, since 7 of the 50 listed agent affiliations in telephone directories, the joint probability of a successful call and record of the call may be as low as 0.06.

The final example of a relative index would involve comparison of deer-law violations reported by hunters themselves. Previous self-reported violation studies of hunter illegal activities have been conducted by Chesness and Nelson (1964), Sawhill and Winkel (1974), and Smith and Roberts (1976). Research is needed to develop a validation methodology for self-reported violations by hunters.

CONCLUSIONS

McCormick's compliance rate procedure is probably the most economical and readily incorporated method currently available for estimating in-season game violations. It should be employed cautiously, and only after considering the assumptions presented by Cowles et al. (1979), and deciding whether the assumptions can reasonably be met and what adjustments for bias may be made. Improved systems of receiving and recording citizen reports of violations would avoid some of the bias problems encountered in McCormick's technique as well as providing both in-season and closed-season study of relative violation rates.

Vilkitis' violation simulation technique is the best method available for estimating absolute closed-season illegal deer kill. There is no reason why the technique cannot be expanded to estimate both closed-season and in-season illegal deer kill. Performing simulations randomly in time and space, drawing simulators from different social groups, performing sufficient simulations to achieve reasonable confidence limits on estimates, and studying appropriate distributions of poaching and agent searches should improve the validity of the technique.

None of the previously mentioned procedures for estimating violations, whether providing a relative or absolute measure, will probably be reliable or valid when employed alone. To the extent that results obtained from 2 or more of the procedures are significantly correlated, convergent validation has been achieved and greater confidence can be placed in statements regarding the validity of inferences about the "deer law violation problem" (Cook and Selltiz 1967).

Most of the estimation techniques have never or only occasionally been employed by wildlife law enforcement divisions. Because of this lack of consistent use, problems associated with employing the techniques have not been solved and an "optimum" set of indexes or estimators cannot be recommended at this time. The validity of estimation procedures must be established to improve the procedures' usefulness as an aid to allocation of enforcement manpower and related processes. Once the validity of 1 or more estimation procedures has been established, the procedures must be used repeatedly and consistently to provide a basis for manpower allocation and other decisions. The trend has too often been to employ a procedure once, such as the violation simulation technique, obtain a number, and remove the procedure from consideration for future use. Validated estimation techniques, whether providing absolute or relative measures, must be incorporated into seasonal or annual enforcement management plans.

Poaching estimation is a new and only slightly studied area of research. Progress in estimating deer mortality from poaching may likely be achieved in:

(1) Poacher interviews to determine mean annual take per poacher, a shift in emphasis from deer to poacher estimates.
(2) Changes in winter roadside spotlight counts of deer (adjusted by weather variables). The assumption is that popula-

tions under poaching pressure will decrease more rapidly than others.

(3) Regression analyses. Mechler (1970) showed high R^2 values for simple equations that were predictive of legal deer kill in Virginia counties. The implication is that illegal kill is either so slight as not to influence the variance in annual harvest or to be a constant proportion of the legal harvest. Which of these options (or others) is operational needs study.

(4) Substantial rewards for information about deer poaching.

(5) Mathematical analyses of time between deer poaching arrests, enforcement effort, and probability of repeat arrests.

(6) Educational and enforcement efforts incrementally applied that reduce deer poaching arrests may be back-projected to estimate the initial levels of poaching arrest potentials.

(7) Computer simulations of population dynamics may be used to interpret a range of feasible poacher-caused mortalities that may allow the legal harvest or other herd characteristics (e.g., sex ratios) to be achieved.

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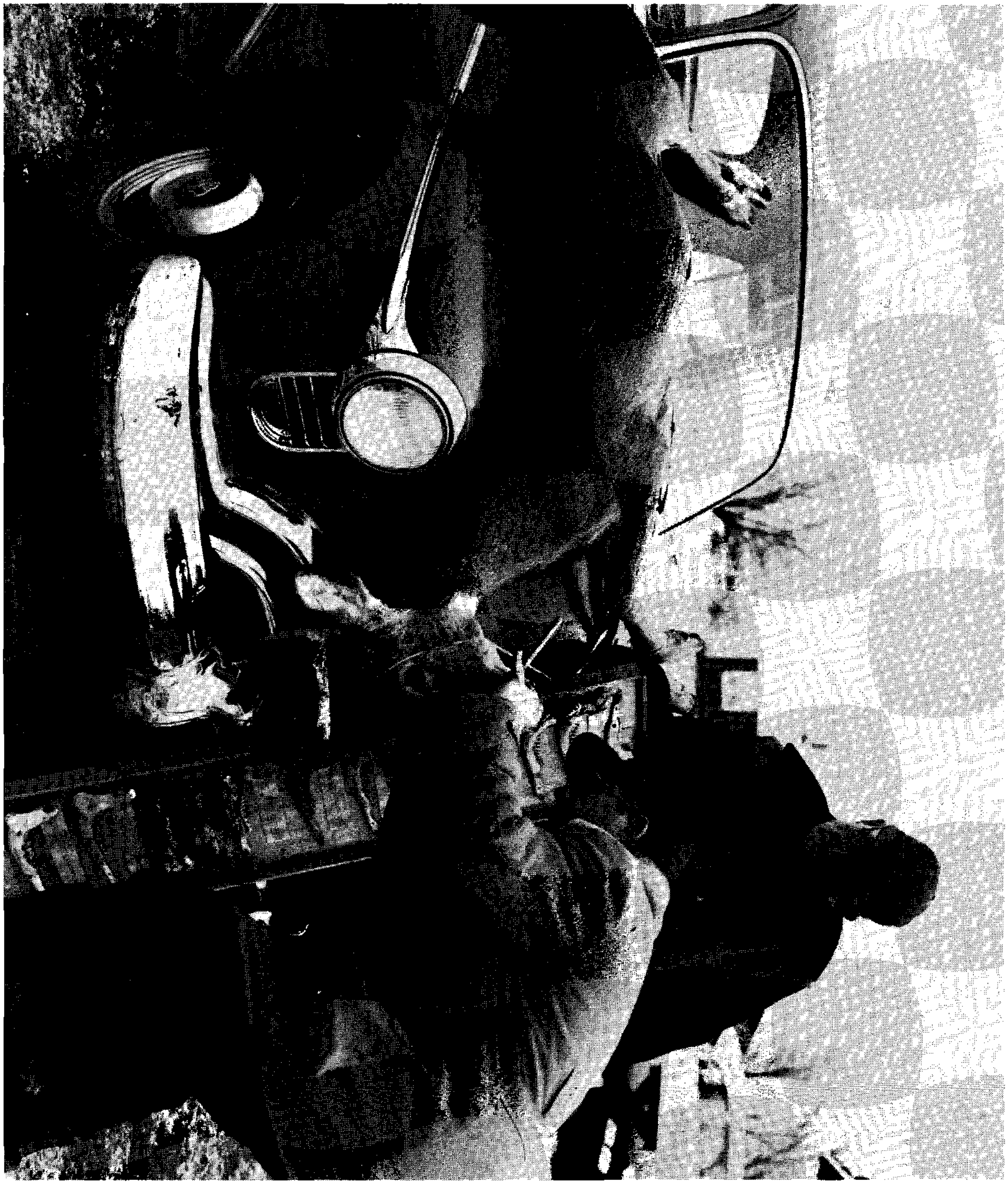

Wisconsin DNR

AGE DETERMINATION OF WHITE-TAILED DEER IN THE MIDWEST – METHODS AND PROBLEMS

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Abstract: This paper reviews the various methods of age determination for *Odocoileus* and examines comparative results from their application. A survey of midwestern state wildlife agencies indicated that ages are assigned to harvested animals based primarily on criteria involving molariform tooth eruption and wear, external incisor characteristics, and cementum annuli counts. Most agencies expressed satisfaction with their particular methodology although the various techniques have been shown to produce conflicting results. Nonuniformity of aging criteria hampers the interstate exchange of information and the interpretation of age-specific research results. Needed is a well-planned, coordinated, and definitive evaluation of the various techniques using adequate known-age material representing all geographic and ecological regions of the Midwest.

INTRODUCTION

Wildlife management has been criticized for failure to properly emphasize the principles and concepts of population dynamics (Scott 1954, Caughley 1976). It is therefore appropriate that the present symposium on white-tailed deer *(Odocoileus virginianus)* consider the management implications of population phenomena. Many such phenomena are reflected by and/or contribute to changes in population age structure. The ability to accurately determine ages of individual animals is an acknowledged requisite for effective management. Knowledge of age distribution enhances understanding of population dynamics; and, important parameters such as fecundity and survival rates are most useful when age-specific (Caughley 1977).

Age data present 3 major concerns to the deer biologist: (1) are the data accurate, (2) are they representative, and (3) how can they be used to improve management? This paper considers only the first problem, especially as it relates to analysis of harvested samples. Various methods of age determination are reviewed and comparative results examined. Procedures currently used in the Midwest are viewed in light of these findings. Technological aspects of the techniques are not emphasized.

METHODS OF AGE DETERMINATION

Techniques for determining age of fetal (Armstrong 1950, Hudson and Browman 1959) and early postnatal deer (Haugen and Speake 1958) will not be reviewed. The following emphasizes techniques for assigning age past 4-5 months.

Antler Dimensions

A once popular, though presently less common, notion among laymen was that number of antler points was indicative of age. Cahalane (1931) suggested that beam diameter could segregate male white-tailed deer into age classes. Hunter (1947) attempted to segregate male mule deer *(O. hemionus)* into age classes by a combination of dental and antler characteristics. Subsequent work confirmed that antler dimensions tend to increase with age but are unsuitable for assigning animals to year classes (Severinghaus et al. 1950, Severinghaus and Cheatum 1956). Nevertheless, weights of shed antlers might provide clues to population age structure (Anderson and Medin 1969).

Maturation of Long Bones

An index of skeletal maturity (degree of epiphyseal closure) developed from known-age black-tailed deer *(O. h. columbianus)* enabled Lewall and Cowan (1963) to accurately estimate age to 72 months. However, the technique has obvious limitations for harvested samples and has received little further attention.

Molariform Tooth Eruption and Wear

The normal sequence of tooth development in white-tailed deer permits segregation of autumn-killed animals into 3 age groups: fawns (4-7 months) possessing less than 6 molariform (cheek) teeth, yearlings (16-19 months) showing deciduous or newly erupted permanent 4th premolars, and adults (28+ months) having fully erupted permanent teeth. Assignment of the latter group to individual age classes is by degree of wear on

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the occlusal surface of molariform teeth (Taber 1969). Terminology used here and elsewhere follows Riney (1951) who described the dental formula of *Odocoileus* as follows:

$$\mathrm{I}\frac{0\ 0\ 0}{1\ 2\ 3}\quad \mathrm{C}\frac{0}{1}\quad \mathrm{P}\frac{0\ 2\ 3\ 4}{0\ 2\ 3\ 4}\quad \mathrm{M}\frac{1\ 2\ 3}{1\ 2\ 3}$$

According to Severinghaus and Cheatum (1956), American pioneers used tooth wear to differentiate among young, prime, and old deer. Biologists as well have long regarded tooth replacement and/or wear as potential criteria of age in deer (Cahalane 1932, McLean 1936, Cowan 1936, Park and Day 1942). Unquestionably though, the signal contribution was by Severinghaus (1949) who described tooth replacement and wear for a large collection of known-age whitetails from New York. Various adaptations of the technique were subsequently applied to *O. hemionus* and *O. h. columbianus* (Robinette and Jensen 1950, Leopold et al. 1951, Moreland 1952, Jones 1953). Robinette et al. (1957) later described these criteria for known-age mule deer and developed a quantitative index of molariform tooth wear (molar ratio). This index is not generally reliable for assigning individual ages (Brown 1961, Ludwig 1967, Erickson et al. 1970). With respect to quantitative indexes, Roseberry and Hardin (1978) suggested that the multivariate statistical procedure, discriminant analysis, might be used to distinguish among age groups and classify unknown subjects based on a combination of dental and mandibular measurements and characteristics.

Subjective (visual) evaluation of tooth eruption and wear has been tested on known-age specimens with mixed results. Ryel et al. (1961) and Brown (1961) reported the following accuracy by age class for white-tailed and black-tailed deer, respectively: 1½ (97 and 90%), 2½ (69 and 60%), 3½ (57 and 42%), 4½ (41 and 26%), and 5½ (23 and 22%). Experienced personnel in both studies tended to overestimate ages of jaws in younger classes and underestimate those in older age groups.

It is generally acknowledged that tooth wear may vary according to climate, soil type, food habits, and genetic makeup (Ludwig 1967). Ryel et al. (1961:310) applied Severinghaus's (1949) New York criteria to Michigan whitetails and concluded: "Agreement is good in the 2½- and 3½-year age groups but falls off rapidly as the age increases." Ludwig (1967), in contrast, reported correctly aging 33 of 36 known-age (2½-4½) whitetails from southern Illinois using Severinghaus's criteria.

Methods of age determination must be judged for precision and applicability as well as accuracy, i.e. are the criteria unambiguous and will they produce consistent results? Brown (1961) found that individual examiners tended to consistently err in one direction or the other. Ryel et al. (1961) noted significant differences among individuals and several levels of proficiency in assigning ages based on tooth wear. Others reporting variable interpretation of the same material include Low and Cowan (1963), Gilbert and Stolt (1970), Brown and Peabody (1972), and Roseberry and Hardin (1978). Brown (1961) recorded slightly greater accuracy in assigning ages to males than females among black-tailed deer. There is some indication that teeth of males of *O. hemionus* wear faster leading to underestimation of female ages (Erickson et al. 1970, Thomas and Bandy 1975). However, Hill (1973) and Roseberry and Hardin (1978) reported no significant difference in rates of agreement between age assignments based on tooth wear and dental cementum annuli for male and female *O. virginianus* from Pennsylvania and Illinois, respectively. Likewise, Kuehn (1970) noted no difference in quantitative measurements of tooth wear for male and female whitetails from Minnesota.

Despite evidence that tooth eruption and wear is not a precise indicator of age past 1½ years, it is generally assumed that the technique is adequate to definitively segregate fawns, yearlings, and adults (Brown 1961, Ryel et al. 1961, Connolly et al. 1969, Erickson et al. 1970). However, check station examination of jaws *in situ* may present some difficulties. From a sample of 418 whitetails, Roseberry and Hardin (1978) judged that Illinois check station operators correctly segregated 98% of all adults from younger animals and classified 92% of all yearlings correctly. Kuehn (1970) reported that previously instructed Minnesota check station personnel correctly identified 98% of all fawns and 95% of all yearlings from clean, excised jaws.

External Incisor Characteristics

Severinghaus (1949) described the sequence of incisiform tooth replacement for known-age *O. virginianus* from New York; however, Ryel et al. (1961) found the criteria too variable to permit aging Michigan fawns to the nearest month. Brown and Peabody (1972) and Rice (1977) mentioned the use of external incisor characteristics to identify fawns, yearlings, and adults. The latter 2 classes are separated by crown wear whereas fawn incisors are deciduous; or, if permanent, show incomplete closure of the root canal.

Eye Lens Weight

The lens of the mammalian eye presumably grows continuously throughout life, although not at a constant rate. Use of eye lens weight as a criterion of age was first described by Lord (1959) for cottontail rabbits *(Sylvilagus floridanus)* and subsequently applied to a variety of wildlife including deer (Friend 1967). Lord (1962) concluded that the eye lens growth curve in deer was influenced by nutritional status thus limiting its usefulness as an indicator of age. Longhurst (1964:773), however, developed regression equations describing eye lens weight-age relationships for known-age black-tailed deer and pronounced the technique: "satisfactory for aging deer at least through 5 years...." Longhurst's data, along with additional known-age specimens, were reanalyzed by Connolly et al. (1969:703) who concluded: "a considerable fraction of adult deer aged by the lens method may be assigned to the wrong age class...." Downing and Whittington (1964) recommended the technique for separating fawns, yearlings, and adults; however, Ludwig (1967) considered lens weight no better than body weight or beam diameter for assigning age to male whitetails from Illinois. Lueth (1963) earlier reached a similar conclusion for deer in Alabama. Friend (1968:285) concluded from a review of published and unpublished studies that: "fawns and yearlings could be separated with a high degree of accuracy, yearlings and 2½ year olds with less certainty, and thereafter year class assignment was unreliable for individual deer." Other studies have also shown that eye lens weights are unsatisfactory for assigning individual ages, especially past 1½ years (Hoffman and Robinson 1966, Urbston 1968, Erickson et al. 1970, Keller and Landry 1976).

In a related effort, Ludwig and Dapson (1977) attempted to correlate the accumulation of insoluble lens proteins with age in white-tailed deer. They found, however, that individual ages could be estimated only within 2 or 3 years.

Dental Annulations

Morphological characters that change continuously with age are inherently less accurate for age determination than those which change by annual quanta (Caughley 1977). Annular growth patterns of mammalian teeth are an example of the latter phenomenon (Scheffer 1950, Laws 1952). The first attempt to so age cervids was by Sergeant and Pimlott (1959) who related growth layers in the cementum of moose *(Alces alces)* incisors with age. Based on early work with *Odocoileus,* Low and Cowan (1963:468) wrote: "The passage of a year in a deer's life usually results in a distinctive pattern of increment to the cementum. A pale-staining zone of rapid increment is added during the spring and summer. During the winter, there is a reduction in increment rate that shows as a dark-staining zone." Low and Cowan associated the latter, called "rest lines" by Thomas and Bandy (1973), with the normal restriction of food intake characteristic of a deer's annual cycle. Sauer (1973) further investigated and described the physiology of cementum annulus formation.

Ransom (1966) examined known-age molars from Michigan and Minnesota white-tailed deer and claimed that growth layers were visible without histological preparation. Campbell (1967) was unable to duplicate Ransom's findings with Illinois material but reported that cementum annulations from sectioned and stained molars were in agreement with known age for 75 of 76 animals. Subsequent cementum analyses have generally involved microscopic examination of histologically prepared incisor sections. Complete agreement between incisor cementum annuli counts and known age of *Odocoileus* has been reported from several studies (Low and Cowan 1963, Gilbert 1966, Erickson and Seliger 1969, Lockard 1972, Thomas and Bandy 1973); however, except for the latter study, it is unclear whether blind tests were conducted, i.e. final annuli determinations made prior to knowledge of true age. Sauer (1971) achieved 84% agreement between incisor cementum annulations and known age for white-tailed deer from New York while Hill et al. (1975) recorded 86% accuracy for a small sample of known-age Pennsylvania deer.

The above cited studies dealt primarily with cementum analysis of limited geographic material at University laboratories. Increasingly though, wildlife agencies are considering commercial laboratories for processing large samples. One of the more popular of these, Matson's Commercial Microtechnique, has been the subject of limited evaluation with known-age material. Citing personal communication with R.L. Cook, Texas Parks and Wildlife Department, Hackett et al. (1979) reported an 83% error for 29 known-age white-tailed deer from Texas. In contrast, 13 (72%) of 18 age assignments based on cementum annuli for Illinois deer were correct and none erred by more than 1 year (Table 1). These results suggest possible differential applicability of the technique. Specifically, northern deer may have more clearly defined cementum structure than do animals from southern regions (Matson 1978). Regardless of geographic origin, all areas of the cementum do not produce uniformly distinct growth layers; and, false, split, and compound annuli can occur (Gilbert 1966, Campbell 1967, Erickson and Seliger 1969, Lockard 1972, Thomas and Bandy 1973, Rice 1980). Gasaway et al. (1978) reported that 2 experienced workers agreed on only about 60% of the moose incisor sections they examined. Gwynn (1978) also presented evidence of variable interpretation of cementum growth layers from white-tailed deer in Virginia. In addition, paired incisors do not always show identical patterns of annulation (Rice 1977). In a test of precision achieved by a commercial laboratory, 30 pairs of incisor teeth (I_1) from southern Illinois whitetails were labeled and submitted separately for sectioning and age determination. Twelve (40%) of the 30 deer were assigned a different age from their 2 incisors although the discrepancies never exceeded 1 year (Table 2). This particular laboratory assigns 1 of 3 certainty codes to each age estimate: "results nearly certain", "some error possible", or "error likely" due to confusing or indistinct annulus patterns. Such classifications assigned to a sample of deer from Illinois varied significantly by region and age class but not sex (Table 3). Therefore, it would not be possible to simply ignore the "error likely" samples without biasing results.

COMPARATIVE RESULTS FROM CRITERIA OF AGE

The literature on deer aging methods contains several examples of ambiguities in reporting results of accuracy tests. One involves the base from which percentages of agreement are computed and reported. For example, suppose 140 animals were identified as 2½ years old from a large group which actually contained 100 animals of that known age. Suppose also that 70 of the animals termed 2½ were actually that age.

assignments for known-age white-tailed deer from Crab Orchard National Wildlife Refuge, southern Illinois.

Known Age	Age According to 2 Different Techniques		
	Cementum Annuli*		
	Incisor No. 1	Incisor No. 2	Tooth Wear**
2½	2½(B)		2½
3½	2½(B)	3½(B)	3½
3½	3½(B)	3½(B)	3½
4½	4½(A)	4½(A)	3½
4½			4½
6½	5½(B)		4½ +
6½	6½(C)		4½ +
6½	6½(C)	6½(C)	4½ +
6½			4½ +
6½ +	6½(B)		3½
6½ +	9½(C)		4½ +
7½	8½(B)	8½(B)	4½ +
7½	7½(B)		4½ +
8½	7½(C)	8½(C)	4½ +
8½			4½ +
9½	9½(B)	9½(B)	4½ +

* Incisors sectioned and aged and codes assigned by Matson's Commercial Microtechnique, Milltown, Montana, 1978: A = results nearly certain; B = some error possible; C = error likely.

** Age assignments made at Illinois Department of Conservation check station, Crab Orchard National Wildlife Refuge, 1977 and 1978.

tailed deer based on region, age, and sex, 1977 and 1978.

Variable*	No. Deer	Percent Assigned to Certainty Levels**		
		A	B	C
Region				
North (42°)	159	19	50	31
Central (40°)	275	23	61	16
South (37°7')	335	11	50	39
Age Class[1]				
1½	360	19	51	30
2½	232	17	61	22
3½	87	14	65	21
4½ +	113	15	44	41
Sex				
Male	54	4	50	46
Female	79	13	54	33

* Region: $X^2 = 43.0$, $P < 0.001$
Age: $X^2 = 18.8$, $P < 0.01$
Sex: $X^2 = 4.5$, $P > 0.10$

**Codes assigned by Matson's Commercial Microtechnique; A = results nearly certain, B = some error possible, C = error likely.

1 Matson assigned individual age classes to all deer; those 4½ and older combined for this comparison.

TABLE 2. *Independent age assignments for 30 white-tailed deer from cementum annuli counts of both incisors.**

Incisor No. 1	Incisor No. 2												
	1½	2½	3½	4½	5½	6½	7½	8½	9½	10½	11½	12½	13½
1½	2												
2½	2	3	1										
3½		1	5										
4½			3	1	1								
5½				2	1								
6½						1							
7½								1					
8½								1					
9½									3				
10½										1			
11½													
12½													
13½													
14½													1

* Incisors collected and labeled by the Cooperative Wildlife Research Laboratory, Southern Illinois University-Carbondale. Material sectioned and analyzed by Matson's Commercial Microtechnique, Milltown, Montana.

Thus, 70% of all known-age 2½-year-olds were accurately identified (70 of 100); yet, the assigned age group was only 50% correct (70 of 140). Another problem involves confusion of accuracy with precision. Bell (1974) stated that the square of the coefficient of correlation (r^2) between known and estimated age for a particular sample was a measure of accuracy. Hackett et al. (1979), perhaps understandably, interpreted these reported values as the percentages of accuracy achieved during Bell's study. In actuality, the data showed considerably less agreement than suggested by the r^2 values which were a measure of precision and not accuracy. For example, if all estimates were exactly 1 year greater than actual age, perfect correlation would result ($r = 1.00$) yet accuracy would be 0%.

Tooth Eruption and Wear vs. Dental Cementum Analysis

Comparisons of independent age assignments by tooth eruption and wear and cementum annuli counts have been reported by several authors. Lockard (1972) found 74% agreement between the 2 techniques for a large sample of *O. virginianus* from various locations. Similar rates of agreement were recorded for this species in Indiana (Olson 1967) and Alabama (Boozer 1969). Low and Cowan (1963:470), however, noted "many discrepancies" in mule deer. With the exception of Campbell (1967) and Thomas and Bandy (1975), results of other comparisons of tooth eruption and wear and cementum annuli counts have been generally disappointing, especially for deer 2½ + years (Table 4). Closer agreement with annuli counts was generally achieved when eruption and wear was evaluated from clean, excised material in the laboratory as opposed to jaws *in situ* under check station conditions (Roseberry and Hardin 1978). In general, private analyses of cementum structure produced somewhat better agreement with eruption and wear than did commercial efforts; however, the only direct comparison (Gwynn 1978) showed commercial annuli counts superior in identifying "known-age" fawns and yearlings. The poor results using annuli counts in Mississippi may have reflected physiological anomalies of the sample. Hackett et al. (1979) suspected that their animals had experienced a summer drought-induced stress period and, therefore, a double annuli deposition.

External Incisor Characteristics

Use of external incisor characteristics as criteria of age is not well documented in the literature. Working with Kansas white-tailed and mule deer, Brown and Peabody (1972) reported that a group of deer aged as "questionable yearlings" based on this technique contained 6% 2½-year-olds according to dental cementum analysis. The proportion of all yearlings considered "questionable" by external incisor criteria was not reported. Rice (1977) also recorded a 6% error for 261 mule and white-tailed deer from South Dakota designated 1½ by incisor crown wear. Unlike the Kansas sample, "questionable yearlings" were not included in this test. Karl Menzel of the Nebraska Game and Parks Commission (pers. comm. 1979) tested external incisor and tooth eruption and wear criteria on 537 mule and white-tailed deer and found 86% and 79% agreement for 1½ and 2½ + categories, respectively. According to Lee Gladfelter of the Iowa Conservation Commission (pers. comm. 1979), 15% of 74 whitetails designated yearlings by external incisor characteristics were called 2½ by a commercial laboratory using annuli counts, and "many" deer aged as 2½ + by the former method were called 1½ by the latter.

TABLE 4. *Some comparative age assignments by tooth eruption and wear vs. cementum annuli counts for unknown age Odocoileus.*

Location	Source	No. Deer	Percent Agreement*						Procedure**	
			½	1½	2½	3½	4½	5½ +	TEW	CAC
British Columbia	Thomas and Bandy (1975)	769	100	100	94	68	44	100	Excised	Private
Colorado	Erickson et al. (1970)	116			95		—47—		*In situ*	Private
Illinois[1]	Campbell (1967)	128	100	100	100	87	75	100	Excised	Private
Illinois	Roseberry and Hardin (1978)	801		88	51	25	72(4½ +)		*In situ*	Commercial
Illinois	Roseberry and Hardin (1978)	413		92	60	32	77(4½ +)		Excised	Commercial
Kansas	Brown and Peabody (1972)	300		100	72	67	44	21[2]	Excised	Private
Maine	Gilbert and Stolt (1970)	682		94	66	52	32	9[2]	*In situ*	Private
Minnesota	Kuehn and Karns (1970)	854			70	39	25	87	Variable[3]	Private
Missouri	Porath and Torgerson (1979)	1125			60	25	20	89	*In situ*	Commercial
Mississippi	Hackett et al. (1979)	404	0	17		—27—			*In situ*	Commercial
Pennsylvania	Hill et al. (1975)	199			65	58	55	69	Excised	Private
Virginia	Gwynn (1978)	312	50	42					Excised	Private
Virginia	Gwynn (1978)	190	100	84					Excised	Commercial

* Age classes based on TEW except for Maine and Kansas studies; 5½ + category created for this comparison.

**TEW = tooth eruption and wear; CAC = cementum annuli counts.

[1] Sample contained some known-age animals.

[2] Mean percentage agreement for individual age classes past 4½.

[3] 62% *in situ*, 38% excised.

Implications of Incorrect Age Assignments

It is obvious that techniques currently available for age determination of *Odocoileus* are not infallible. Of primary concern is whether errors are compensatory and if not, are their consequences trivial or important. Robinette et al. (1957) felt that tooth eruption and wear errors should be compensatory and therefore the technique satisfactory for determining population age structure. Caughley (1977), however, pointed out that aging errors are not necessarily compensatory even when they occur at a constant rate for all age classes. For example, suppose that a sample contained 80 2½-year-old deer and 60 3½-year-olds and the probability of mistaking one for the other was exactly the same (e.g., 0.30). Such aging errors would result in an estimated ratio of 74:66.

The rate and direction of aging errors appears highly variable among age classes, techniques, and geographic regions. The cementum analysis technique has been suspected of overaging deer from Virginia (Gwynn 1978) and Mississippi, but underaging animals from Texas (Hackett et al. 1979). Moen and Sauer (1977) believed that tooth eruption and wear underaged deer at New York's Seneca Army Depot. In contrast, Brown and Peabody (1972) reported that Kansas biologists using tooth eruption and wear tended to overage deer through 6½ years (based on annuli counts). Gilbert and Stolt (1970) felt that Maine biologists using tooth eruption and wear were inclined to overestimate the ages of younger deer (1½-2½) and underestimate those 3½ and older. Bell (1974) noted the same tendency among 4 Louisiana biologists. Thomas and Bandy (1975) also noted a trend toward underestimation of deer 3½ to 5½ but high accuracy for younger animals. According to Kuehn and Karns (1970), use of the tooth eruption and wear technique resulted in age being underestimated in some regions of Minnesota and overestimated in others, presumably because of regional variation in tooth wear. In Illinois, rates of agreement between tooth eruption and wear and annuli counts did not vary regionally (Roseberry and Hardin 1978).

Some workers have concluded that age assignment by tooth eruption and wear causes underestimation of the strength of the 2½-year cohort and overestimation of the 3½-year age class (Ryel et al. 1961, Lockard 1972). In contrast, Erickson et al. (1970) and Roseberry and Hardin (1978) felt that the 2½-year cohort was inflated by this aging method. The strength of this cohort influences calculated survival rates for 1½-, 2½- and 3½-year-olds. In fact, aging discrepancies may significantly alter age-specific survival schedules (Kuehn and Karns 1970, Roseberry and Hardin 1978, Hackett et al. 1979).

AGE DETERMINATION PROCEDURES USED IN THE MIDWEST

Procedures for acquiring samples and assigning ages to harvested deer from midwestern states are summarized in Table 5. Most agencies operate some type of check station (either mandatory or voluntary) where hunters may bring their animals for registration and/or data collection. Age determinations are generally based on criteria of molariform tooth eruption and wear. Several of the less populated states do not operate check stations, but rely on hunters to voluntarily submit incisors from harvested animals. Typically, biologists from these states attempt to segregate fawns, yearlings, and adults by external incisor characteristics; then, incisors from adults and "questionable yearlings" are sectioned and ages estimated by dental cementum analysis. Two of these states send material to a commercial laboratory for cementum analysis and 2 use in-state facilities.

CONCLUSIONS

Most state agencies expressed satisfaction with their procedures for aging deer; yet, research has shown that the methods currently used often produce conflicting results. Lack of a common means for assigning ages to midwestern deer is regrettable though perhaps understandable. Deer management programs operate at various levels of funding; and, the problems associated with collection of harvested material vary greatly from state to state. More importantly, however, research has thus far failed to produce a definitive, unequivocal aging procedure for *Odocoileus* suitable for large samples of harvested animals. The lack of a common system for aging deer hampers the interstate exchange of information and the interpretation of age-specific research results. Needed is a well-planned, coordinated, and definitive evaluation of aging techniques using adequate known-age material representing all geographic and ecological regions of the Midwest. Such research should focus on age classes 1½ to 4½, as fawns can be satisfactorily identified by a number of easily applied criteria and older animals are numerically less important in exploited populations.

Several aspects of the aging question need particular attention. Use of external incisor characteristics to separate fawns, yearlings, and adults has not received adequate scientific testing. Another problem is occasional disagreement between dental cementum analysis and tooth eruption and wear regarding the separation of yearlings from older animals. This situation is especially troublesome when the techniques are used in combination as suggested by Gilbert and Stolt (1970) and Kuehn and Karns (1970). The role of commercial laboratories in providing cementum analysis services to wildlife agencies needs additional evaluation. This technique is apparently going through a developmental stage and further improvement may follow the acquisition of more known-age material from various geographic

TABLE 5. *Procedures for acquiring samples and assigning ages to harvested white-tailed deer in the Midwest.*

State	Approximate Sampling Intensity (in Percent)	Source of Material	Method of Aging*	Age Categories Defined	Personnel
Illinois	100	Mandatory check stations	TEW	½-4½ +	College Students
Indiana	10	Special hunt check stations	TEW	½-4½ +	Professionals
Iowa	25	Incisors voluntarily submitted	EIC	½, 1½, 2½ +	Professionals
			CAC**	2½-5½ +	Commercial Lab
Kansas	90	Incisors voluntarily submitted	EIC	½, 1½, 2½ +	Professionals
			CAC**	2½. . .	Commercial Lab
Michigan	10	Voluntary check stations	TEW	½, 1½, 2½ +	Nonbiologists
			TEW	½. . .	Professionals
Minnesota	10	Mandatory registration stations	Size	½-1½ +	Nonprofessionals
		Mandatory registration stations	TEW	½, 1½, 2½ +	College Students
		Voluntary check stations	TEW	½, 1½, 2½ +	Professionals
		Incisors voluntarily submitted	EIC	½, 1½, 2½ +	Professionals
		and collected at stations	CAC**	½. . .	Professionals
Missouri	10	Selected mandatory check stations	TEW	½. . .	Professionals
Nebraska	50	Mandatory check stations	TEW	½-7½ +	Professionals
		Incisors voluntarily submitted	EIC	½, 1½, 2½ +	Professionals
Ohio	15	Mandatory check stations	TEW	½-5½ +	Professionals
South Dakota	50	Incisors voluntarily submitted	EIC	½, 1½, 2½ +	Professionals
			CAC**	2½. . .	Professionals
Wisconsin	10	Selected mandatory check stations	TEW	½, 1½, 2½, 3½, 4½-5½, 6½-8½, 9½-12½, 13½ +	Professionals & Nonprofessionals

* TEW = tooth eruption and wear; EIC = external incisor characteristics; CAC = cementum annuli counts.

**Used to assign yearly ages to adults segregated by other methods.

regions (Gwynn 1978). One approach to the problem of regional variation in cementum structure would be for agencies to make their own age determinations from commercially prepared slides. Several experienced interpreters could be assembled to concurrently examine sections projected on a screen, with ready access to known-age slides.

Whereas the preparation and interpretation of tooth sections may be a developing art, the same cannot be said for the tooth eruption and wear method, i.e. its inherent accuracy will not improve. However, better application of the technique can provide more reliable results. Whenever possible, age assignments should be made from clean, excised jaws by experienced professionals with immediate access to representative known-age material. Attempts to age jaws *in situ* should probably be limited to segregating fawns, yearlings, and adults. Even then, liberal use should be made of such aids as flashlights, wash bottles, and jaw spreading and cheek splitting devices.

Cost and personnel requirements of the various aging techniques must be considered in addition to their accuracy and precision (Erickson et al. 1970). Equipment and facility needs are much less for tooth eruption and wear than for annuli counts, although the training and experience necessary for proper interpretation are not. Hunter-supplied incisors are the least expensive source of material; but, additional biases are introduced. Check stations are labor-intensive regardless of whether tooth examinations or incisor collections are involved; however, they accommodate public relations and collection of additional biological information. Cost of private annuli counts depends on availability of equipment and personnel; but, commercial rates for histological sectioning (Matson 1978) seem competitive, even when compared to less time-consuming procedures such as grinding sections (Brown and Peabody 1972).

Assuming that further research with known-age material improves or confirms the dependability of commercial work, the following might be an appropriate data collection scheme for many midwestern states. Check station operators could separate fawns, yearlings, and adults by tooth eruption and wear, and then collect adult incisors for commercial processing and local age determination. This approach would: (1) maintain the benefits of check stations, (2) exploit the advantages of tooth eruption and wear and bypass the disadvantages, (3) utilize relatively cost-efficient commercial preparation of slides, and (4) employ local expertise for their interpretation. If necessary, data costs could be further reduced by processing only adult female incisors. Little information would be sacrificed by simply designating males as fawns, yearlings, or adults.

Acknowledgments. Appreciation is expressed to midwestern deer biologists and managers who provided information regarding their programs and, in some cases, unpublished data from their files. All state agencies contacted responded positively to requests for information.

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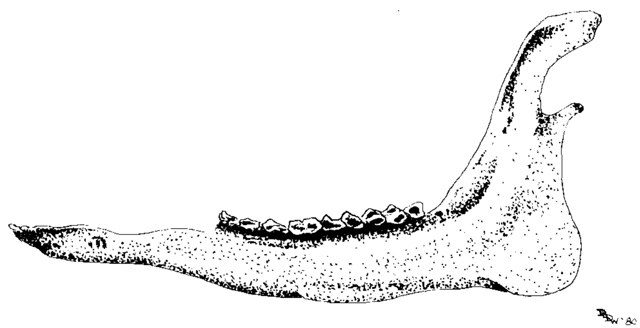

DEER HERD MANAGEMENT – PUTTING IT ALL TOGETHER

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Abstract: Wisconsin's deer management program employs a system of 96 deer management units with deer density goals specified for each unit. On a statewide basis, the current goals prescribe an average overwinter herd of 575,000 permitting an annual gun harvest of up to 150,000 deer. Since 1964, annual gun season harvests have averaged 105,000 ranging from 71,000 to 151,000. Bow harvests during the same period have added 3,000 to 18,000.

Primary inventory methods include: (1) registered kill trends; (2) sex-age-kill population estimates calculated from kill, ages, and observed fawn:doe ratios; and (3) pellet counts in northern units from 1955 to 1978, which have recently been superceded by deer trail counts. Registered kill trends and population projections therefrom form the backbone of the program. Supplementing and complementing the 3 basic inventories are measures of winter severity, hunting pressure, and winter losses.

Wildlife managers maintain ongoing histories for each unit, tabulating annual records of populations, harvests, and hunting pressure. These provide the background for annual harvest recommendations. Antlerless quotas commonly range from 60 to 80% of the antlered buck kill when population levels are near goals, but may exceed or fall short of these ratios when herd levels are above or below specified goals. Winter severity measurements and predicted population responses have recently played an increasing role in the quota-setting process.

Antlerless quota recommendations are subjected to annual review at public hearings and by the Conservation Congress, a statewide sportsmen's group. Recommendations by the Congress, as well as by the technical staff of the Department of Natural Resources, are considered by the Natural Resources Board in establishing the final quotas.

Creed, William A. and Frank P. Haberland. 1980. Deer herd management – putting it all together. Pages 83-88 *in* Ruth L. Hine and Susan Nehls, eds. White-tailed deer population management in the north central states. Proc. 1979 Symp. North Cent. Sect. Wildl. Soc. 116 pp.

INTRODUCTION

Details of herd management policy, survey design, and harvest regulations may vary from state to state, but the basic ingredients of a management program pose many similarities. All states must establish objectives, measure populations, and establish regulations. The purpose of this paper is to describe how one major deer state in the Midwest, Wisconsin, goes about the annual business of regulating its white-tailed deer resource.

HERD MANAGEMENT POLICY AND GOALS

The Wisconsin Department of Natural Resources is governed by the Natural Resources Board which consists of 7 members appointed by the Governor for staggered 6-year terms. An important function of the Board is the establishment of policy for guiding DNR programs. The Wisconsin deer management policy states, in part, that "regulations shall be designed to meet the following objective: to maintain a deer herd in balance with its range and at population levels reasonably compatible with agricultural and forest management objectives in each deer management unit." Deer management units are areas of similar habitat bounded by major roads. Currently there are 96 units averaging about 1500 km^2 (580 mile^2) in size. Each unit is surveyed on air photos to determine the area of deer range.

Deer population goals are expressed as deer per square mile of deer range overwinter. Goals in individual management units range from a low of 2 to a high of 12 deer per km^2 of range (approximately 5-30 deer per mile^2) and total 575,000 deer statewide. Deer population goals in the forested deer range are based on long-term average carrying capacity as determined by unit population responses to past winters of varying severity. Goals in the agricultural range reflect an estimate of hunter demand balanced with an assessment of human tolerance to deer numbers, particularly as it relates to crop damage and the frequency of deer-vehicle collisions on highways.

The overwinter population level of 575,000 deer is capable of providing a fall herd in excess of 800,000 deer which permits an annual gun harvest up to 150,000 or more depending on the effects of winter severity.

Management policy prescribes annual hunting seasons to maintain deer population goal levels and allows the use of buck (3 in. + antler), either-sex, or buck and antlerless permit harvest strategies. Buck-only seasons are occasionally used to allow herd increases where numbers are below goals because of the effects of severe winters or continuous either-sex seasons. Either-sex seasons regularly apply in the intensive agricultural areas of southern Wisconsin. Buck hunting combined with antlerless quotas for specific management units is the system applied over most of the state.

The antlerless permit in Wisconsin is called the "party permit" because it requires the formation of a group of at least 4 hunters to submit a valid application. The permit entitles the party to harvest 1 deer of any age or sex in addition to the 1 deer allowed on each hunter's regular license. In practice, it is an antlerless permit because only about 3% of the deer harvested under the permit are antlered bucks. The party permit system has been in effect continuously beginning with the 1963 deer season.

Since that time, Wisconsin gun hunters have enjoyed an average annual gun harvest of over 105,000 deer, ranging from a low of about 71,000 in 1971 to a high of almost 151,000 in 1978 (Table 1). These totals include an average of almost 33,000 party permit deer annually ranging from 12,500 in 1971 to almost 54,000 in 1978.

Wisconsin became the first state in the nation to establish an archery deer season back in 1934. Since that time, bowhunter numbers and harvests have steadily increased. Recent bow deer harvests have increased from about 3,000 in 1964 to over 18,000 in 1978. Licensed archers increased to 158,000 in 1978. Present regulations allow the bowhunter to take any 1 deer during an approximately 85-day season, in addition to the deer the hunter is entitled to shoot during the gun season.

TABLE 1. *Wisconsin deer gun harvests, 1964-78.*

	No. Deer Harvested		
Year	Antlered Bucks	Antlerless Deer	Total
1964	65,052	28,393	93,445
1965	60,994	37,750	98,744
1966	67,362	42,700	110,062
1967	71,302	57,295	128,597
1968	62,521	57,465	119,986
1969	52,655	45,353	98,008
1970	50,308	22,536	72,844
1971	48,994	21,841	70,835
1972	49,416	25,411	74,827
1973	57,364	24,741	82,105
1974	67,313	33,092	100,405
1975	73,373	44,005	117,378
1976	69,510	52,999	122,509
1977	82,762	49,148	131,910
1978	87,397	63,448	150,845

POPULATION INVENTORIES

Unit deer populations are monitored through a variety of surveys adapted to specific range types and harvest problems. The primary inventory methods include registered kill trends, sex-age-kill population estimates, and pellet group surveys in northern units.

Deer Registration

Wisconsin has a long history (1953 to present) of compulsory deer registration which requires hunters to present their deer to official registration stations for inspection and tagging. These stations, including DNR offices, gasoline stations, stores, sheriff's offices and similar public places, total about 450 statewide and are well dispersed across the state. Cooperators have been paid 10¢ per deer registered or $10 per season, whichever is greater. In 1979 these amounts were increased to 20¢ and $20. Registration data include breakdowns by sex, age, license type, county, and management unit.

Deer registration is the cornerstone of our herd management program. It has convinced most doubters about the reliability of our deer kill figures, and more important, registered buck harvest trends have supplied one of our most dependable measures of deer population change. Kills are pinned down to much smaller land units than would be possible with all but the most elaborate questionnaire schemes.

Sex-age-kill

Used in Wisconsin since the early 1960's (Creed 1964), the sex-age-kill method for calculating deer densities has become increasingly important in the statewide management picture. It currently serves as the primary index to deer populations over most of the state.

Our version of the sex-age-kill method is modified after Eberhardt (1960), the prime difference being that we employ a 20% nonharvest adjustment for calculating populations of adult bucks. Further, we use Severinghaus and Maguire's (1955) procedure for estimating adult sex ratios. And, fawn recruitment estimates are obtained from routine July-September field observations by all DNR field personnel.

Steps in our analyses are as follows:

(1) Adult buck populations. Minimum numbers of adult bucks (1½ + years) for a previous year are determined by totalling the subsequent legal harvest of adults alive (shown by age structure) in that previous year. To correct for nonharvest mortality, we assume an 80% final recovery rate. This includes an estimated 10% crippling loss plus a 10% adjustment for bowhunting and nonhunting losses. This correction has worked well for heavily hunted units, but has proved inadequate for the wilder, relatively inaccessi-

ble units where nonhunting mortality (particularly winter losses) often exceeds 20%.

(2) Adult sex ratios. These are computed by procedures described by Severinghaus and Maguire (1955). Very briefly, the calculation involves dividing the proportion of yearling bucks by the proportion of yearling does, after first correcting the yearling buck proportion according to the male/female ratio derived from shot samples of fawns.

(3) Fawn:doe ratios (net recruitment). These ratios are obtained from observed numbers of fawns and adult does annually reported by Department field personnel during July, August, and September. In any-deer season zones, ratios of fawns:doe in the legal kill are substituted for observed summer ratios.

(4) Buck to total population expansion factors. Expansion factors *(E.F.)* are recomputed annually for each of 13 zones according to the following formula:

$$E.F. = 1.00 + (B/D) + (B/D)F$$

where B = corrected yearling buck proportion, which is determined from the proportion of yearling bucks in adult buck kill divided by male/female fawns aged; D = proportion of yearling does; and F = fawns:doe ratio from summer observations.

Zone expansion factors are updated annually and used to calculate deer populations for all units with adequate age samples. Annual expansion factors are used where samples are adequate (200 bucks aged; 200 does aged; and 200 doe-fawn observations) and long-term factors are used where samples are small. These expansion factors are then converted to buck kill to total population factors and applied regionally to obtain approximate population estimates for units where aging information is not available.

Pellet Surveys

Deer pellet surveys (Eberhardt and Van Etten 1956, Olson et al. 1955) formed the basic population inventory for the Northern Forest Region from 1955 to 1978. They also provided the initial background for the establishment of unit population goals in 1962.

Our application of the method involved sampling 11 to 12 deer management units per year on a 3-year rotation. Estimates of deer per square kilometer of deer range were then computed for individual units and also projected for the entire Northern Forest Region (ca. 38,500 km² of deer habitat).

The main value of the pellet group survey was to establish modern deer density "bench marks". Prior to 1955, density estimates came primarily from deer drive censuses (Swift 1946). Reliability of pellet surveys on a unit basis was highly variable, but when projected to the entire Region, they correlated closely ($r = 0.83$, $P < 0.01$) with subsequent buck kills (McCaffery 1976*a*) and even better with buck kills of the previous fall ($r = 0.92$, $n = 15$).

Pellet counts lost favor in Wisconsin during the 1970's, primarily because of increased costs, but also because other methods, especially sex-age-kill estimates and trail counts, produced similar information at less cost. Hence, they were discontinued following the spring survey in 1978.

Trail counts (McCaffery 1976*b*) now substitute in part for pellet surveys. Similar coverage can be achieved for about 1/4 the cost of pellet survey, and precision is somewhat better (ca. ± 15-20%, $P = 0.05$). Trail counts are not as yet considered fully operational in our state because training of field personnel is still underway. But, results to date look quite promising.

Supplemental Surveys

A continued search for better, less expensive, or less time-consuming methods has led to development of a number of surveys which play important roles in assessing the current status of deer populations and hunting effort.

Hunter Pressure Poll. A sample of 10,000 license buyers are mailed a questionnaire to determine where and when they hunted. Expansion of replies produces hunter density estimates for management units by day and for the season.

Dead Deer Surveys. From 1955 to 1978, dead deer searches were conducted simultaneously with pellet surveys. But in some very severe winters, we have also field-checked randomly selected blocks with 5- to 10-person crews. Such surveys inherently are quite imprecise because of the clumped distribution of deer carcasses, but they do help to evaluate impacts on regional population levels.

Analysis of Winter Severity. Measures of winter severity relate to spring deer condition and fawn survival (Verme 1968, 1977). In Wisconsin (B. E. Kohn pers. comm.) a combination of days with 46+ cm snow on the ground plus days below −18°C temperatures correlated very closely ($r = 0.99$, $P < 0.01$) with the immediate percentage change in the buck kill (B. E. Kohn 1979 pers. comm.). This severity index also provides an estimate of winter losses and subsequent fawn recruitment.

ANNUAL REVIEW OF HERD STATUS

Each deer season begins a reappraisal of deer population levels. Buck kills especially are examined closely because we have found that harvest rates are relatively consistent for a given management unit and thus buck kill trends approximate population changes. At this time we also study yearling percentages from age samples to determine recruitment. Upturns or stability in yearling percentages generally indicate satisfactory recruitment, while downturns reflect herd losses since the previous deer season.

Preliminary kill estimates are available soon after the deer season ends and computer-summarized data are available by mid-February.

Just recently (Creed et al. 1979), we developed expansion factors relating long-term-average buck kill to total population. These factors are quickly and easily used by field managers to estimate approximate

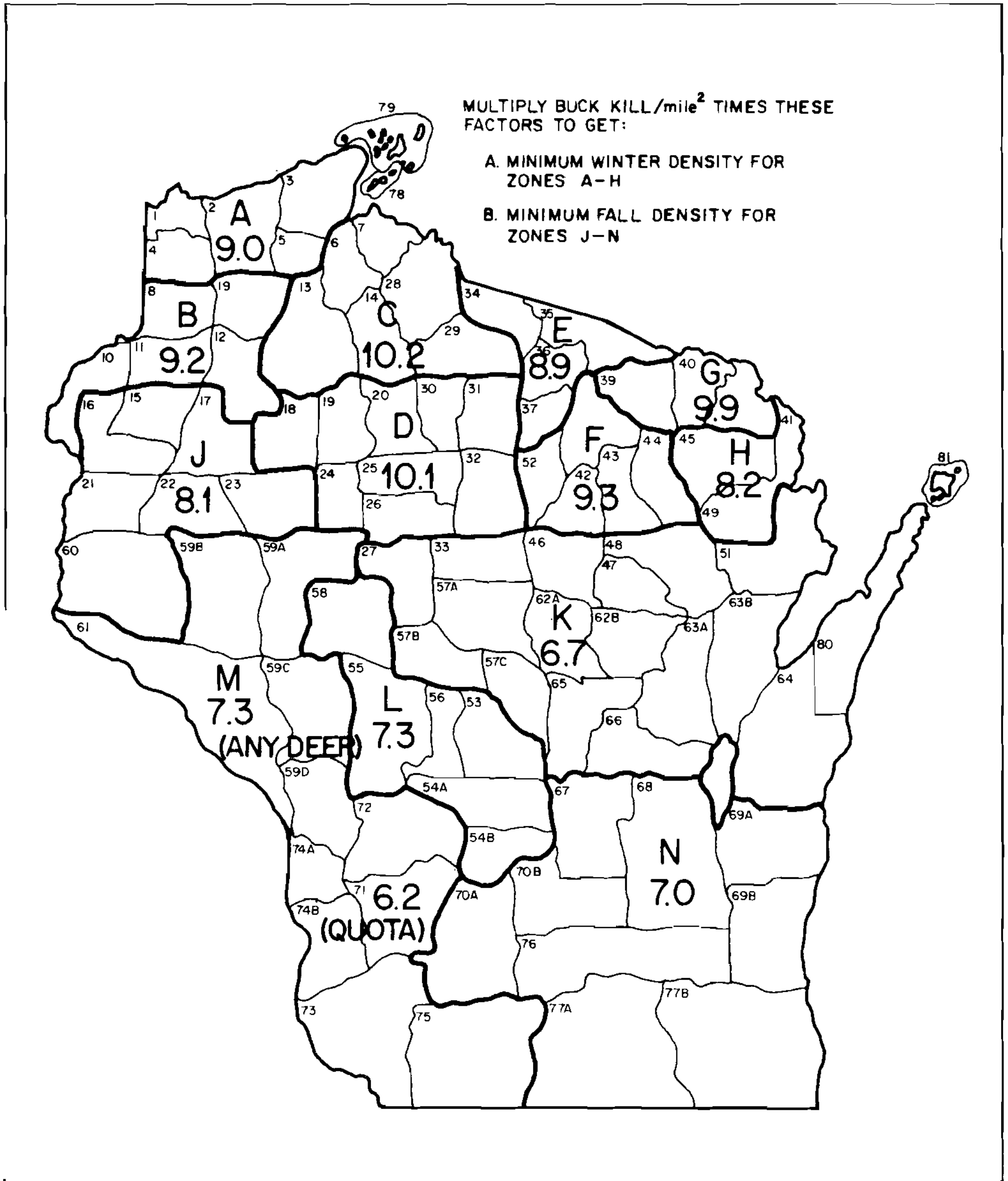

FIGURE 1. *Average buck kill: total population expansion factors by summer observation zone. These are based on sex-age-kill estimates.*

population levels (Fig. 1). Final estimates are computed by the normal sex-age-kill method in early March. By this time, managers are able to update deer management unit histories which chart harvest, population, and hunting pressure data (Fig. 2).

By reviewing and updating management unit histories, managers quickly determine the status of current population levels relative to long-range goals and also assess whether past harvests were consistent with these goals. They are now able to weigh the impacts of antlerless kill rates relative to trends in the buck kill, and adjust their harvest recommendations accordingly.

HARVEST RECOMMENDATIONS

Deer harvest recommendations are based primarily on 3 considerations:

(1) The status of the unit deer population in relation to established population goals (at the goal, or higher or lower) as determined by inventories previously described.

(2) The past effect on unit deer herds of varying antlerless harvest levels gained from 16 years experience with the variable quota system.

(3) The estimated impact of the previous winter's severity on deer survival and subsequent fawn recruitment.

In the beginning years of variable quota management, it was common to harvest from 15 to 25% of the estimated fall population, with heaviest kills in central and southern units and with buck harvests usually exceeding antlerless kills. These harvest rates often failed to halt herd growth when recruitment was good, but were occasionally excessive in years immediately following severe winters.

With the lengthening accumulation of kill histories for individual units, we have improved the setting of antlerless harvest quotas, and we have leaned heavily on buck kill as a guide. Through experience it has been found that most populations will sustain an antlerless harvest of from 70 to 80%

Deer Management Unit History
Form 2300-74

Department of Natural Resources

Management Unit or County: 54A

Gross Area 620 Sq. Mi.	Population Goal Deer/Sq. Mi. 25
Deer Range 431 Sq. Mi.	Total Deer 10,775

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Spring Population Estimate										
Fall Population Estimate (S-A-K)			26.0	29.8*	32.8**	29.8	27.6	33.8	38.3	
Buck Kill	1063	1120	1400	1572	1624	1601	1550	1815	1901	
Antlerless or Quota Kill	255	429	801	1016	1311	1288	1254	1096	1594	
Total Harvest	1318	1549	2201	2588	2935	2889	2804	2911	3495	
Deer Quota Recommended	500	500	800	1200	1400[1]	1300	1300	1150	1600	
Deer Quota Approved	250	500	800	1000	1200	1300	1300	1150	1600	
Permits Issued	350	700	1200	1500	1850	1900	1875	1675	2400	
Yearling Buck Harvest Percent	—	—	—	77.2	82.1	74.0	71.6	79.7	83.0	
Hunters/Sq. Mi. Opening Day	24[2]	28[2]	27	25	34	24	27	—	27	

Remarks:

*Extrapolated by wildlife manager.
**Extrapolated from Zone 1.
[1]First recommended May 8.
[2]For entire Unit 54.

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FIGURE 2. *Sample deer management unit history.*

of the buck kill. This in effect prescribes a heavier harvest in central and southern units where buck harvest rates account for a higher proportion of the bucks available, but also where recruitment is higher than farther north.

Establishing quotas has not yet become a purely mechanical process, but improved predictive capability based on analyses of winter severity has led to a tentative formula system which is being tried for the first time this coming season.

PROCESSING RECOMMENDATIONS

Field wildlife managers submit deer quota recommendations to their respective district headquarters. A consolidated recommendation from each of the 6 district offices is then submitted to the Bureau of Wildlife Management in the central office in early March. The Bureau resolves any differences between districts, reviews the recommendations with the Forest Wildlife Research Group, and prepares a statewide deer quota proposal. The statewide proposal is then returned to the field managers and made available to members of the Wisconsin Conservation Congress prior to official public hearings held in April.

The Wisconsin Conservation Congress is an important organization in the rule-making process for all hunting and fishing regulations. It is an official citizen's advisory body to the Natural Resources Board. Three regular and 2 alternate delegates from each county are elected to staggered 3-year terms by the citizens attending the public hearings. Wildlife managers are instructed to meet with their local Conservation Congress members to explain the deer quota recommendations.

Wisconsin law requires public hearings on proposed administrative rules (regulations). A public hearing on fish and game regulations is held in each county on the 4th Monday in April. Citizens attending vote on the proposals, including deer quotas, and these votes and other public testimony become part of the official hearing record. Wildlife managers are present at many of these hearings to explain and answer questions about the deer quota proposal. The results of these hearings are only advisory and not binding on the DNR or the Natural Resources Board.

The Conservation Congress conducts a meeting of its statewide members in late May or early June. The approximately 300 delegates discuss and vote on the DNR proposals to develop recommendations for presentation to the Natural Resources Board.

At its June meeting, the Natural Resources Board acts on deer quotas for the coming season. Recommendations from the DNR and Conservation Congress and the public hearing results are presented to the Board for a decision. Throughout the time period from early March until the final DNR recommendation to the Natural Resources Board in June, wildlife managers have been evaluating the effects of the past winter and have the opportunity to submit revisions of their original quota recommendations.

Following the Natural Resource Board's decision, the resulting rules are submitted to the Legislature for review. If no objections are raised by the Legislature, after the 30-day review period provided, the rules are published and become the regulations in effect for the hunting season. During the history of this procedure, the Legislature has not objected to the deer quotas proposed. The period provided for public review and response to the proposed quotas has been effective in minimizing legislative involvement in the regulations process.

THE FUTURE

The major problem now facing deer management in Wisconsin is the declining quality of the gun deer season. The activity of more than 600,000 deer hunters is confined to no more than a 9-day period creating a highly competitive atmosphere in parts of the state. Excessive hunter concentrations foster poor hunter conduct and a bad image of the sport to nonhunters. Our deer management policy states another objective as "achieving and maintaining opportunities for a quality deer hunting experience while still allowing to the extent possible, freedom of choice by hunters. Regulations should provide incentives or disincentives to encourage better distribution of hunting pressure. If hunter numbers continue to increase, control of hunting pressure may become necessary."

Efforts to date to achieve this objective have not been successful because of public opposition to change. However, the Wisconsin DNR will continue seeking methods to better distribute hunting pressure over time and area to improve deer hunting quality.

Acknowledgments. Thanks are due Keith McCaffery and Bruce Kohn, biologists with the Forest Wildlife Research Group, Wisconsin DNR, for use of unpublished data and comments on the manuscript. We are also grateful to a large number of wildlife managers, technicians, wardens and others who over the years have contributed in so many ways to the management program we describe. Portions of the manuscript are derived from studies supported by the Federal Aid in Wildlife Restoration Act under Pittman-Robertson Projects W-79-R and W-141-R.

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POPULATION PHENOMENA – THEIR MANAGEMENT IMPLICATIONS

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Abstract: The use of quantitative techniques for summarizing deer data followed close on the heels of the first concerted efforts at collecting data about deer. More elaborate quantitative techniques for analyzing such data were soon developed to provide additional information not obvious from a qualitative examination of the data. Such quantitative analysis techniques have become fairly widespread. While these techniques are an improvement over simple qualitative perusal, they are often limited by considering only a few factors. Mathematical models can be developed to include all of the data about a population incorporating both well-known and hypothesized relationships. Such models need not be computer based, but they will provide a better framework for integrating data into deer management decisions. More importantly, the models can provide an explicit framework for objectively incorporating the feedback, the learning experience provided by new data which measures the response to recent management decisions. While modelling in various forms is being incorporated in more decision making, much still remains purely subjective and poorly documented. In such a system, feedback is much more difficult to incorporate and management is much slower to improve its performance.

INTRODUCTION

Mathematical modelling has been widely incorporated into the business world, greatly improving the performance of decision makers and planners (Ackoff 1970). This does not appear to be true in wildlife management. However, when deer management has reached the scale such that several states are harvesting well over one hundred thousand deer per year, are serving hundreds of thousands of hunters, and are generating millions or billions of dollars worth of recreation revenue, it is difficult to argue that this is not big business. Why have wildlife managers avoided the operations research and mathematical modelling techniques that have proven so useful elsewhere?

One might argue that wildlife managers, like most people, are unfamiliar with using models. This can only be partly true since each of us uses models extensively in running our everyday lives. The way one drives an automobile is based on a conceptual model of how the automobile responds to the various controls such as steering, braking, and throttle. It is easy to see that there are occasions when this model and the decisions based upon it are far from perfect. Almost everyone has had the shock of applying power brakes for the first time; one expects a gradual stop and is surprised to have a very sudden stop. Many have had a more frightening example of model failure when applying brakes in a manner suitable for dry pavement only to discover that the pavement is icy. While most of our models are not explicitly mathematical, some of them are. In fact, many of us use a mathematical model almost every day of our adult lives. A checkbook register is nothing more than a mathematical model of the transactions in a checking account. Actual cash flows into and out of the checking account can occur in a very different order than in the register. In fact, depending upon how well the register is kept, one may have experienced the surprise of finding that the model is imperfect – when a check bounces.

Certainly it appears that wildlife management problems are more complex and less well defined than traditional business problems (Halter et al. 1972). Wildlife managers must consider a wide variety of factors when making decisions regarding the management of a game population such as deer. The wide variety of subjects covered in this volume attest to the complexity of the decision-making process. And yet, deer managers still talk a great deal about deer numbers: numbers born, numbers surviving, and quite importantly, numbers to harvest. Gabrielson (1951) pointed out that after considering all the other factors, the wildlife manager must first and foremost control harvesting by humans so that a breeding stock remains.

Wildlife managers should take advantage of every available tool for making the task less complex. It appears that one very useful tool, population modelling, has been neglected although it has the potential to increase the manager's ability to use population information.

It has been suggested that the newness of population modelling has held up its use. However, the idea of using population

Burgoyne, George E., Jr. 1980. Population phenomena – their management implications. Pages 89-94 *in* Ruth L. Hine and Susan Nehls, eds. White-tailed deer population management in the north central states. Proc. 1979 Symp. North Cent. Sect. Wildl. Soc. 116 pp.

models in population studies and population management has been with the field from the very beginning. Through the discussion of the history of population study by Allee et al. (1949), one can trace conceptual models at least as far as Plato (Cole 1957). However, truly mathematical aspects of population study did not appear until the 17th century (Eberhardt 1969).

Looking back through the wildlife management literature, there are many discussions of both conceptual models and explicitly mathematical models. Trippensee (1948) talked about the subject in his discussion of variations in the numbers of wild animals, as did Gabrielson (1951) in his discussion of population controls. The very first article one finds in the first volume of The Journal of Wildlife Management is a mathematical treatment of pheasant mortalities by Errington and Hamerstrom (1937). Even earlier, in Game Management, a book wildlife managers might think of as "The Bible" of wildlife management, Leopold (1933) dealt very explicitly with both conceptual and mathematical models. His breeding potential charts and the accompanying discussion could not provide a clearer foundation for the use of mathematical modelling in the field of wildlife management.

And yet, over a quarter of a century later, Ruhl (1959) found it necessary to call for the incorporation of operational research techniques based on modelling to improve big game management in the lake states. While the literature contains many population models, there appears to be very little use of modelling in the actual management of deer in the United States (Caughley 1976).

Perhaps the most widely publicized use of modelling in big game management has been a result of the work by Jack Gross and his associates in Colorado (Gross et al. 1973). Pojar (1977) pointed out several examples where the ONEPOP program actually contributed to the management decision-making process in Colorado. It appears that Wyoming is also committed to utilizing ONEPOP to improve the use of population data in management decisions (Strickland 1979).

Meanwhile in the Midwest, Minnesota has developed its own modelling system and is utilizing it as part of the management process (Karns and Snow 1979), and Indiana uses modelling on military reserves (J.C. Olson pers. comm.). While much less publicized than the Colorado work, Pennsylvania has developed its own modelling system for deer management and has been using it since 1966 (Lang and Wood 1976). By now virtually every state has attended Jack Gross' modelling workshops in Colorado. In addition, 20 states have received their own copies of the ONEPOP program (T. Pojar pers. comm.). In spite of this, only a small number of the states have actually incorporated population modelling in their management decision-making process (Pojar and Strickland 1979). Contact with the North Central states reveals that many states hope to incorporate modelling into the management process in the next few years. However, both Ohio and Wisconsin utilize their own version of the age-sex method analysis technique developed by Eberhardt (1960) while in Michigan.

VALUES OF MODELLING

Since we have already concluded that all wildlife managers are already using mental models, why should one pursue the further development of models outside the brain? Why should one attempt to incorporate mathematical modelling in the management of wildlife populations?

The first benefit to be gained is that the person writing down his ideas for a model will find that it helps him to clarify and learn about his own ideas. Secondly, defining a model outside the manager's head makes it available for other workers to learn from and to improve upon.

Often touted as a major benefit of mathematical models is that the models can handle more factors than a human brain. In fact, the brain can handle a large number of factors, but it appears to lump them into smaller groups for separate consideration. A problem arises in that there is no requirement that these separate considerations reach consistent results. The model's advantage here then comes from the idea that by explicitly defining a model outside the mind, it is possible to build in checks for consistency.

After the modelling work has become sufficiently sophisticated, one may take advantage of certain types of mathematical formulations that permit solving for unknown values very like solving equations in algebra problems (Wagner 1969). Other, more complex, models can be resolved by using trial and error to explore a variety of alternatives and then to choose the one which seems best. While just the process of developing the model can be quite valuable, there is much more value to be gained by getting the model into actual use in assisting with decision making (Halter et al. 1972).

MODEL DEVELOPMENT

Perhaps the greatest problem in incorporating modelling into the decision making process is that the manager must trust a model's predictions before basing a decision on them. But before one can trust the predictions, it is necessary to understand the basic inner workings of the model (Ackoff 1970). It sometimes appears that model developers look upon their model as the "better mouse trap" and expect that users will beat a path to their doorway. If more thought and time had been devoted to the implementation stage there would be fewer models buried in the literature or gathering dust on someone's shelf.

Our approach in Michigan has been designed to mesh model development with needs and use so that the state does not end up developing a purely theoretical model of our deer population that would go unused because it was not understood. We are exploring the value of theoretical models to contribute to our understanding of the dynamics of the deer populations, and there have been significant findings regarding the information in age structure data (Burgoyne, in press). On the other hand, we are working with our field biologists to utilize the benefits that the most basic forms of modelling can provide. While our deer management program is benefitting immediately, the stage is being set for the incorporation of more advanced techniques to further enhance the ability to manage deer populations.

Early work in Michigan led to the conclusion that 2 beliefs were at fault to a large part for preventing or delaying the incorporation of population models into the decision-making process in wildlife management. The 2 beliefs are: first, that one must be a mathematician to understand modelling and second, that if the modelling works it will take away the wildlife manager's role as decision maker.

Neither of these is true but they have been encountered by people attempting to incorporate modelling into management in other states. Colorado has been actively pursuing work in modelling with ONEPOP longer than many of the rest of the states and yet it appears that they are only now turning the corner on these problems (T. Pojar pers. comm.). It appeared that experience with models would be the only path which would show: (1) that one did not have to be a mathematician to understand modelling, and (2) that modelling would not replace biologist decision makers; it would only provide them a tool.

Deer Population Dynamics Summary

We began an exercise in modelling based on ideas no more complex than adding and subtracting from a check deposit book. The approach is perhaps so trivial that it needs little explanation and yet it can yield such important results that it merits further discussion.

The idea is to have the biologist put together the most basic form of life table for the deer population; combining, from all information sources, the manager's best estimates of additions to and deletions from the population.

This is certainly not a drastic new approach. It seems reasonable to conjecture that deer managers have always had to do something like this, at least informally, in order to put together their recommendations for harvest levels. There are probably unpublished compilations similar to this lying around in the files of every game management agency.

Appendix 1 contains the basic outline for the summary which Michigan has employed for the past 3 years. The procedure for filling out the form is as follows: first, the biologist is required to define the specific area or population he is describing.* The population described may be a district or part of a district. Then he must estimate the initial population in the spring prior to fawning *(A)*. Michigan compiles population estimates from deer pellet group surveys for the districts in our major deer-producing areas; however, the biologists are not restricted to using these figures. Each biologist may start with any figure that he can justify. This could be estimated on the basis of last year's buck kill or total kill, or may be a modification of the pellet survey figure.

Then if the biologist has the information available, he *may* describe the age and sex composition of the deer population at this point *(B)*. Next he must estimate the production of deer fawns, the input of new animals into the deer population *(C)*. In order to predict the population size just prior to harvest *(E)*, he must estimate the losses between fawn drop in June and October 1 *(D)*. At this point he has estimated the population from which he will be removing animals by his recommendations for legal harvest *(F)*. However, the idea of wildlife management is to leave a sufficient residual population to continue to provide a harvestable surplus and yet to fit into habitat and cultural limitations.

*Although I recognize that a biologist may be a man or woman, I have used only the pronoun "he" rather than "he or she" in the interest of avoiding cumbersome reading!

Hence, the biologist must balance his recommended legal harvest against his concept of illegal losses and wounding losses *(G)* to predict the residual population *(H)*. Finally, additional space is provided for recording an assessment of range conditions *(I)* and special considerations *(J)* regarding management recommendations.

The wildlife manager may choose not to fill in the detail if he doesn't believe he has the information, but he must explain how he gets from one step to the next. He must explain his rationale for his figures.

The biologists' responses to the request to fill in this information often fall into 1 of 2 categories: (1) the information to complete that is not available, or (2) why bother with filling out a form like that since we already do that informally?

It is true that hard, scientific estimates of some of the losses are not available, but the wildlife managers must have some general ideas about the relative magnitude of these events in order to have some expectation that there will be a population available to harvest. The biologist can learn something about his own ideas by working through this exercise with what information he has available and examining the feasible ranges for those factors for which he doesn't have good information.

A major benefit of this exercise is that it forces the biologist to examine the consistency of his ideas about the population being managed. As our biologists put together their best information and ideas about their deer populations, they discover that certain combinations of ideas or ideas and data are inconsistent. For instance, a biologist who believes that his population is reproducing at a high rate but is not growing, must put together reasonable values for drains on the population due to natural losses, legal hunting losses, and illegal hunting losses in order to hold the population in check. A biologist is doing more than just making the figures reasonable, he is learning about his own ideas regarding the relative effects of different drains on the population (Halter et al. 1972).

However, an important part of the learning comes when, in the next year, he must again go through such an exercise for the same population. In the interim, he has had some new data such as legal harvest results, population estimates, or observation results. These provide the feedback to help learn whether the population figures assembled the year before were reasonably close. If they were not close, it might point him toward another idea which would help him come closer this year. If he was close, he may be able to refine the ideas to do even better this year.

Certainly this appears to be an extremely simplistic exercise. Yet it provides a structure for learning more about the dynamics of a free-living population about which there is *some* information. Without this written record only a sketchy recall of last year's data and decisions is available to compare with actual results. That sketchy recall inhibits getting full learning experience from successes and failures. Moreover, this will set the stage for further development of mathematical modelling in wildlife management.

When the biologist finds that his last year's estimates were not as close to what actually happened as he would have liked, he must generate new ideas in an effort to make the estimates closer. However, it is time consuming to go back through several years' calculations to find out whether the new idea would have made the previous figures come out closer to what actually appears to have happened. When the project has reached this stage, the biologist can be relieved of the busy-work of the calculations by substituting a computer.

Computer Modelling

A computer-based model can substitute for the biologist's calculator and pencil and paper. It can store many years of data and with the biologist's ideas translated into simple equations, the computer can quickly recalculate to try out new ideas. In fact, this is exactly what models such as ONEPOP do (Halter et al. 1972, Gross et al. 1973). Elaborate computer programs have been developed to make the computer easier for the wildlife manager to use. But the computer model is doing nothing more complicated than the biologist was doing before.

THE MODEL IN DECISION MAKING

This exercise does not end here. Only the busy-work of certain types of calculations has been taken off the biologist. The data must be compiled and processed and the decisions must be made each year. The biologist has seen that the basic structure of the model is no more complicated than what he can understand. Similarly, he can see that the model is a tool to help him understand what is happening, not a replacement decision maker. As other modelling and field research identifies promising relationships between environmental factors and population phenomena, it will be much easier to explain how such relationships can be incorporated into the model to further help the biologist make use of the data. Quite importantly, the simple model provides the biologist a precise framework in which new data or better ideas can be incorporated and a clear background with which to compare the new information.

This system has worked quite well in Michigan. Over the past few years, it has become an accepted part of the process for setting up deer management regulations. The process is not entirely smooth. Some biologists have found that it is sometimes easier to try to argue that one cannot sum losses and gains from a population to get a reasonable resulting population than it is to admit that one's ideas about the losses and gains are inaccurate or inconsistent.

This exercise provides an excellent method for learning about a population and the effects of management practices upon it. Since it organizes all the best information about a population into a simple form, it enhances the chance of incorporating new information as feedback to help learn from experience. It provides a clear, concise document which can be valuable for convincing others of the wisdom of controversial management decisions, and it builds a framework into which new research discoveries and more powerful mathematical modelling tools can be incorporated.

Regardless of the modelling methodology which an organization is developing, an ongoing exercise such as this can help bridge the space between the theoretical model and the management decision process.

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APPENDIX 1: Deer Population Dynamics Summary

Specific area or population description

A. Spring population before fawns

Pellet survey estimate	____
Starting population estimate	____

B. Herd composition June 1, 19____

	Male	Female	Population
1-year-olds			
2-year-olds			
Older			
Total			

C. Fawn production

	Productivity rate	Fawns
1-year-olds		
2-year-olds		
Older		
Total		

Male fawns	Female fawns

D. Losses before October 1

	Male	Female	Population
Fawns			
1-year-olds			
2-year-olds			
Older			
Total			

E. Herd size October 1, 19____

	Male	Female	Population
Fawns			
1-year-olds			
2-year-olds			
Older			
Total			

F. In-season legal kill

	Male	Female	Population
Fawns			
1-year-olds			
2-year-olds			
Older			
Total			

G. In-season illegal kill and wounding loss

	Male	Female	Population
Fawns			
1-year-olds			
2-year-olds			
Older			
Total			

H. Herd size January 1, 19____

	Male	Female	Population
Fawns			
1-year-olds			
2-year-olds			
Older			
Total			

I. Assessment of range conditions relative to herd size

J. Special considerations (including crop damage and car-deer collisions). Pinpoint the areas affected.

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CONVINCING THE DECISION MAKERS

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Abstract: This paper assumes the final decision maker is the political appointee(s) or policy-making body. Decision making begins with determination of objectives based first on biological situation, then on the social and political implications. It is important that all levels of the organization are involved in the process and that the level of knowledge of all participants be as high and as broad as possible. The news media should be given an opportunity to participate in events leading up to the decision as should the decision makers. Those who make the final decision should realize the consequences of a wrong decision.

When we offer the biological recommendations for harvest to Directors, Commissioners, and those people having the final word on the regulations for the deer season, we are recommending them to people who are political appointees, by one system or another. The political selection causes the appointee to become very cautious in affirming decisions which may bring adverse criticism to the appointee and/or the appointor. For the purposes of this paper, the decision maker(s) are the Natural Resources Commission, appointed by the Governor and the Director, appointed by the Commission.

To be convincing to the decision maker(s) then, you, your staff, and all your field people must be firmly convinced, and supportive yourselves, of the biological decision which you are offering.

Probably the best way to elaborate on this subject is to briefly review the period when I was Chief of the Wildlife Division in Michigan. I took over the Division during a relatively low period in its history. The budget was small, about $1.7 million, most of which was for employees' salaries; and as the old axiom goes, "The lower the budget, the lower the morale." Very little was being spent in "on the ground" activities for the people who were paying our salaries, the sportsmen of Michigan. However, legislation had just been passed which raised the deer license by $2.50, $1.50 of which was earmarked for deer habitat improvement in the northern two-thirds of the state. I give full credit for the passage of this legislation to people like "Curley" Davenport, Dave Arnold, John Byelich, and others. As an aside, the term "deer" would have been better left out of the "habitat improvement" because any habitat change is good for some creatures and not so good for others.

During the first couple of months that I was Chief, we reviewed with the Commission several objectives we felt were in order for the "new" Wildlife Division. (I say "new" because shortly after I became Division head we changed the name of the Division from Game to Wildlife to better reflect the broadened responsibilities in modern resource management.) In order to be convincing, we set goals that we felt were realistic, achievable, and of interest to a majority of the publics that we served.

During our discussion on objectives with the Natural Resources Commission, we said that with the receipt of new funds, habitat activities properly applied to summer and winter range, primarily swamp edges and the intolerant tree types (aspen and jack pine), would enable us to double the preseason deer herd in about 10 years.

Our claim made headlines throughout the state, the most prominent one being "One Million Deer by 1980". We heard from some of the more vociferous sportsmen – many who had opposed a license increase because "there ain't no deer". *However, this was our objective and all of our wildlife biologists believed that it was one that could be achieved!* And it was. Although the original target date was 1980, mild winters, and some habitat improvement resulted in our goal of 1 million deer being achieved in the summer of 1975.

In setting this objective, we had to consider the resources involved: the habitat, the deer and their reproductive potential, and the interested user groups. Our habitat biologists believed that by using commercial harvest of the intolerant types and specific habitat management on an additional 30,000 or 40,000 acres of key habitat annually, this goal could be achieved. We all knew the reproductive potential of the animal. Deer, given adequate food during the most of the year, do remarkably well in filling their range. We told the primary interest group, the

Petoskey, Merrill L. 1980. Convincing the decision makers. Pages 95-97 *in* Ruth L. Hine and Susan Nehls, eds. White-tailed deer population management in the north central states. Proc. 1979 Symp. North Cent. Sect. Wildl. Soc. 116 pp.

sportsmen, that with 1 million deer, they could expect a legal harvest annually of 200,000 animals. A kill of this magnitude raised quite a few eyebrows, but we knew what the animal can do given adequate food and cover.

To be convincing to the public, we had to first be convinced ourselves. Consequently, in making these decisions on habitat and on harvest, we involved the people who were closely allied to the resource itself – biologists, officers, and many other field people – in developing the final recommendations or, as we are saying here, the decision.

We faced several challenges within the DNR. First, many of our younger biologists had not lived through the 40's, 50's, or early 60's when Michigan's deer herd probably numbered in excess of 3 or 4 million. Without having the first-hand experience of seeing the reproductive potential of a well-fed deer herd, these younger biologists needed convincing that the harvest could be increased as the range improved. Secondly, some of our biologists were inclined to be a bit provincial and seemed to want to manage the animals as individuals in the local situation. We tried to point out the shortcomings of this kind of management by working together and looking at different situations to encourage broader thinking.

To meet these challenges and explain the rationale for our 1980 goal, we attempted to enumerate the alternatives. With the severity of winter in Michigan in some years, underharvest can be serious. In addition to losing animals, the carrying capacity of the range is greatly reduced. The loss of habitat has a serious detrimental effect on the reproductive potential of the herd.

My advice was – never gamble with the range because the effects and the rebuilding process are long term. If you are not sure of the harvest recommendations, it is better to be liberal than conservative because, with good range conditions, the animal will bounce back in a short time. The range does not have this potential for quick response.

After convincing our own biologists, we next had to try and convince the sportsmen. Some of them, particularly the more vocal ones, did not believe, and still do not believe, that you can harvest more deer and still maintain a stable, high population. I will not go into the oft-repeated, anti-doe hunters' claim that for every doe you shoot you are losing 2 animals, etc., ad infinitum. (That's one advantage to being employed in Washington. I am spared the advice that is so freely offered by the proponents of bucks-only seasons.) I am a firm believer in the "silent majority"! If you are open with your facts to all groups, their support is yours. A resource manager must recommend the best for the resource and people. The "aginers" are always there and always will be, but darn few managers are removed because they are right.

Deer are of interest to many, many people – not all of whom are hunters. Therefore we tried to keep our information on the status of the herd flowing constantly from deer season to deer season. We gave our information to all forms of the mass media to reach as many publics as possible. Weekly papers in the rural areas, the big urban dailies, and radio and television outlets all figured in the process. Field and staff people were on the road, going to meetings, helping our publics better understand plant succession and the animal products, deer and other wildlife. We worked hard to inform for understanding.

In the decision-making process, we tried to eliminate as much opinion, both our own and the vocal minority's, from the decision as we could. Facts, cold, hard facts, were the important thing. It was our feeling that the decision offered to the decision makers (political appointees) should be as purely biological as possible, realizing that politicians are subject to a variety of pressures and are inclined to compromise under such pressure. This was the big question: Would the politicians let us do it?

When it came to the year-to-year decisions that had to be made to implement our long-range goal, we were often forced to make recommendations prematurely, not for biological reasons, but for administrative ones. Acquisition of paper and printing of the law digest too often forced a decision before all of the information had been gathered and analyzed. It's amazing how, in bureaucracy, the tail often wags the dog. I hope this problem has now been solved in Michigan.

The policy makers wanted an early decision so they could give it long consideration. We tried to delay as long as possible to be sure that our offerings were sound. In reality, the final decision should have been made in July or August, but it was usually demanded in May or June. However, these are the shortcomings of the public process.

Needless to say, the "deer meeting", as the June Commission meeting came to be known, was always an interesting one. We would make our presentation, hopefully as objectively as possible, and give our recommendations for harvest. The meeting was heavily attended by politicians, sportsmen, newspaper people, and those representing radio and television.

Members of the Michigan United Conservation Clubs, with a membership of over 100,000, would always support the biological decision. Members of the Michigan Deer Hunter's Association and the Northern Michigan Sportsmen's Association (both purporting to represent about 3,000 members) would always criticize it. As a public servant, it is somewhat amazing to me that spokesmen for a few people seemingly carry the same weight in a public meeting as spokesmen for many thousands of people. Of course, the few, if supported by members of the House of Representatives Appropriations Committee, seem to carry a somewhat larger stick.

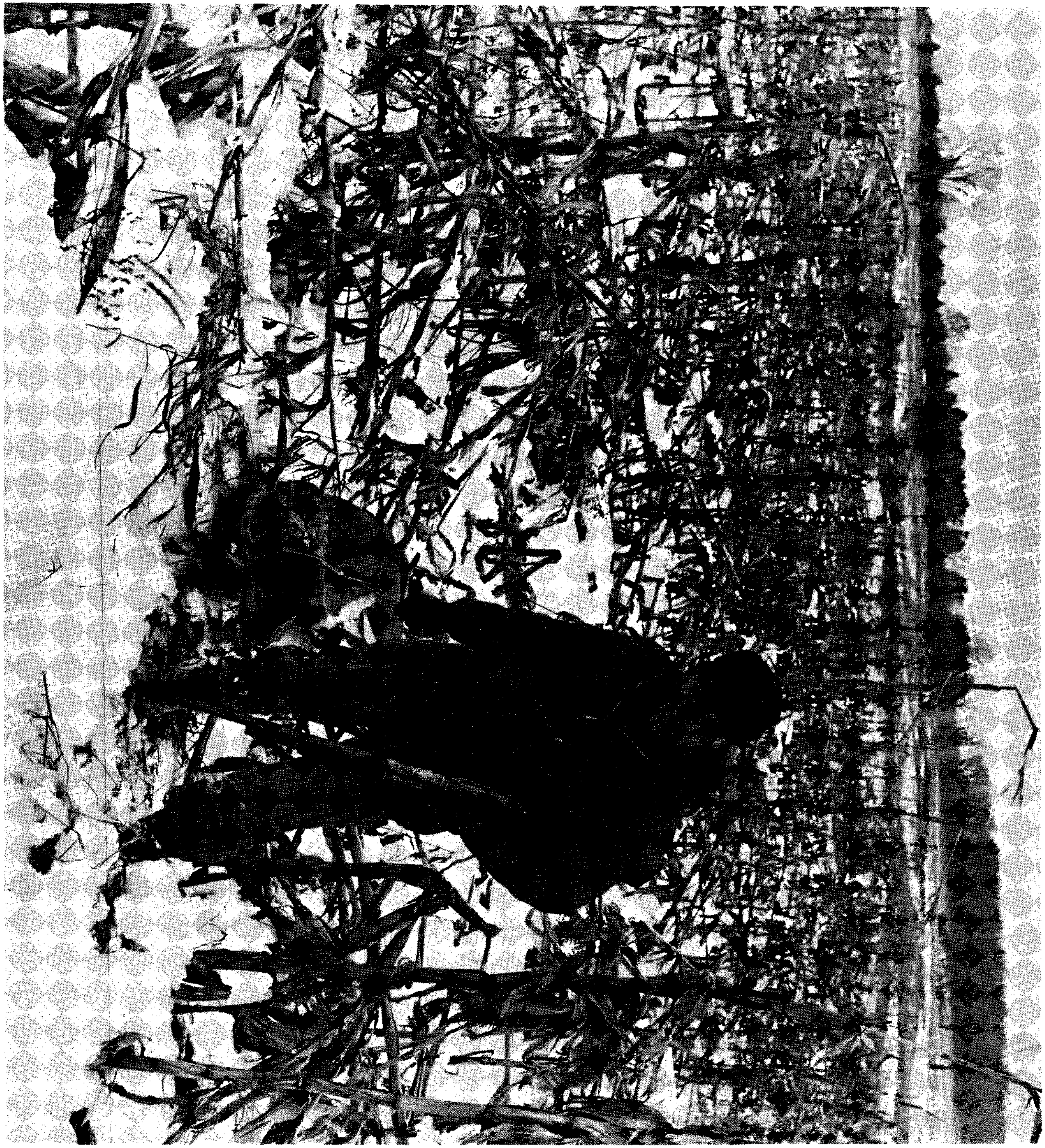
Usually, the anti's were able to force the Commission into a compromise, to the detriment of the majority of people, the range, and the deer. Such compromises are totally irresponsible, and have resulted in the loss of countless thousands of animals, plus unholy deterioration of the habitat. It is unfortunate that the millions of Michigan people who are also served by the DNR were unrecognized by the decision makers. However, few politicians or others are willing to accept the blame for such compromises. It is easier to blame the DNR.

I have found this and similar situations to be encouraging over time. The usually silent citizen, given the facts and an opportunity to participate in a decision, most often makes the right choice. Most resource departments are quite free of partisan politics and the "spoils" system. Citizens have decided this. The "bottle bill", which was recently passed in Michigan and is doing much towards reducing litter, was decided by a referendum. These are good reasons to keep your publics informed on the facts and what you plan to do.

Therefore, following the decision, we kept the people informed through press, radio, and television of the results of the harvest from the several annual deer seasons. Currently, and for the past several years, there has been an archery season of 3 months, a rifle season of 16 days, and a muzzle-loader season of 10 days.

A variety of surveys following the rifle season give an immediate estimate of the harvest which, I am pleased to say, was over 171,000 animals in 1978. Not quite as much as we predicted in 1970, but very close to our prediction and would have been higher without compromise. However, if this record harvest is coupled with the measured starvation losses of over 100,000, it makes our prediction of the early 70's look pretty good. The sad part is the waste of animals for recreation and food, and most of all, deterioration of precious range.

In summary, field and staff together set annual harvest regulations pointed toward a 1980 goal. We informed our interest groups of the objective and the reasons leading to it. We told them what would and would not happen and then after the decision was made and carried out, we told them what did happen when the seasons and winters were over. A history of this kind of procedure is convincing, to say the least. You must believe in what you are doing and stand up to be sure that it is done. Someday, such convincing history can strengthen the decision-making process and help others who must make the final decision.


Michigan DNR

SELLING MANAGEMENT TO THE DEER HUNTER

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THE CLIMATE

All state wildlife agencies have deer management problems that result from lack of acceptance of recommended practices. This is of 2 general types: the unwillingness or inability of the landowner to provide habitat diversity, and the reluctance of certain publics to accept management innovations.

Almost all of the latter–which is what concerns us here–is likely to emanate from hunters. The primary public that must be sold on deer management innovations is, as always, the rank-and-file deer hunter.

Every deer state has its distinct climate of hunter-opinion and mood. This is the result of regional and local traditions, the political health of the conservation agency, and the historic relationships between hunters and the agency. A public relations campaign to promote a management innovation must be adapted, to some degree, to these historic relationships and traditions. The nuts and bolts of the campaign are disarmingly simple in principle. What is far less simple is the execution therof.

Much of the success in introducing deer management innovations or changes in annual regulations lies in anticipating any problems well in advance of action. Overnight crash programs to persuade the public are always ill-advised. Unless, of course, such actions have been necessitated by some natural calamity that the public can readily associate with the need for short-notice innovations. Ideally, long-range shifts in basic management are prefaced with carefully planned public relations strategies–although there's a rather consistent tendency in conservation departments to never patch the roof until it begins to rain.

The anticipation of a management problem is part empirical and part intuitive. The agency must weigh the potential problem in terms of experience: what responses, from what quarters, were evoked by analagous innovations in the recent past? What action was taken, with what effect? Since then, have there been any shifts in public attitudes that could influence the issue today?

CITIZEN ADVISORY GROUPS

One way to assess the climate of public opinion is to solicit the response of a citizen group formed specifically as a sounding-board. For 45 years, Wisconsin has used a Conservation Congress as an advisory body. April hearings are held in each Wisconsin county to air proposed regulations and other actions. People attending these hearings elect delegates to attend a statewide meeting held the weekend after Memorial Day. An average of about 3 persons per county attend this annual meeting as part of the Wisconsin Conservation Congress. They contribute a general response to the agency's proposed regulations and management innovations–they may reflect approval, disapproval, or offer suggestions. Department personnel explain and justify their recommendations–and more often than not, the various factions find common ground for agreement.

Several years ago in Illinois we experienced a severe public relations problem with the issuance of deer hunting permits. There was much bitterness about the allocation of these licenses and their alleged use as political favors. An Illinois Deer Task Force was formed–composed of members of the conservation department, hunters, and other citizens. It was successful in establishing a more equitable system of permit allocation.

In Pennsylvania a new organization, the Pennsylvania Deer Association, has been recently formed of biologists, educators, naturalists, hunters, administrators, and other concerned citizens. It is designed to represent all technical and nontechnical factions with interest in the Pennsylvania deer herd. Management proposals and recommendations are made, evaluated, and modified if necessary. Beyond the fact that certain laymen act as efficient sounding boards of public attitudes, such groups are of value as political buffers. And maybe–just maybe–there may be thoughtful, experienced laymen who know something we don't know.

PROCEDURES FOR CHANGE

But with or without such citizen advisory groups, the deer manager and his or her administrator are certain–sooner or later–to undertake controversial management innova-

Madson, John. 1980. Selling management to the deer hunter. Pages 99-102 *in* Ruth L. Hine and Susan Nehls, eds. White-tailed deer population management in the north central states. Proc. 1979 Symp. North Cent. Sect. Wildl. Soc. 116 pp.

tions. The most common action of that sort is likely to be a particular restriction or readjustment in deer hunting regulations.

Let's assume such a change is being contemplated, and that there's little doubt it will be met with significant opposition. What general course of action should be taken? To begin with, such an innovation must always be based on good data, on findings carefully gathered and competently assessed. This is the most critical step in developing any change in current management. Nothing is more important. Furthermore, the innovation must fall within the parameters of established departmental policy.

In the initial stages, care must be taken to overlook none of the obvious fundamentals. The first steps in any management innovation are critical, for they are the basis of all subsequent effort. For example, any new regulations must be drafted with great care. I was with the Iowa Conservation Commission when we held Iowa's first modern deer season in 1953–a 5-day, any-deer season with a daily bag and possession limit of 1 deer. However, we neglected to set a season bag limit. Several hunters killed 5 deer that week, taking 1 deer each day and legally disposing of it before they went out again the next morning. From the beginning, some newspapers had been sure that outrageous deer season would wipe out Iowa whitetails once and for all–and their fears were confirmed by a Conservation Commission that had given tacit permission for every hunter to kill 5 deer! We were quite awhile digging out from under that one.

Early in the process, everyone in the department must be made aware of the proposed change, its rationale, and its implications. Don't keep anyone in the dark. Enforcement and I&E must be in on the ground floor, of course, but effort should be made to apprise all sections and divisions of the proposed change and the good reasons for it. (Doug Gilbert gives an example of a janitor in a U.S. Forest Service office who happened to be commander of the local VFW post. Although he was at the bottom of the office hierarchy, he proved to be a valuable public influence.)

And again–have similar innovations been rejected by the public? Why? When? Who led the opposition? What were the results?

From start to finish, a good I&E section can be the deer biologist's best friend. Bring the communications specialists in at the very beginning and map strategy. Develop a media contact program. Schedule departmental news releases and magazine articles in a well-developed sequence.

A good I&E section maintains close personal contact with the key media–and particularly newspaper editors and outdoor writers. Missouri is an excellent example of this. Jim Keefe and his people cultivate contacts in the Missouri Daily Press Association, meetings of that association are attended faithfully, and close liaison is maintained with key editors and writers. This is the front line of public relations and every effort must be made to cultivate a solid working relationship with the press. Finally, there is an axiom that all game managers should have tattoed inside their eyelids: *never* get into a fight with anyone who buys ink by the barrel!

Start your public relations campaign at a modest and reasonable level–especially if the management innovation isn't initially controversial. But if and when it begins to heat up, stand ready to call in your shock troops. You should have a list of key allies on whom you can count all the way–zealous friends who'll throw their full weight into the fight at a moment's notice. It is important that you keep in regular touch with such people, keeping them up to date on basic developments. They should hear from you frequently, and not just when you're in a jam. Use them sparingly and only when really necessary, and don't cry wolf. However, if it's a choice between being undergunned or overgunned, take the latter course. Always use enough gun–but not too much. Again, the competent I&E section will know what caliber of public relations to employ.

DIRECT PUBLIC CONTACT

Few public relations strategies are more effective than direct contact with the public. This can take several forms: open public hearings, presentations to specific groups, and one-to-one contact with key individuals.

Open public meetings will include the landowners, naturalists, environmental activists, and some hunters, while the sportsmen's club contact focuses on hunters. Beyond these are the individual "engines of public opinion"–the influential local citizens. They may be ministers, doctors, lawyers, businessmen, sporting goods dealers, barbers or bartenders.

Every community has persons who exert considerable influence on resource management attitudes. These key local contacts are important even though they may have fought your programs in the past. Over the years I've known several local "engines of public opinion" who habitually opposed departmental policy because they had been alienated by what they construed as arrogant, overbearing behavior by public servants. What they appeared to want more than anything else was a measure of recognition–and were bent on raising hell until they got it. Some patient, personal attention may work wonders with such critics.

Whatever the reason for opposition to management, a personal confrontation with a particular editor, legislator, landowner, resort owner or sportsmen's club president can often have astonishing results. Who should make these contacts?

If it's a key issue being blocked by a key critic, the conservation director should make the contact. Even if resistance to the innovation is widespread, it would be wise for the director to hit the sawdust trail. Because what we're talking about here is active politicking–and there's no substitute for stumping the electorate. For one thing, it's flattering to a club, legislator, or newspaper publisher to be called upon by the head of the agency. The director may make more political hay in one hour with a publisher or editor than a biologist could accomplish with an all-day seminar. Not only that, it is often the director's immediate responsibility, for the real I&E chief of any conservation department is, or should be, the director.

The biologist's prime function is to provide his or her chief with the best field data possible. It is up to the boss to translate that information into management decisions that make biopolitical sense. If the director makes a crucial management decision with the use of your data, he or she is the logical person to explain and justify that decision to the key publics in the state. One way of doing so is by heading, say, a 3-person team that includes a uniformed biologist standing ready to reinforce the director's statements with easily understood material, and a uniformed I&E person to conduct a compact, well-organized visual program.

Never underestimate the effectiveness of a good slide presentation. Most slide shows aren't much good. But there should be people in your I&E section who can provide top-quality slides and advise you in making smooth, tight narrations. In the field or in an auditorium, keep the basic message simple. Always remember: the capacity of the average listener to be confused approaches infinity–and so does the capacity of the average biologist to be confusing. Don't wear out your audience; don't tell them more than they want to know.

I'd also like to put in a good word for the show-and-tell field trip. Like the slide presentation, it can be a boring flop that does more harm than good. It can also be immensely effective if it offers some graphic demonstrations and *if* it is properly planned and publicized. Field trips should focus on the most dramatic and easily understood situations. For lay appeal, no computer printout can possibly compare with a high browse line or some necrotic jawbones.

If there's one thing we can be sure of in game management, it's the necessity for perpetual repetition of fundamentals. To this end, there should be certain public relations perennials–materials that can serve from year to year rather than just during annual campaigns. Good motion pictures are the best example of this.

Missouri has met this continuing need with a series of superb motion pictures covering the life histories, biology, and management of certain major game species: cottontails, bobwhites, mallards, doves, turkeys, and Canada geese. This is long-range public relations at its best. Yet, I've always been puzzled by the lack of a Missouri film on deer. Obviously, the decision makers have not felt such a film is necessary. The official wisdom must be that Missouri deer problems do not warrant a major film effort–and they should know. However, the day will surely come when a good deer film is needed in the excellent Missouri film series. As a matter of fact, I can't recall ever seeing what I consider to be a truly effective motion picture on life and times of the white-tailed deer.

THE WRITTEN WORD

Running a close second in perennial public relations value is a comprehensive paperback deer publication. The most popular in our Winchester-Western series of booklets on major American game species has been "The White-Tailed Deer", which now sells at its production cost of $2. It has gone through 6 printings, and we are about to order a 7th. Like the Missouri wildlife films, our deer booklet is a popular translation of technical biological and management materials, and there's a never-ending public appetite for such things.

Like it or not, we're all in the business of product promotion just as surely as any toothpaste company. And there's something to learn from the toothpaste commercials. Some of the most effective are ones that don't tout their product for the good of the resource, i.e. good dental health, but because it will improve our love lives. Selling the public in general, and the hunter in particular, on good deer management is most effective if that public is convinced there's something in it for them. Your best public relations, obviously, is persuading the hunter that your proposed regulations or management innovation will benefit hunting by benefiting the deer resource. And the only way to execute that persuasion is with honesty, simplicity, and directness. The converse of that is the worse possible public relations: duplicity, complexity, and evasion. Unfortunately, those elements have prevailed in too many resource conservation programs.

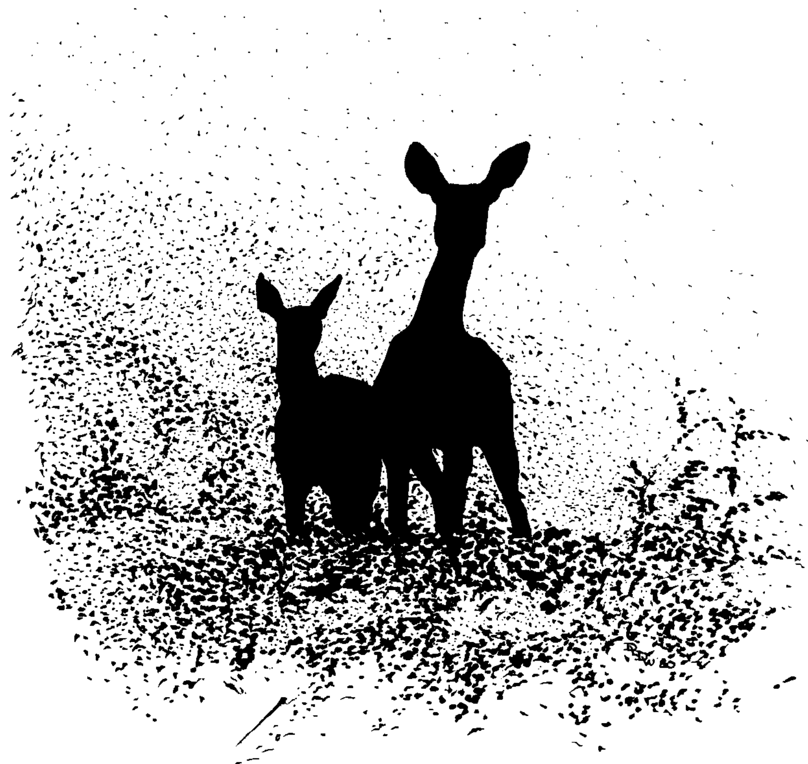
THE UPSHOT

In his book "A Voice For Wildlife", biologist Victor Scheffer commented: "During its 40 years of existence, professional management has been weakened by inbreeding; in this respect it resembles the professions of education and medicine. The consequences are narrow vision, resistance to change, emphasis on structure at the expense of broad helpfulness, and a dwindling sense of humility." All of these shortcomings are dangerous, but in public relations terms none is more serious than that "dwindling sense of humility." Nothing can be more effective in hardening public resistance to management innovations.

Yet, in broad terms of public relations with the rank-and-file hunter, we have certain advantages today that are greater than ever before. More and more hunters (not just the leaders, but the rank-and-file as well) are realizing that one of the best basic supports of their act of hunting is the fact that it's conducted in concert with professional game management. Without such game management we would have nothing but emotion with which to counter emotion–and that's a contest I do not think we could win. Our modern systems of hunting are wholly dependent on competent game management and its support by the hunting public. Such management is the only solid ground from which we can defend the sport of hunting–

and the lack of it is the only solid ground from which our enemies can attack.

Convincing the hunter of this is the strongest kind of public relations. And again–first, last, and always–good biology must precede and supersede any public relations program. There may be an exception to that: when an intense public relations effort is required to establish a solid, professional game management system in the first place. From that point on, the most basic and effective public relations result from the good biology they helped create. To think otherwise is to build a house from the attic down.



DEER MANAGEMENT FOR WHAT?

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INTRODUCTION

Sponsors of the symposium requested that some information on public aspects of deer management be included. In response, a lengthy literature review was prepared on ~~people and deer (Langenau 1979a) and was~~ submitted as a working paper. This review is available upon request to the Rose Lake Wildlife Research Center. The review included 57 pages of text plus an 11-page bibliography and could not be reproduced in its entirety in these proceedings. The purpose of the current paper is to summarize the literature review and to highlight key results of research on public aspects of white-tailed deer management.

INTEGRATING PRINCIPLE

Literature on people and deer is considered in the context of a "multiple-satisfactions" policy (Potter et al. 1973). This approach recognizes that a wide variety of satisfactions are derived from wildlife-oriented recreation, and that these satisfactions are measurable and can be used to establish goals and evaluate wildlife programs (Hendee 1974).

Langenau, Edward E., Jr. 1980. Deer management for what? Pages 103-5 *in* Ruth L. Hine and Susan Nehls, eds. White-tailed deer population management in the north central states. Proc. 1979 Symp. North Cent. Sect. Wildl. Soc. 116 pp.

TOPICS REVIEWED

Research on Public Groups

Deer Hunters. Review of literature on the characteristics of deer hunters showed that these individuals are not much different than the general public (Hendee and Potter 1976), despite stereotypes that they are less educated, rural, and blue-collar workers. Research has also suggested that the number of hunters will increase in the near future but that the quality of hunters will probably decline (Langenau and Mellon 1980).

Landowners. About 58% of the big game hunting in the United States during 1975 occurred on private land (U.S. Fish and Wildlife Service 1977). Much of this hunting included the landowner and friends or relatives of the landowner. The percentage of landowners who hunt deer has increased during the past 20 years (Evans 1979). It was concluded that state wildlife agencies may be over-identifying with the hunter who does not own land.

Literature on the trespass problem was also summarized, with the striking finding that the ratio of trespassers to hunters given permission has been as high as 1.3 to 1 (Brown and Thompson 1976). The granting of permission for strangers to hunt on private land is related to crop damage from deer (Queal 1968). However, landowners have tolerated substantial losses in exchange for the presence of deer (Brown et al. 1978).

Nonconsumptive Deer Enthusiasts. There are 3 nonconsumptive deer users for every deer hunter in Michigan (Langenau 1979*b*). These recreational uses appeared to be compatible in the field because of the seasonal nature of deer hunting and the renewable nature of the resource. More (1979) has thoroughly discussed policy issues concerning nonconsumptive wildlife recreation.

Violators. In general, violators are younger and more often of local, rather than urban, residence (Melynk 1978). They are also normally the more proficient and skilled hunters (Jackson et al. 1979). The chance of getting caught taking a deer illegally in Michigan was shown to be 1 in 200 (Stoll and Hussain 1979). Research has suggested that a primary effect of illegal activity is the reduction of satisfaction among other hunters (Purol et al. 1978).

Anti-hunters. Research has shown that 30-60% of the public is opposed to hunting, depending on the region of the country and wording of the question (Shaw et al. 1978, Kellert 1978). A notable finding has been that there is *not* a large group of undecided individuals to be swayed in either direction (Applegate 1975). Characteristics of people (Applegate 1973*a*), levels of wildlife knowledge (Wywialowski 1977), and basic perceptions that people have about wildlife (Kellert 1978) are strongly related to anti-hunting sentiment.

Management Preferences of Deer Hunters

The limitations and uses of opinion polls were discussed at some length in the literature review. Results of research on the attitudes of deer hunters were summarized on several issues: paying for the right to hunt, trophy hunting, introduction of exotic species, scientific wildlife management, control of hunter densities, and antlerless deer hunting.

Vehicle-Deer Collisions

Biological and economic aspects of this problem were presented in the review. Vehicle-deer collisions have significant economic impact, with cost estimates of about $10 million annually just for the State of Michigan (Hansen 1978). People who have been involved in accidents with deer do not want less deer. They do think that deer are more abundant than those not involved in vehicle-deer collisions.

Deer Hunting Accidents

Deer hunting is safer than many other outdoor recreations and 3.7 times safer than driving to and from deer hunting sites (Ryel 1973). Results of research on hunting accidents have shown that being hit with stray rounds was not very common: muzzle to victim distances were usually 10 yd or less, most hunters were shot by members of their own party, and many hunters shot themselves (Kerrik et al. 1978). Studies have shown no difference in accident rates under bucks-only or either-sex regulations and there has been no statistically significant relationship between accident rate and hunter densities (Jenkins 1960).

Social Impacts of Deer Habitat Improvement

The advent of Environmental Impact Statements has increased the need for research on social impacts of management. Studies of trail development (Thomas et al. 1976) and clearcutting (Bennett et al. 1980) have shown positive hunter response.

Deer Hunting Satisfaction

The dimensions of satisfaction in hunting have been thoroughly studied. Commonly reported factors have been nature, escapism, ingroup companionship, shooting, skill, vicariousness, trophy display, harvest, equipment, outgroup verbal contact, and outgroup visual contact (Potter et al. 1973). There has been some disagreement as to the importance of kill. Some authors have found killing deer to be unrelated to satisfaction (Kennedy 1974), and others report a need for some minimum probability of success (Stankey et al. 1973).

Economic Aspects of Deer Management

Wildlife economics is a rapidly expanding discipline, evidenced by the review of 691 references by Leitch and Scott (1977). The most commonly used figure for the value of a day of big game hunting is $50 (Horvath 1974), although estimates vary by method (Hoover 1976). Economists are also beginning to evaluate deer management programs with benefit-cost and cost-effectiveness analyses (Hansen 1978).

Communication and Education

Research findings indicate that deer hunters lack basic knowledge about wildlife management (Watson et al. 1972), but that the general public is even less informed (Applegate 1973*b*). Anti-hunters have less knowledge about the environment than nonhunters and hunters (Dahlgren et al. 1977).

The literature review summarized findings on media use and potential for education of target groups. Education of hunters in the field through interpretation of population changes and with management demonstration areas was also stressed.

MANAGEMENT IMPLICATIONS

A significant number of general and specific recommendations were made in the literature review. It was concluded that sociological data have an important role in deer management but that these data should be collected and used together with biological data. The consequences of using and not using research findings on public behavior in program planning were discussed. It was argued that an outline for action must be formulated to apply this type of information. Specific recommendations were made to managers and researchers on how to proceed with the management of deer for public benefits.

Acknowledgment. Supported in part by the Federal Aid in Wildlife Restoration Act under Pittman-Robertson Project W-117-R.

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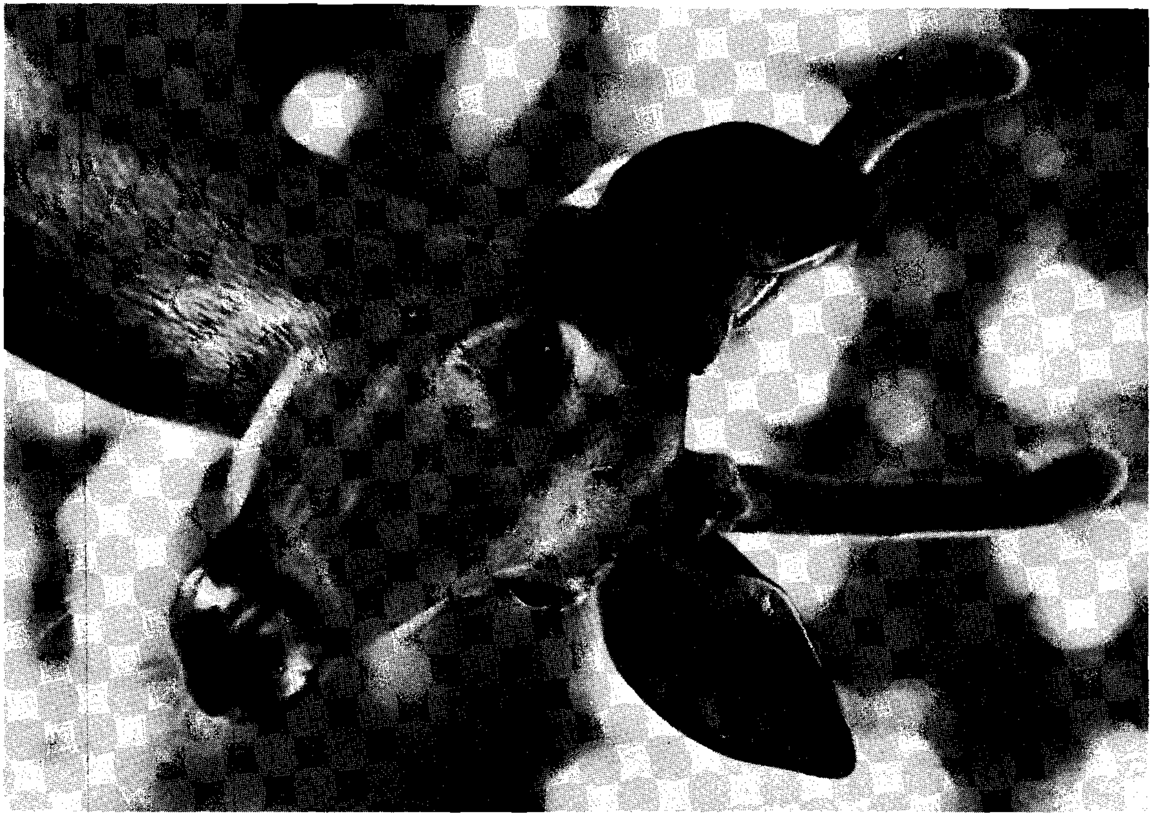

Wisconsin DNR

WHITE-TAILED DEER MANAGEMENT IN THE MIDWEST – SYMPOSIUM SUMMARY

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INTRODUCTION

The presentations at this symposium, and the discussions which each has stimulated, have revealed not only some high points in our current knowledge of white-tailed deer management but also reflect some trends. We now address the challenge of pulling together the highlights, the significant points, the threads of this symposium. As a result, we hope this summary will serve as a stimulator for thought and action in the future.

Eleven years have elapsed since the last white-tailed deer symposium in the Midwest (U.S. Forest Service 1970). In 1968, participants at the 30th Midwest Fish and Wildlife Conference held a symposium on nonyarding white-tailed deer populations in the Midwest covering issues of habitat quality and distribution, range appraisal, and use of agricultural lands. Now we have focused attention on both yarding and nonyarding deer populations in the Midwest, and have emphasized such diverse issues as population dynamics, harvest monitoring, aging techniques, and involvement and cooperation of various publics.

Karns reviewed the changes in deer management in the last 10 years. We have seen advances in technology and new emphases in technological applications. The use of telemetry and computers has expanded and extended our management capability. There has also been a gradual shift in basic management concepts, from a game concept emphasizing single species, to broader considerations of wildlife species and an ecosystem approach to management. It is interesting to look at this symposium and compare what we have heard here in light of these trends.

PARAMETERS IN DEER MANAGEMENT

Those of us who are primarily big game biologists and have been in this business for a while have watched these shifting emphases in the basis for white-tailed deer management. In the 1940's and 1950's the emphasis was on food supply and range quality; habitat surveys were "in". We measured the annual growth of selected browse species in the fall, then measured the amount remaining in the spring and determined the percentage of available browse consumed. Plant species composition was also figured in. Thus biologists could determine if the herd exceeded its food supply.

At the 1968 White-Tailed Deer Symposium, Verme (1970) observed that in midwinter deer become less active and speculated that this phenomenon could be a physiological downshifting as a survival mechanism. That speculation has now been substantiated, and we are using this knowledge in our management. Now we talk about deer physiological limits as affected by temperature, and numbers of days and depth of snow. Karns, referring to Minnesota, Michigan, Wisconsin, and Ontario, has shown the use of such calculations for estimating overwinter deer losses.

The pendulum has swung from food supply to broader issues of population dynamics and conditions. The trend from habitat evaluation to use of population dynamics is a good trend, one leading to a more balanced, more refined approach to management. It shows a sophistication in the use of tools available to the modern wildlife manager.

Burgoyne has shown that mathematical models incorporating many factors can give us a better framework for management decisions. Not a paper today focused on habitat as a single issue. Yet, the importance of habitat to the total well-being of deer cannot be disputed. Habitat needs will be a topic at the 1980 Midwest meeting in Minnesota. Porath has shown us that certain herd characteristics, such as fawn mortality, are importantly interrelated with habitat quality. Harder discussed deer reproduction as influenced by the females' diet. Karns and Creed and Haberland related weather, habitat, and winter severity to winter deer mortality in the northern range.

Costs are becoming a more important part of management considerations. Mooty pointed out that a broad ecological approach to management is not only biologically sound, but economical too. Gathering as

Cook, Robert S. and Rebecca Field. 1980. White-tailed deer management in the Midwest – symposium summary. Pages 107-10 *in* Ruth L. Hine and Susan Nehls, eds. White-tailed deer population management in the north central states. Proc. 1979 Symp. North Cent. Sect. Wildl. Soc. 116 pp.

much needed data as possible during our censusing efforts makes good sense and reduces the cost per unit of information.

Time has allowed the accumulation of much data on deer populations and their habitats. It is the refinement of these data and in our methods of using them that has led to our present high level of herd control through harvest. We have heard repeatedly in this symposium that statistically reliable population estimates are essential to deer herd management. Although a number of suitable methods have been discussed, no single method seems to serve all needs best. Gladfelter recommended data from car-killed deer for an accurate economic source of reproductive data. Harder pointed out that natality and reproduction provide basic information in estimating population size and setting harvest quotas. While most such data are used to characterize past populations, the application of computers now offers us opportunities for advanced predictive capabilities. We can begin to ask "what if" questions that arise when considering a variety of alternative management decisions. Burgoyne reported that Minnesota, Colorado, and Pennsylvania have incorporated mathematical models of population data into their deer management. Also, several other north central states are planning to make modelling systems a central part of their management decision-making process.

In discussing legal kill and the usefulness of the resulting data, Ryel showed that compulsory deer registration provides more timely and acceptable information than do hunter report cards and mail-back questionnaires. The illegal kill, however, as discussed by Beattie, Cowles, and Giles, seems to be an area of deer herd statistics that has often been overlooked, although there are methods to use in estimating illegal kill. This factor in deer harvest regulation could become increasingly important as the increased cost of living enhances the attractiveness of poaching and legal complexities add to the problems of the law enforcement officers. Cooperation of the public is vital in suppressing illegal kill, yet obtaining reliable data on this segment of herd loss is still a problem.

Age ratio determination is basic to herd management. Roseberry has shown that the techniques for obtaining the basic age information, separation of fawns, yearlings, and adults, are quite adequate although not infallible. While much time and money has been spent on aging to the year class, this detailed information does not seem essential for most management needs. However, if computers are used for predictive modelling, detailed age distinctions may be worthy of more effort. As pointed out by Roseberry, it is disturbing that age data are often not comparable between states due to different techniques and interpretation. It is regrettable to think that a pooling of age data for several midwestern states could be impeded by lack of coordination. This constraint may prevent us from characterizing white-tailed deer populations on a regional basis. How to deal with and correct such inconsistencies could be addressed in future symposia such as this one.

In other respects white-tailed deer management is becoming much more concise in the Midwest. Creed and Haberland have described a program for Wisconsin that appears basically sound and is strengthened with every year of experience. The core of the program is a series of calculations that have shown, over time, rather consistent correlations leading to 3 fundamental considerations upon which harvest recommendations are based. These considerations are status of the deer population in relation to the goal for that population, past effects on the population of varying antlerless harvest, and estimated impacts of the previous winter. While Wisconsin and other states are on the way to balancing herds, habitat, and harvest, the well-calculated results and harvest recommendations still must meet the test of public acceptance.

INVOLVING THE PUBLIC

Petoskey and Madson, as well as others, pointed out the 2 major components of any good management program: (1) sound biological data and interpretation, and (2) a well-planned program for engendering the understanding and support of the majority of our constituents for our management decisions.

Most of the papers in this symposium which dealt with the biological data for deer management also referred to the need for public contribution, or at least understanding and acceptance of the data base. The involvement of the public was acknowledged at this symposium in complying with harvest registrations, providing reproductive tracts, and locating fawns.

Langenau recognized a special public group, private landowners. With the high percentage of hunting occurring on private lands, landowners can have a direct role in deer management and harvest.

Systematic evaluation of public attitudes, especially those of user groups, must be a factor in assessing the success of any resource management program. A recent study conducted by Dr. Stephen Kellert of Yale University, financed by the U.S. Fish and Wildlife Service, has sampled the attitudes and behavior of all Americans toward wildlife and their habitats (Kellert 1979). That study should be helpful in improving our understanding of the nonhunting public.

Langenau found that nonconsumptive users of game species have generally been ignored by managers although white-tailed deer are high in public preference. He reviewed the effects on management of hunter and nonhunter attitudes towards wildlife. Langenau suggested that a well-planned education and communication program can be a useful tool for managers in influencing user understanding and preferences.

Educational research in wildlife management appears to be a badly neglected area. Langenau cited several studies indicating that both deer hunters and the general public understood little about basic deer biology and management. Public involvement and attitudes in management decisions make public education and information programs all the more important. A well-planned program for educating and informing our publics must focus not only on the finished management recommendations, but on all phases of deer ecology – from an understanding of deer and their habitat and winter stress to such things as reproduction and censusing.

As Madson said, we are in the business of product promotion. He encouraged managers to sell the public on the need for solid, professional wildlife management, *and then* on the management recommendations that follow. Both "sales" must be based on dependable biology, the management partnership between agencies and their public, and the perceived welfare of the resource they both seek to perpetuate. "Selling" a program to the public is a vital part of any management recommendation. The public must "buy" the idea to make the project more than just an intellectual exercise for the managers. Advertising is based on the simple goal of creating a market and promoting acceptance of an idea, a product, or a program. Private industry does a tremendous job–how well are we doing?

As Petoskey clearly pointed out, the selling job begins in our own agencies. Our efforts must be effective inside our agencies before we go "outside". It is a discomforting truth when one realizes that some of our greatest antagonists may exist in our own organization. For every outside critic or opponent, there is too often a person on the inside willing to supply them with a premature draft or other information not yet ready for the "light of day". Good cooperation must begin at home. Good education must begin at home.

Outside of our agencies, interests in white-tailed deer are diverse and include many groups. Many midwestern states already have programs designed to include the public in the decision-making process. Madson and Creed and Haberland referred to the role of the Wisconsin Conservation Congress in directly involving the hunting public in management. Other publics to include are conservation organizations, environmental groups, legislators, and local or regional organizations as well as individual, influential decision makers. Petoskey reminded us that the more people are involved in the decision making, the better the decision will be and the better it is accepted. That is good advice for the states as well as the federal agencies. In his 1978 Environmental Message, President Carter gave emphasis to this important management dimension.

The Fish and Wildlife Service and many states are initiating a new thrust in public involvement and understanding. We are seeking to involve the public in problem discussion before management decisions are made rather than telling people about the decisions after they are made. For example, we need to let the white-tailed deer lovers of North America know why deer distributions are affected by logging in the northern limits of their present range and why that habitat is changing back to the climax stage, making it less capable of supporting deer. If that kind of educational approach doesn't help generate understanding as well as support for our programs, it should at least raise the intellectual level of the arguments.

It is our obligation as public officials to provide education and background information to the people on the management decisions affecting their wildlife. As Russell Train has said, "It is the American people who own America's wildlife with both the Federal and state governments exercising control of that wildlife in their role as trustees of the people" (Train 1978:276).

We must work among ourselves as well as with private organizations and the public if we are to perpetuate our resources in this age of accelerated consumption and economic motivation. It is through single species symposia such as this that experts in specific areas can share their research and advance the techniques, hypotheses, and ideas of others. The sharing of knowledge and experience among professionals is all too often confined to successes and not failures; it is only through sharing both that our science really progresses.

The Fish and Wildlife Service, as well as other federal agencies, has encountered several problems solved only through cooperation and coordination with states and other interested groups. Through the shared efforts of many, we were able to get a grip on the chlorinated hydrocarbon problems and we are working together to save our wetlands, our migratory waterfowl, and many of our endangered and threatened species. Faced with a growing need for well-trained resource managers, we established cooperative agreements between the Fish and Wildlife Service, state agencies and state universities for graduate training of fish and wildlife biologists through 50 Cooperative Research Units across the country. Similar cooperative agreements are being developed to enhance extension education efforts.

THE FUTURE

Looking down the road, what new problems are facing us? If we meet here again in the Midwest in 1989 to share the latest in white-tailed deer management, what will be the most pressing issues?

We predict that the demands on deer habitat will increase and become more entwined in the interrelationships with other management problems. There are 2 topics we would like to mention that have special potential for significant modification of deer habitat and will require major cooperative efforts to deal effectively with them.

The first is acid rain, of more significance currently for our fisheries resources, yet one which could lead to significant vegetative alterations in the future. In August 1979, President Carter identified the acid rain problem as a new national initiative in his second Environmental Message. Although the problem is large, current research efforts are fragmented. Cooperation has extended to an international level. A scientific advisory group was set up in 1978 at the mutual request of the U.S. and Canadian governments to examine data on long-range transport of acid precipitation and other air pollutants.

The pH of certain Canadian streams has already been altered to the point of interfering with spawning of anadromous salmonids. Breeding populations are being established in hatcheries in order to preserve the affected genetic strains. If ground water, surface run-off, and riverine systems can be so affected, what about soil micro-organisms, soil acidity, vegetation types and, ultimately, the deer and other vertebrates? This is a red-flag issue that must be watched carefully.

The second topic is habitat modification resulting from energy demands on forest products. Such fuels as gasohol and just wood for home and industrial heating have great implications for forest inhabitants, including our white-tailed deer. Right now the possibilities seem remote. However, with face-cords of firewood priced up to $80-$125, the economic motivation is there and farm woodlots are close to the market. Which impacts are beneficial or harmful will depend on the woodlot managers and their decisions.

The North American Forestry Commission has formed a Wildlife Study Group to address the possible impacts of energy demands on forests and their wildlife. It will be on the agenda of the Commission's 1980 meeting in Mexico City. In remarking on the 1968 Symposium, Verme (1970) discussed deterioration of deer habitat, especially in the northern range. He said, "A major miracle is needed to reverse the problem of serious range deterioration, but none is in sight" (Verme 1970). Perhaps energy demands on wooded areas will provide the incentive we need for deer habitat improvement.

And so the trend in management continues, expanding from a single-species focus to broad ecological concerns. White-tailed deer management will continue to include not only habitat appraisal, harvest statistics, and life tables, but will also have to consider chemical balance of rain, soils, and vegetation and include problems of economic and legal issues of land use demands. No one specialist will be able to tackle all aspects of white-tailed deer management in the future. More and more, we will have to depend on cooperation and shared knowledge and efforts. This gathering has set us on the right track for the next decade.

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APPENDIX

A Wisconsin Deer Management Chronology (1836-1980)

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[For some time Walter Scott has been assembling new materials and consolidating and updating earlier chronologies dealing with management efforts on Wisconsin's white-tailed deer. His complete paper will be published by the Wisconsin Department of Natural Resources. Excerpts highlighting changes during 10- to 20-year periods in land use, deer policy and management, public attitudes, and related historical events are presented here to create a brief perspective for understanding the high points and low points of the past, and for approaching the opportunities and decisions of the future.–Eds.]

1836-1860

•Counties of the Territory [of Wisconsin] (except Brown) may pay a bounty of $3.00 for each wolf or "wolf's whelp" killed in the county (1839).

•American Fur Company purchases 10,124 deer skins at Green Bay and Milwaukee posts (1839).

•Wildlife begins decline under impact of civilization (1840).

•Severe winter of deep crusted snow in 1856-57 permitted slaughter of deer with clubs by Indians and settlers. Considerable deer starvation also took place.

•Land clearing and lumbering by settlers was progressing in central counties (1859).

•Federal censuses showed human population increased from 219,456 (1847) to 775,881 (1860).

•Deer open season was reduced from 7 to 5 months.

1861-1880

•Wisconsin produces more than 1 billion board feet of lumber (1870).

•Slashings in the pineries along the Black, Chippewa, Wolf, St. Croix, and Wisconsin rivers (as well as parts of Barron, Kewaunee, and Manitowoc counties) reported to be a "raging sea of flame"; Peshtigo fire (1871) burned over 1,280,000 acres in Brown, Door, Kewaunee, Manitowoc, Oconto, and Shawano counties. Over 1,000 people perished and no doubt many deer were killed.

•Substantial increase in acreage under cultivation in farms partly due to discharged soldiers' return to agricultural life (incidentally with their greater ability as hunters).

•Legislature set aside over 50,000 acres of state lands in Iron, Oneida, and Vilas counties for a "state park reservation" which was not to be sold or cut for timber (1878).

•H.C. Putnam, who made a forest census of the state, urged withdrawal from sale of all state-owned timber land at this time (1880).

•Railroads now were extending lines across the North and advertising it as a "sportsman's paradise" (1880).

•Protection of fish and game meets with much opposition and laws continually are violated by offenders not brought to justice (1879).

•Federal census showed human population rose from 1,054,670 (1870) to 1,315,407 (1880).

•Use of poison bait was permitted for killing wolves and wildcats from 10 January to 10 February (1866); this poison bait law was repealed in 1867.

•State bounty was increased to $10 each and extended also to wildcats and lynx. Payments indicated over 1,600 were bountied (1867).

•Bounties were dropped (1879).

•Last timber wolf taken in southern Wisconsin (Jefferson Co.) (1880).

•Deer open season generally reduced to 3 months (1880).

•Hunting of deer with dogs prohibited throughout state (1876).

•Commercial hunting increased in the central and northern counties; lumber camps also hired hunters to shoot deer for their use (1866).

1881-1900

•Of the state's original 5 million acres of solid pine, only 2-3 million were left by 1881 and this amounted to about 40 billion feet not counting areas of mixed hardwood and pine.

•Wisconsin ranked near No. 1 in lumber output and had about 1,000 sawmills with an output of around 4 million board feet annual-

Scott, Walter E. 1980. A Wisconsin deer management chronology (1836-1980). Pages 111-16 *in* Ruth L. Hine and Susan Nehls, eds. White-tailed deer population management in the north central states. Proc. 1979 Symp. North Cent. Sect. Wildl. Soc. 116 pp.

ly. Cut was almost entirely white pine and turned to hemlock and hardwoods several years later (1896). About 40 pulp and paper mills were active, employing more than 5,000 workers (1900).

•Forest fires raged in the Northwest (the Phillips fire in Price Co. burned 100,000 acres) (1894); a million dollars damage recorded in 1898, especially in Polk and Barron counties, and in 1900 on the Chequamegon Bay and Menomonie River area.

•State Park Reservation in Iron, Oneida, and Vilas counties was ordered by the Legislature to be sold and the average price ran about $10 per acre on the first 133,876 acres sold for cutting (1897).

•The Legislature funded the University of Wisconsin College of Agriculture for preparation of a pamphlet on farming opportunities in northern Wisconsin and "A Handbook for the Homeseeker" was published. A large immigration to northern Wisconsin resulted from liberal state and county appropriations for this purpose (1896).

•Federal census showed a population of 2,069,042 – a 22.6% rise in the last 10 years (1900).

•State bounty on wolves was reduced from $5.00 to $3.00 and on lynx and wildcat from $3.00 to $1.00 (1899).

•Severe winter of 1887-88 resulted in reports of starvation in the far north.

•Deer open season reduced from 3½ months statewide, with any number of deer of either sex legal without a license (1881), to 20 days, 1-20 November, and a bag of 2. Two counties were closed (1895).

•Some sportsmen were proposing a closed deer season for at least 5 years (1891).

•Deer hunting license was required: resident, $1 and nonresidents $30, and 2 coupons with each license. Possession of deer in red or spotted coat was prohibited (1897). Over 32,000 resident licenses were reported sold (1900).

•The Legislature ordered publication of the state's fish and game laws by the Secretary of State and a 32-page booklet was issued this year (1887).

•The office of State Fish and Game Warden was established by the Legislature (1890).

•Chief Warden reports that public sentiment is so much against his staff that "it is exceedingly difficult to secure a conviction on the strongest evidence" (1894).

•Federal Lacey Act prohibiting interstate commerce in violation of state game laws was passed (1900).

1901-1910

•The Legislature established a state Department of Forestry (1903).

•Forester E.M. Griffith was appointed Superintendent of Forests and also given the duties of state fire warden with the result that many new fire prevention laws were introduced and 300 fire wardens hired (1904).

•The State Forest Commission (changed to a state Board in 1905) arranged for reservation of 40,000 acres in northern Wisconsin as a nucleus of the state forest system; another 20,000 was soon added (1904), and 194,000 acres in 1905.

•The woodlot tax exemption law was passed. Since wild fires had been stopped in the southern agricultural area, forest cover on pasture land often had increased substantially. Farm woods were being cut up by agricultural development so there was more woodland "edge" which stimulated wildlife production (1907).

•The Governor appointed a Conservation Commission on basic resources, including forests (1908).

•Between 1904 and 1910, the State Forester reported 3,789 fires which burned 2,491,975 acres. First report of the Wisconsin Commission featured Forest Griffith's recommendations for many new fire protection methods and laws (1909).

•Federal census showed state population was 2,333,860 (1910).

•The last record of a cougar taken in the state was reported from Douglas Co. (1908).

•Deer open season continued to be 20 days, but there were increasing restrictions in southern and central counties, until, 1907-08, 36 southern counties were closed. First deer tag was required (1903). Approximately 100,000 hunters were licensed (1908). For the first time, both residents and nonresidents were limited to only 1 deer (1909).

•Wisconsin Hunters and Fishers Association recommended the establishment of a "one-buck" law (1910).

•In spite of the Federal Lacey Act on transportation of game contrary to state laws, shipments of venison continued to the cities labeled as butter, veal, mutton, etc. (1902).

1911-1920

•Federal figures report over 2,176,000,000 board feet of lumber cut in Wisconsin during 1919 and 1920.

•A forest tree nursery was started at Trout Lake for a replanting program (1911), and by 1919, state tree nurseries at Trout Lake and Tomahawk Lake shipped 509,000 seedlings for planting and by 1920, 320,000.

•The Governor went along with Forester Griffith to declare all state parks as wildlife refuges (1913).

•The State Forester now reported the state's Forest Reserve had grown to 340,000 acres. He also proposed a mill tax which would support forest land acquisition and management, but this was defeated by agricultural interests with powerful friends in the Legislature (1912). The Supreme court held the state forest reserve policy unconstitutional and Forester Griffith left Wisconsin (1915).

•Over ½ million acres were burned on state Forest Reserve lands. Fire protection work proceeded with the erection of fire towers and telephone lines and development of fire lanes. By 1916 there were 1¼ million acres under intensive protection of forest rangers using hundreds of miles of fire lanes, roads, and telephone lines.

•State aid to counties for highway development started this year and in 4 years, over 5,000 miles of highways had been improved to take care of the 124,000 registered vehicles (1912).

•University of Wisconsin Agricultural Extension personnel promoted many educational projects, including how to control weeds, clear lands, drain fields, and raise cattle, concentrating during these early years largely in northern Wisconsin (1915).

•In the Town of Remington (Wood Co.), drainage and settlement were in full swing with many new farms, roads, and schools (1912), but by 1920 the "drainage boom" had run its course and finished anything left of the tamarack and spruce swamps.

•First large state game refuge was established – 2 townships in Forest Co. (Argonne) (1915).

•It was reported that timber wolves were common in northern Wisconsin (1912).

•C.B. Cory's book on "The Mammals of Illinois and Wisconsin" (published by the Field Museum of Natural History in Chicago), shows deer as "common" in only 21 northern counties and in the northern parts of Barron, Eau Claire, and Polk counties (1912).

•The 20-day any-deer season continued until 1915, when the first one-buck law came into effect. The season was shortened to 10 days (1917) and fawns were protected in 1918. About 5,000 bucks were taken in 1915, and 53,593 hunters took about 18,000 deer in 1918.

•The nonresident deer hunting license fee was increased to $50 and the first settler hunting licenses were issued. Paper tags (10¢) were required for the first time (1917), and later, metal (1920).

•The Conservation Commission wrote to all state legislators urging just a buck season – or maybe even a closed season – because of an unusually large harvest in 1919 (18,000-25,000).

•The Chief Warden launched an educational program in schools to reduce game violations caused by "crass ignorance". He also started a training school for game wardens (1912).

•About 155,000 hunters were licensed and 992 people were arrested (of which 52 were hunting without a license) (1914).

1921-1930

•The federal government passed laws which provided more state aid for forest fire fighting, promotion of farm forestry, and enlarging of the federal forests (1924).

•Seventeen northern counties had less than 1½ million acres of saw timber left on their 11 million acres; only about 6% of the cutover lands were developed as farms and much was tax-delinquent. There were 55 wood pulp mills operating in the state (1925).

•The Legislature passed an initial act to establish National Forests in Wisconsin and the Northern Highlands State Forest was set up (1925).

•Second vote of the people for a constitutional amendment to permit special taxation of forest lands was passed so that forest management on cutover lands could be promoted (1927).

•The Legislature enacted the "Conservation Act" establishing the Wisconsin Conservation Commission, passed the Forest Crop Tax Law and strengthened WCD powers to set up fire control districts and to require people to get permits to burn in protected areas (1927).

•Legislative actions gave counties authority to engage in forestry activity (Marinette County Forest was established), and authorized a 1/20 mill tax on property to finance state forestry and fire protection activities. Counties also were authorized to zone lands for agriculture, forestry, and recreation (1929).

•Over 5,000 forest fires burned over 1.8 million acres in state and federal protected areas, in spite of more funds and powers in fire control work, and there were extensive peat fires in central Wisconsin. All conservation wardens were also made fire wardens.

•Seventy-one local conservation clubs were affiliated with the Wisconsin Game Protective Association which was active at this time. About 500 people attended the Appleton organization meeting of Wisconsin Division, Izaak Walton League of America. A state congress called by the Conservation Commission in Madison attracted delegates from 100 interested clubs, reflecting the new groundswell of public interest in conservation (1922).

•WCD Superintendent of Game Wallace B. Grange recommended a continuous survey of the state's wildlife, hunter report cards calling for data such as weight of deer taken, establishment of a system of wildlife refuges, establishment of a permanent wilderness park where all predators would be protected, and cancellation of the bounty system in favor of salaried hunters to control serious cases of predation (1928).

•WCD hired 6 state trappers to work with a supervisor loaned by the U.S. Biological Survey animal control division to clean out a "severe infestation of wolves" (1930).

•Wallace Grange investigated reports of deer starving on Chambers Island (Door Co.), and found deer food completely unavailable. Local wardens verified deer starvation on the island – maybe as many as 100 in the winter of 1927-28. Deer were also starving on Rock Island (Door Co.) and damage to trees and shrubs was severe (1928).

•The experience of Michigan led the way for Wisconsin by a few years with reports of deer dying in some yards as early as 1926 and I.H. Bartlett's first report on "Deer Yards in the Upper Peninsula of Michigan" was published in 1928.

•A survey of conservation wardens and sportsmen indicated that at least 20 counties contained no deer (1929).

•The one-buck deer season was open in 27 counties for the last 10 days in November, and in 1926 was changed to the first 10 days of December. Harvest in 1930 was estimated at 23,000. Cost of deer tags increased to 50¢

1931-1940

•In the first 6 years of the decade, about 12,000 forest fires burned over 1.2 million acres.

•A special session of Legislature appropriated ½ million dollars for forest protection facilities and a state work relief program. These funds opened and improved over 1,000 miles of forest roads and hundreds of miles of firebreaks in addition to many other jobs. This program was continued the next year with cooperation of the federal government (1932).

•In the decade after 1936, forest fires were held to less than 50,000 acres a year.

•To encourage reforestation of the cutover areas, the Legislature increased the forestry mill tax to 2/10 of a mill which greatly promoted public and private forestry work. At this time, county forests totaled over 1½ million acres and private land placed under the Forest Crop Law (open to public hunting) totaled about 160,000 acres (1937).

•The Legislature requires teaching of conservation in public schools and authorized state fencing for areas having continuous deer damage (1935).

•The Wisconsin Conservation Congress of elected citizens held its first statewide meeting at Madison to consider wildlife regulations and discuss deer problems (1935).

•About 260 conservation clubs with a total of 40,000 members were listed for the state (1936).

•The Civilian Conservation Corps was organized in Wisconsin with 14 camps of about 200 men each and 24 additional camps on the national forests and Indian reservations. They greatly improved forest protection, but also made possible wildlife management techniques such as deer census. With the Works Progress Administration (WPA), much forest improvement work was accomplished and needed installations built (1933).

•Ernest Swift reported that "as early as 1930, isolated cases of overbrowsing, winter food shortage, and starvation were showing up" and claimed he was one of the first wardens to report starvation in the deer yards during early 1930's.

•During the decade, artificial feeding was begun and many instances of overbrowsing and serious winter losses of deer in yards were reported – e.g., Flag Yard (1935), Apostle Islands overrun, entire NE with more deer than ever before, Jackson Co. with 200 deer per section in one area (1937); the U.S. Forest Service urged removal of 14,000 deer from the Chequamegon National Forest (where deer mortality was reported at 1300 for the winter of 1934-35); severe overpopulation of deer in Wisconsin with natural winter feeding grounds on the decrease (H.W. MacKenzie, F.N. Hamerstrom, James Blake, 1937-39).

•Aldo Leopold urged that the newly formed Wisconsin Conservation League attempt to bring the resort owners and deer hunters together to "argue out their conflict" – at least to try. He claimed the only successful regulators for the deer herd were the deer predators (1940).

•On 12 June the Conservation Commission approved several Pittman-Robertson research projects, one of which was on deer (1940).

•During the decade, the deer season generally went from 10 days (one-year-old bucks) to 7 days (forked antler bucks) – with 3 closed seasons and one 3-day season (1931, 1933, 1935, and 1937). Numbers of hunters increased from 70,000 (1932) to 105,000 (1940) and the estimated kill ranged from 15,000 (1937, 3-day season) to 35,000 (1932, 10-day season).

•Over ¼ million acres of land was closed for protection of deer (1939).

•A voluntary sportsmen's license was established for a fee of $5.00 or more and some of the money was to be used for refuges and public hunting grounds (1937).

1941-1950

•The American Forest Products Industries, Inc. reported that Wisconsin had almost 18 million acres under intensive forest protection. Of this, 1,800,000 was federally owned lands while the rest were in state and private ownership (1949).

•Over 25 million trees were distributed for planting in the state. Of these, 2½ million were planted by the U.S. Forest Service on national forests and 1¼ million on the industrial forest planting program (1950).

•The deer population over much of northern Wisconsin averaged 30 deer per square mile and some places at this time were as high as 50 and 60 (1941). Aldo Leopold estimated the deer population at 500,000 (1943).

•The natural predators of deer (timber wolves and cougar) were practically gone (1941).

•Out of 60 reports, on deer damage to young forest tree plantations, only 10 had no damage and 12 were more than half destroyed (1946).

•Deer yard conditions were rated as "poor" in 1941; 1948, 78% poor; 1949, 65% poor in north, 52% poor in central. An estimated 15,000-20,000 deer died of starvation in northern deer yards (1949-50). Continued deterioration in 1950.

•An extensive outlay of funds and tonnage of artificial feed occurred (e.g., $600,000 in 1943; $73,000 in 1948 for almost 2 million pounds of alfalfa, hay, concentrated feeds, and small grains).

•Aldo Leopold spoke at the Conservation Congress meeting on "carrying capacity" of the land for game and later was appointed Chairman of a 9-person Citizen's Committee to study the deer situation (1942).

•Public relations became a big part of deer research project work, with presentations to Citizen's Deer Committee, WCD Commissioners and personnel, radio broadcasts, and field inspections – taking people "into the bush and letting them use their own eyes" (1943).

•Aldo Leopold said that "the price of progress in conservation as a whole was to soft-pedal the deer problem" (1946).

•Leopold and other deer experts recommended a more liberal season on deer, reduction in size of large refuges, and temporary removal of bounties on wolves (1943). Leopold proposed "controlled deer hunting" as a necessary addition to the state laws (1945); Governor Rennebohm urged the legislators to pass "some form of controlled hunting law which will be adequate to solve our deer problem" (1949); and the Wisconsin-Upper Michigan Section, Society of American Foresters recommended that the Legislature give WCD broad authority and power to regulate the harvest of surplus deer in managed forest areas (1949).

•"In Wisconsin you brawl and argue endlessly over the management of white-tailed deer. You have more deer than any state in the Union. What your state needs is an immediate kill of 200,000 deer." – Dr. Durward L. Allen at a conference on Wisconsin natural resources (1949).

•During 1946-48, bounty was paid on 6,967 coyote and wolves and 1,004 wildcat and lynx – with no definite figures for timber wolves and lynx (1948).

•The deer season was open for bucks throughout the decade, ranging from 5-9 days; a split season in 1943 included antlerless deer, and from then on from 3-7 agricultural counties were opened for deer of either sex. In 1950 the first "any-deer" season (7 days) since 1914 was held. Numbers of hunters increased to 312,000 (1950) and deer harvest ranged from 29,000 (1944) to 168,000 (1950).

•A so-called "Save Wisconsin's Deer Committee" was organized in the north country to protest the "shameful slaughter" of does and fawns in 1943 (1944).

•The first controlled antlerless deer hunt was held on the Necedah National Wildlife Refuge (Juneau Co.) with 36 deer taken per square mile (out of a reported population of 60 per square mile). There were 2,028 permits issued in cooperation with the federal government as landowner (1946).

•The Conservation Congress and Conservation Commission voted for an any-deer season in 1948, but Governor Rennebohm, who was running for re-election, refused to sign the order and sent it back with suggested changes because the legislative majority was unfavorable.

1951-1960

•Wisconsin's population was 4,040,000 (1959).

•The state expended $93,200 on wolf and coyote bounties, paying for the killing of 4,498 adults and 324 cubs. Dr. A.W. Schorger called this an "unfortunate bounty" (1960).

•A Forest Habitat Improvement Project was set up and financed through Federal Aid with the objective of improving wildlife management techniques, many of which were directed toward deer (1951).

•At the International Association of Game, Fish, and Conservation Commissioners meeting in Rochester, N.Y., Ernest Swift presented a paper, "Deer Herd Control Methods and Their Results". Much of this by now was a success story, with the hunters' approval, except for failure in attempts to get authority for "controlled hunting" on deer (1951).

•In the March *Conservation Bulletin,* Stanley DeBoer wrote a piece called "Feed 'Em–With An Axe!" He pointed out that this program was no cure-all, but it was less costly than trying to feed starving deer with hay and concentrated deer foods (1952).

•Artificial feeding of deer in winter by WCD was discontinued (1955).

•In the north, 50% of the deer yards still were incapable of carrying more deer than in the 1951-52 winter and in a harder winter than one so mild, planned timber cutting would be helpful. So said John Keener, leader of the West Central District Forest Development Project in a *Conservation Bulletin* article on "The Need for Deer Range Management". He also mentioned controlled burning as a possible tool (1952).

•President Ira N. Gabrielson of the Wildlife Management Institute spoke at the Silver Anniversary Forest Conference about "the relation between forestry and wildlife", pointing out that deer management and forest management, when planned and executed cooperatively, gave best results (1953).

•A summary of winter deer yard checks showed that "the major change was in increase in yards in which browsing exceeded current carrying capacity". Another report stated that of the 114 deer found in the north in spring, 46% showed positive evidence of starvation. A survey of 431 does showed that about 82% were carrying young, and that 12% of the yearling fawn does also were carrying young (1956).

•After the second statewide any-deer season in 1951, season type varied from forked horn to spike bucks, with many southern and western counties continuing shorter either-sex seasons. Season length ranged from 7-16 days. Hunters increased to a high of 349,000 (1959) and harvest peaked at 105,596 (1959) after the 1951 any-deer season (279,000 hunters and 129,000 deer).

•For the third consecutive season, Wisconsin led the nation in the white-tailed deer kill and deer reduction was temporarily accomplished (1951).

•In 1954 two-thirds of the bucks taken were less than 3 years old and Washington Co. was opened for the first time since 1906. It seemed evident that the deer herd would increase under buck-only seasons if nonhunting losses were reduced, too.

•Important developments were deer registration (1953), the Unit concept of deer management (1957), and the "party permit" system (1957).

1961-1970

•The state's forest protection covered about 33 million acres of which 17,082,290 acres were considered "critical area" (1968).

•Wisconsin deer herd size is reported at about 750,000 with some in every county of state (1970).

•There was widespread starvation during the winter of 1964-65 in northwestern Wisconsin and scattered losses elsewhere in the north (1964). The winter of 1970-71 resulted in the most severe losses throughout major parts of the north since careful observations began.

•Ernest Swift (now a director of National Wildlife Federation) was quoted in the *Vilas County News-Review* under the headline "Swift Reveals 'Cold War' Between Wardens, Experts" as saying that in his opinion "it is time for the sportsmen and citizens of Wisconsin to pause and evaluate what the results already have been" (1961).

•The WCD goal was to keep a winter deer herd of 430,000 with a plan of harvesting 75,000 to 100,000 annually (1962).

•The Conservation Commission adopted a deer and forest management policy recognizing that these resources now must be managed on an integrated basis (1962).

•Development of the Unit management system resulted in more deer shot and less range damage, with the ultimate goal being a more stable deer harvest and population (1966).

•Research information published on establishing and managing forest openings was an important step forward in range management for deer (1969).

•The basic deer season was a 9-day spike buck season, with either sex open for shorter periods in several agricultural counties. Party permits were prohibited in 1961 and 1962, but in 1963 the variable quota plan was initiated. Hunting pressure reached a high of 507,000 (1969). The highest kill occurred in 1968, with 119,986 registered deer, of which 57,465 were antlerless.

1971-1980

•The estimated population of Wisconsin now was 4,609,000. Rate of increase in the decade from 1960 to 1970 still was rapid – 11.8% (1976).

•Total land open for public hunting under the Forest Crop Law as of 1979 was 2,275,589 acres.

•In view of highway car kills as high as 12,702 in 1967 and severe losses of fawns in the winters of 1966-67 and 1970-71 (when from 50,000 to 60,000 deer died of starvation) it is better to let the hunters do the harvesting, but this is impossible because of "campaigning against the party permit" in 1969 and 1970 (Article in September-October 1971 *Conservation Bulletin*).

•Based on 18,200 deer killed annually by cars from 1976 through 1978, the total loss borne by accident victims was $22.1 million.

•Almost half of the hunters oppose a doe season under any conditions, indicating a lack of understanding of the ecological principles of deer management (*A Profile of Wisconsin Hunters*, Tech. Bull. No. 60, 1972).

•David Jenkins of Michigan DNR noted 2 areas of notable progress in Michigan and Wisconsin: "the slow gaining of public understanding and support for big game management and the inclination of legislatures to grant their commissions or game boards increasing authority" (1977).

•DNR Secretary Earl formed a Hunting Ethics Committee to help solve the quality problems related to deer hunting pressures by such large numbers of hunters (1977).

•DNR aiming at a "wintering" population of 575,000 whitetails, which "would mean about 750,000 deer in the woods come hunting season". Wildlife managers figured car kills could be taking 27,000 deer each year and dogs possibly as many as 10,000 in a bad year (1980).

•License fees increased with sportsmen's license now $22.50; resident big game $11.00; nonresident big game $60.50, and resident bow hunting $9.50 (1979).

•Information sheets on the so-called "Hunter's Choice Permits" were being widely distributed, a system already used successfully in Michigan. These could replace the 4-member party permits of recent years (1980).

•An average of 594,000 hunters registered 100,000 deer, of which 36,000 were antlerless, annually from 1971-77.

Symposia Sponsored by the North Central Section of The Wildlife Society:

1965 Wood Duck Management and Research/Emphasizing Management of Forests for Wood Ducks.

(James B. Trefethen, ed. Publ. 1966, Wildlife Management Institute, 709 Wire Bldg., Washington, D.C. 20005)

1967 Canada Goose Management/Current Continental Problems and Programs.

(Ruth L. Hine and Clay Schoenfeld, eds. Publ. 1968, Reprints available through Student Chapter, Wildlife Society, CNR, University of Wisconsin, Stevens Point, WI 54481, $3.75)

1969 Predator Ecology and Management.

(Albert W. Erickson and Glen C. Sanderson, eds. Publ. 1972, J. Wildl. Manage. 36(2):210-404)

1973 Biology and Management of Pheasant Populations in North America.

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1977 Waterfowl and Wetlands/An Integrated Review.

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Wisconsin DNR