EVALUATION OF PELLET GROUP SURVEYS FOR ESTIMATING DEER POPULATIONS IN MICHIGAN

By

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ABSTRACT

EVALUATION OF PELLET GROUP SURVEYS
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Deer pellet group surveys are used and recommended by wildlife biologists as a deer census technique throughout the northern and western deer ranges. The objective of this study was to evaluate the technique as used in Michigan. The appraisal was based on an examination of data produced by the considerable amount of research and survey work done in Michigan from 1953 through 1969.

Use of pellet group counts as a census method is dependent upon several assumptions: deer defecate at a rather constant frequency, pellet groups persist long enough to be counted, groups can be found and counted accurately, a deposition period can be delineated, and groups found can be aged relative to the deposition period. Calculations of deer numbers from pellet group counts utilize the algorithm:

$$\text{deer population} = \frac{\text{mean pellet groups per plot} \times \frac{1}{\text{plot size}} \times \text{size of area}}{\text{deposition period} \times \text{defecation rate}}$$

For a given survey, plot size, area, deposition period, and defecation rate have been generally considered fixed.

Defecation rates were studied using penned deer fed several diets at the Cusino Wildlife Research Station in the Upper Peninsula and at the Houghton Lake Wildlife Research Station in northern Lower Michigan. Studies were also undertaken at both stations to determine longevity of pellet groups in several types of overstory and ground cover.

Fifteen experimental pellet group surveys were conducted on two

large enclosures with known numbers of deer, the 1.8 square mile George Reserve in southern Michigan and the 1 square mile Cusino enclosure. Systematic sampling designs were employed for the most part.

Extensive operational pellet group surveys were carried out in the Upper Peninsula and northern Lower Michigan since the early 1950's. Since 1959, both regions have been surveyed annually. Two-stage, stratified random sampling with optimum allocation was used. Stratification was based on expected over-winter deer populations. The first stage units were geographic sections (square miles). Second stage sampling units (courses) consisted of eight rectangular 1/50-acre plots, 72.6 feet by 12 feet, spaced 5 chains apart in a straight line. Courses were located within sections by restricted randomization procedures. Average over-winter population levels, obtained directly from pellet group counts, were adjusted to provide estimates of the spring and previous fall herds by considering proportional contributions from deer known to have been removed, i.e. legal harvest and over-winter mortality. Various aspects of these surveys were analyzed.

Studies of defecation rates yielded the following means per deer per day: adult bucks 15.61, adult does 12.89, buck fawns 14.74, and doe fawns 11.89. Indices for a given survey should be weighted by herd composition. Groups of deer fed various winter diets showed little difference in defecation rates within sex and age classes. The available data are less than decisive concerning whether there is a decrease in defecation rates in mid-winter. No data are available for the period from May through December.

All Michigan work has been based on a fall-to-spring accumulation of pellet groups. The autumnal fall of leaves has been used to provide a beginning reference point and the mean date of the spring survey the terminus. Leaf fall dates for 11 years were relatively uniform within northern game districts; the range in most cases was less than 2 weeks.

The average time interval in the spring required to search all sample plots within a game district was 24 days. Adjusting all pellet group counts to a common spring date had little effect on estimates.

Making accurate counts was found to be the most important phase of the technique, including the finding of all groups present through diligent searching, and ascertaining the age of groups found relative to the deposition period. The problem of missing groups was resolved to a large extent by using two experienced men per crew, each checking the other's work.

Studies of pellet weathering revealed nearly all groups deposited during fall and winter were extant in the spring. In addition, many older groups were also visible, up to 5 years in some instances. For survey purposes, groups dropped during the established deposition period are termed "new," while those dropped prior to the period are "old." All groups found on top of recent leaf litter should be considered new regardless of appearance. Correctly aging groups on sites devoid of fallen leaves appears to be a serious problem. Attempts to remove pellet groups from sample plots in the fall were not successful.

A group should be counted only if its midpoint falls within the plot. If possible, pellet group counts should be avoided on bright, sunny days, which makes groups difficult to see in the contrasting light, or immediately following a rain, which tends to make old groups appear fresh.

Results of 10 experimental pellet group surveys on the George Reserve showed a very poor fit with known populations. Available evidence pointed to mistakes in aging pellet groups as the major problem. Five surveys on the Cusino enclosure revealed a much better agreement.

Frequency distributions of pellet group counts on the Cusino enclosure, the George Reserve, and three or four extensive areas in the northern Lower Peninsula were satisfactorily described by fitted negative binomial distributions. The relationship between the log of the means and the log of the variances, however, provided a simpler way of estimating standard deviations for sample allocation purposes. Variances used included only estimates of sampling error in counting pellet groups. Additional contributions due to adding variance components for defecation rate and deposition period were found to be small enough to be safely disregarded.

Accuracy of extensive surveys could not be properly appraised since real herd sizes were unknown. Comparison with other indices indicated a fair agreement. Evidently the technique is more accurate under Upper Peninsula weather conditions and cover types. For estimates of equal precision, stratified sampling resulted in considerable savings in manpower when compared to simple random sampling. Stratification was not accurate enough, however, to warrant annual selection of new samples. No differences were found in pellet group counts by position on course lines. Analysis of time records and comparisons of within course variability indicate optimal strategy would be to reduce the number of plots per course to five and increase the number of courses.

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Grateful acknowledgments are made to my graduate committee, Drs. William E. Cooper, Chairman, George J. Wallace, John L. Gill, and George A. Petrides for their guidance during the course of my studies and in the preparation of this manuscript. Dr. Cooper deserves special credit for supplying the necessary impetus for me to complete my studies. Special thanks are due to Dr. Walter H. Conley and especially to Dr. Charles E. Cress for graciously consenting to fill in for Dr. Petrides and Dr. Gill respectively, both of whom were out of the country when I completed my write-up.

I am grateful to the Michigan Department of Natural Resources for the opportunity to conduct much of this study as a component of my regular job. My supervisor, Dr. David H. Jenkins, Chief of the Research and Development Division, offered continual encouragement and supplied me with invaluable information on the E. S. George Reserve and its deer herd. My colleagues Carl L. Bennett, Jr. and Louis J. Hawn also contributed valuable suggestions and assistance. This study was conducted as part of my work as leader of Federal Aid in Wildlife Restoration Project W-96-R.

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Literally hundreds of individuals from the DNR and the U. S. Forest Service participated in collecting data, and without their help this study would not have been possible. Benjamin C. Jenkins, the DNR's northern game habitat specialist, and Herman F. Olson, formerly Regional wildlife specialist, U. S. Forest Service, Milwaukee, Wisconsin, were responsible for initiating me in the use of the pellet group survey technique. I am especially grateful to wildlife research biologists Robert C. VanEtten, Louis J. Verme, Edward J. Mikula, and Rodney R. Smith who carried out research studies at the Cusino Wildlife Research Station; and to Arlow P. Boyce, Elsworth M. Harger, and Herbert E. Johnson who conducted similar studies at the Houghton Lake Wildlife Research Station.

Dr. M. L. "George" Dudzinski, Commonwealth Scientific and Industrial Research Organization, Canberra, Australia, supplied me with a computer program for fitting the negative binomial distribution to frequency data. Dennis Burck, DNR computer programmer, modified this for use on the Burroughs 5500 computer.

I will be forever indebted to Mrs. H. Rex Caster, Ms. Marilyn L. Moss, and Mrs. Douglas L. Meister for their "beyond the call of duty" efforts to read my writing, correct my spelling, and type the many versions of the manuscript. Dean B. Armstrong did his usual excellent job in drafting the figures.

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I. INTRODUCTION

Objectives

The ultimate goal of this and related studies is the proper management of the white-tailed deer (*Odocoileus virginianus*) in Michigan. The short-term objective is to evaluate pellet group surveys for censusing deer under Michigan conditions. At present, this technique is the one most universally recommended by wildlife biologists throughout the northern and western deer ranges, and has been used and studied in Michigan for a number of years.

The Michigan deer herd is a valuable renewable resource (Appendix A) and its perpetuation is an important activity of the Department of Natural Resources.*

Deer census techniques

Petrides (1968) has defined conservation as

> "... a philosophy which advocates the use of natural resources on a sustained and permanent basis in the public interest."

Moreover, as Lauckhart (1953) states

> "... renewable natural resources are managed for maximum harvest and game is no exception. The success of a game management program is measured by the game in the hunter's bag and fish in the fisherman's basket."

One of the major problems of wildlife managers is determining the size of the populations they are attempting to manage. The magnitude of their problems varies inversely with the closeness of the harvest to

*On November 15, 1968, the name of the Michigan Department of Conservation was changed by law to the Michigan Department of Natural Resources.

sustained level of the populations involved. Carhart (1946) stated it quite simply when he said,

> "The first step in a management plan for deer is to secure a good estimate of the number of deer on a given range."

This basically is the problem considered here. While it may be the first step, it is also perhaps the most difficult.

Population estimators have been the concern of wildlife workers since the inception of the modern profession in the 1930's and the informed naturalists and gamekeepers that preceded them. It is safe to say that present day professional wildlifers are still looking for better methods to use with nearly every game species, and the same is true of zoologists working with wild populations of many kinds of animals.

The difficulties of wildlife census may not be obvious to the uninformed. Only in the case of species in imminent danger of extinction and certain gregarious forms, is it possible to see an entire population (Dasmann 1964, Gilbert 1967). Getting reliable information, at reasonable costs, on the abundance of a game species distributed over millions of acres each year is not an easy task (Ruhl 1932). Censusing most wildlife requires that some form of sampling be used. The real problem is the difficulty of getting accurate counts of the animals on selected sample plots, not the lack of statistical methods (Dice 1941).

Ancestors of white-tailed deer have been identified in some North American Miocene strata, and Pleistocene forms have been found which are almost identical with present species of Odocoileus (Scott 1937). Thus, deer have survived for several million years in North America and continue to be widespread occurring even in areas with high human populations. The survival of deer is primarily due to the continued presence of suitable food and cover, their behavioral and physiological responses to seasonally inclement weather, their reproductive capacity, their ability to adapt to changing conditions, and their skill at detecting and evading predators, including man.

Several of the factors responsible for long-time survival work at cross-purposes to attempts at census. At best, deer are difficult to see and behavior patterns cause unexpected paradoxes. In northern Michigan, deer are most visible at spring break-up when the population is at its yearly low, and least visible 3 months later when the population is at its yearly high after fawns are dropped.

Through the years, a great number of methods have been tried for censusing deer with varying degrees of success. The volume of papers in the literature is an expression of the need and concern for adequate methods. Rasmussen and Doman (1943) in a review article listed 30 references on deer census, Taylor (1947) cited 39 papers describing "new" techniques in hoofed animals including census and determination of population trends, and Hazzard (1958) gives 199 references on big game census methods. McCain and Taylor (1956) summarized methods which have been tried with mule deer (Odocoileus hemionus) to determine population levels: (1) direct counts made on foot, horseback, motor vehicles, and aircraft; (2) indirect counts of tracks, beds, trails, rubbed trees, shed antlers, dung, and plants eaten; (3) hunter kill; and (4) trapping and tagging. The Great Lakes Deer Group (1964) has outlined deer census methods used in Michigan, Wisconsin, Minnesota, and Ontario and pointed out areas needing further research. Jenkins and Marchinton (1969) present an up-to-date comparison of several census techniques used for white-tailed deer in the Southeast.

Alexander (1958) indicates that any wildlife management technique, if it is to be considered practical, must be workable by field men, and he lists several desirable characteristics:

"1. It must have ease of application, requiring only a reasonable amount of experience.
2. It must be capable of obtaining data or giving accomplishments in quantity in a short period.
3. It should not require a large personnel.
4. It must be reasonably inexpensive; requiring limited equipment.
5. It should provide data or results relatively free from the influence of the individual operators.
6. It should furnish data of a type that permits fast and easy analysis and interpretation, or give distinct results, readily measured and evaluated."

Other desirable characteristics for census methods might be added to his list:

7. It should be possible to do it at any time of the year.
8. It should work equally well on all sizes of areas.
9. It should be based on valid sampling theory.
10. It should produce accurate estimates.

Michigan deer census methods

Previous to the establishment of the Michigan Conservation Department in 1921 and particularly the founding of a separate Game Division in 1928, information on Michigan deer numbers is known only from reports by early explorers, trappers, missionaries, surveyors, lumbermen, settlers, hunters, and early naturalists and railroad shipping records. Later, around the turn of the century, there were a few zoological surveys, some authorized by the State legislature and some sponsored by the University of Michigan.

During 1930 and 1931, attempts were made by the Game Division to obtain an estimate of Michigan's deer herd through the aid of Conservation Officers, hunters, lumbermen and timber cruisers. Estimates of 82,200 deer in the Upper Peninsula and 35,000 in the northern Lower Peninsula were arrived at which seemed logical at the time (Bartlett 1945), although later evidence disclosed that these were serious underestimates.

Systematic records originated about 1932 with the establishment of periodic reports from each Conservation Officer, and subsequently other Department personnel, on the number of deer seen per hour in the field. This covered the period from July 1 to the end of October (including also the first 11 days of November from 1932 to 1934). Later (1965) counts were extended to include May and June and still later (1968), April was also encompassed. Essentially these are roadside counts made in conjunction with other duties. Such records probably reflect long-term trends of the deer herd, however; they are influenced by weather, changes in personnel, interest of workers toward deer, amount of night patrol, increasingly better road systems, faster automobiles, etc. On the other hand, they tend to be made by the same workers in the same areas year after year and are based on thousands of hours of observations. Rather large fluctuations in deer seen may occur within a given county from one year to the next, but data for blocks of counties tend to show smaller fluctuations.

The first methods to give actual population levels were census drives on specific areas conducted with the aid of the Civilian Conservation Corps camp program from 1935 to 1940 (Bartlett 1950). Properly handled census drives are quite accurate for small areas, but manpower and terrain limit their usefulness. Roughly, 100 men per section are needed to do a good job.

Results of the early census drives in 1935 were surprising. They revealed that numbers of deer were considerably greater than realized. Total figures were calculated by averaging the results from all drives made in a particular year. Census areas were believed to be representative, but evidently this was not true. Only certain types of areas can be properly driven. Retrospection indicates that the expanded totals were probably too high. Since 1940 only a few areas were driven annually, mostly for public relation purposes.

Michigan biologists felt the need for better information about deer populations because of adverse public reaction following the first large scale antlerless deer harvest in the fall of 1952 (Bennett, Ryel, and Hawn 1966). The pellet group survey seemed to be the best available technique and surveys in four areas of northern Lower Michigan were carried out the following spring in cooperation with the U. S. Forest Service. Surveys quickly became routine annual operations, gradually increasing in extent and consuming considerable time and effort. The U. S. Forest Service had made pellet group counts on the Ottawa National Forest (western Upper Peninsula) as an index to relative deer use of certain timber types from 1950 to 1952 (Olson 1952). However, the 1953 surveys marked the first use of the technique here for actual population estimates. Since 1959 the entire northern two-thirds of the state has been surveyed each year, as well as several other areas.

Eberhardt (1960) developed some methods of estimating the relative abundance of Michigan deer based on sex and age data from hunter-shot deer, embryo counts from car-killed does, estimates of legal harvest, sight records, and the number of deer killed on the highways. Nevertheless, he considered pellet group counts as the most accurate method and used them as a standard for comparison with his other estimators. Recently, Croon et al. (1968) and McCullough, Olson, and Queal (1969) have experimented with infrared scanning for deer census in Michigan, but as yet this technique cannot detect deer through green foliage nor discriminate between animals in the size range from foxes to horses.

<u>Scope of the present study</u>

Normally, considerable research precedes use of a technique; however, only limited study evidently had been done anywhere before 1953 on pellet group surveys. Neff (1968), in a review paper, lists but four papers earlier than this date.

I suppose that technically, research preceded census applications in Michigan, but the lead time was less than a week. Studies on defecation rates were begun at the Cusino Wildlife Research Station, near Shingleton, on April 1, 1953, just prior to the beginning of extensive field surveys in the northern Lower Peninsula. The first plots were searched in Lake County on April 8. On April 29, an experimental survey was carried out on the E. S. George Reserve, near Pinckney, to census the confined deer herd there.

Since 1953 Michigan workers have probably carried on more research on the technique and conducted more surveys than any other state, yet most of the accumulated data have never been analyzed. Only two technical papers (Eberhardt and VanEtten 1956, VanEtten and Bennett 1965) have been published.

Research studies at Cusino were done under Federal Aid to Wildlife Restoration Project W-70-R. Those at Houghton Lake were carried out under Projects W-63-R and W-95-R. Planning and computational phases of extensive surveys were included in the work of Project W-96-R. Progress summaries were included in the various unpublished Quarterly and Annual Reports submitted for these Projects. In addition, annual reports giving population estimates from operational surveys were written. Figures 1 to 4 show the locations of the various areas involved in these studies and surveys. Table 37 lists the various surveys and cites

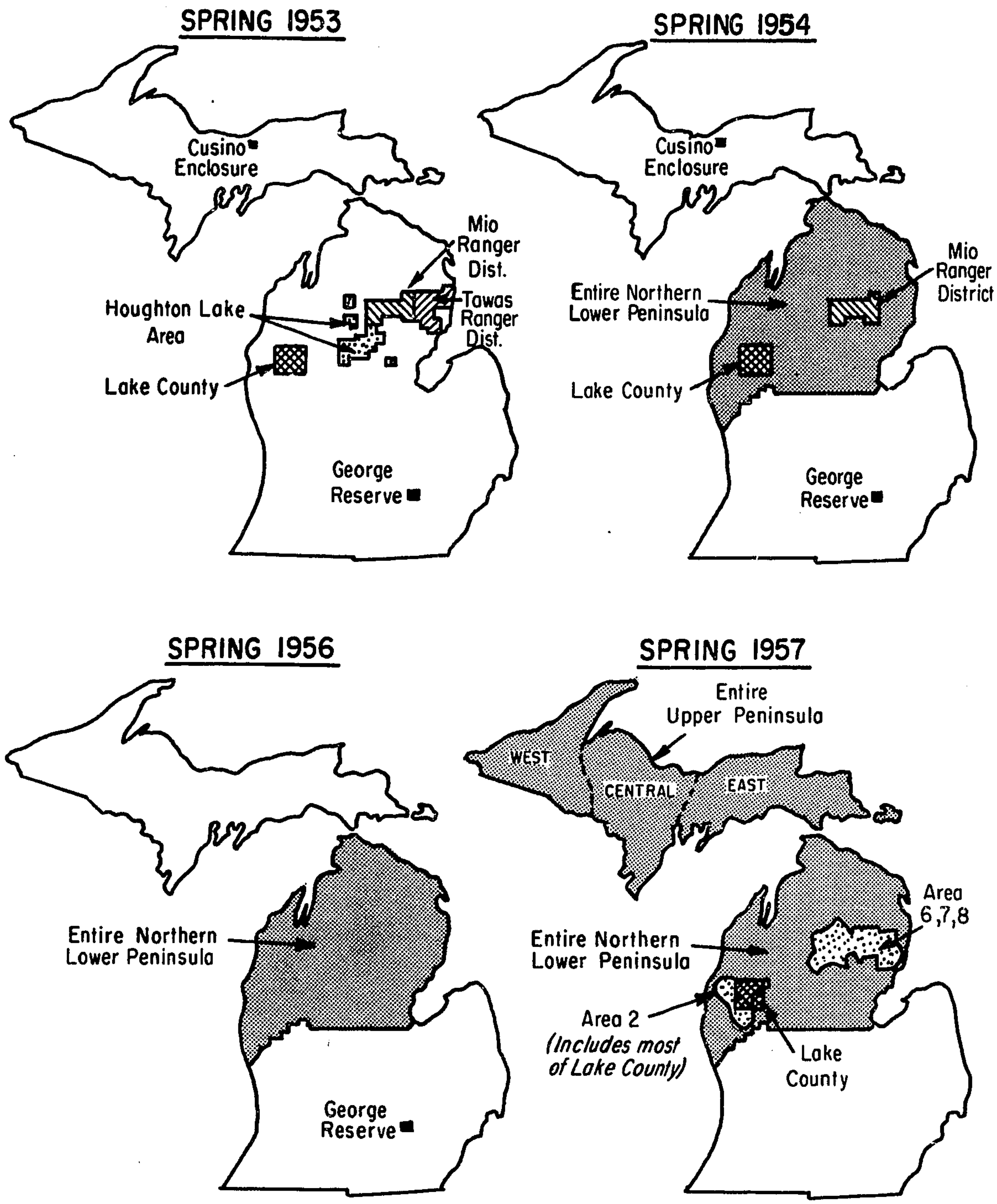

Figure 1. Locations of deer pellet group surveys, 1953-1957.

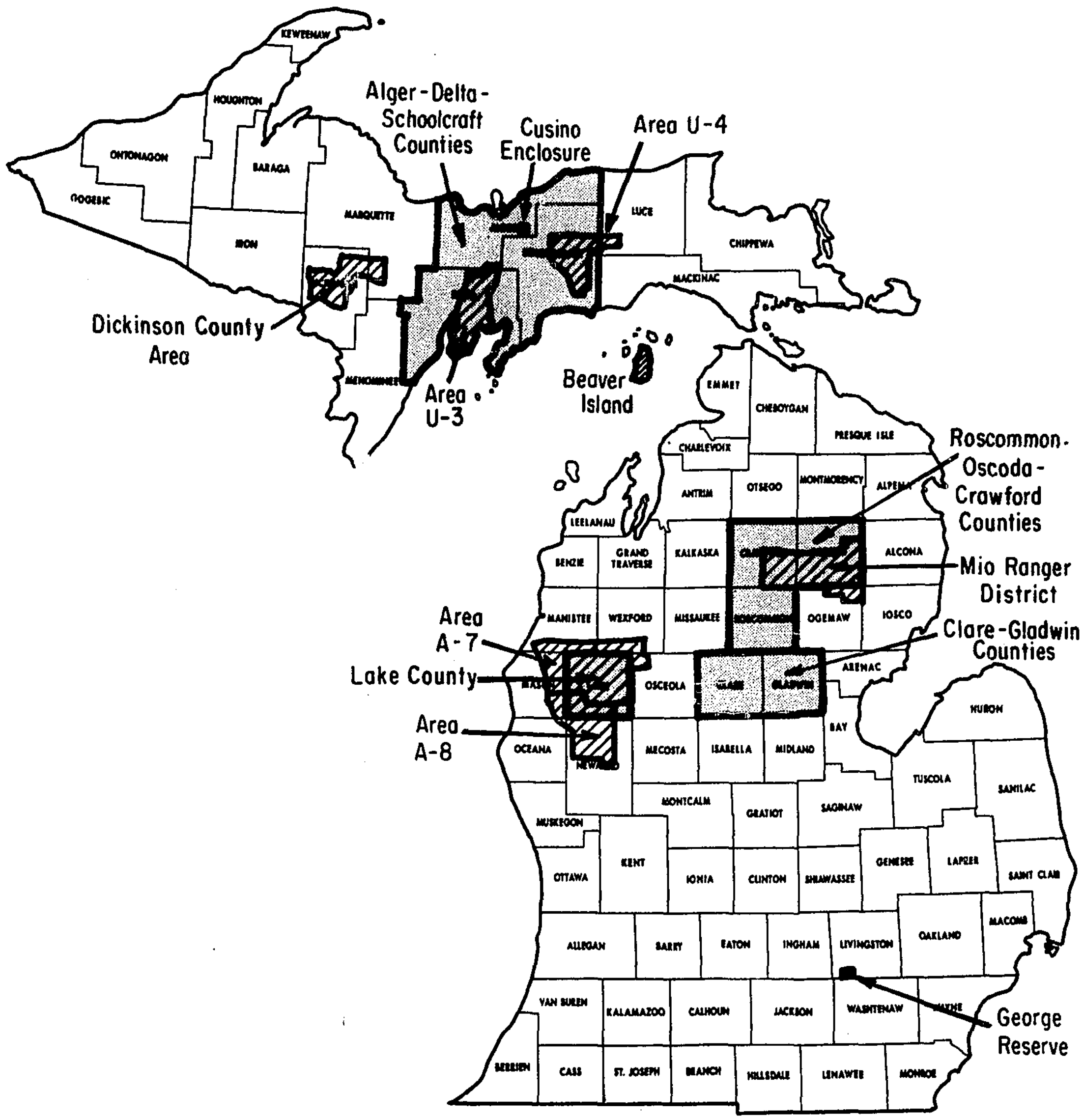

Figure 2. Locations of deer pellet group surveys, 1958.

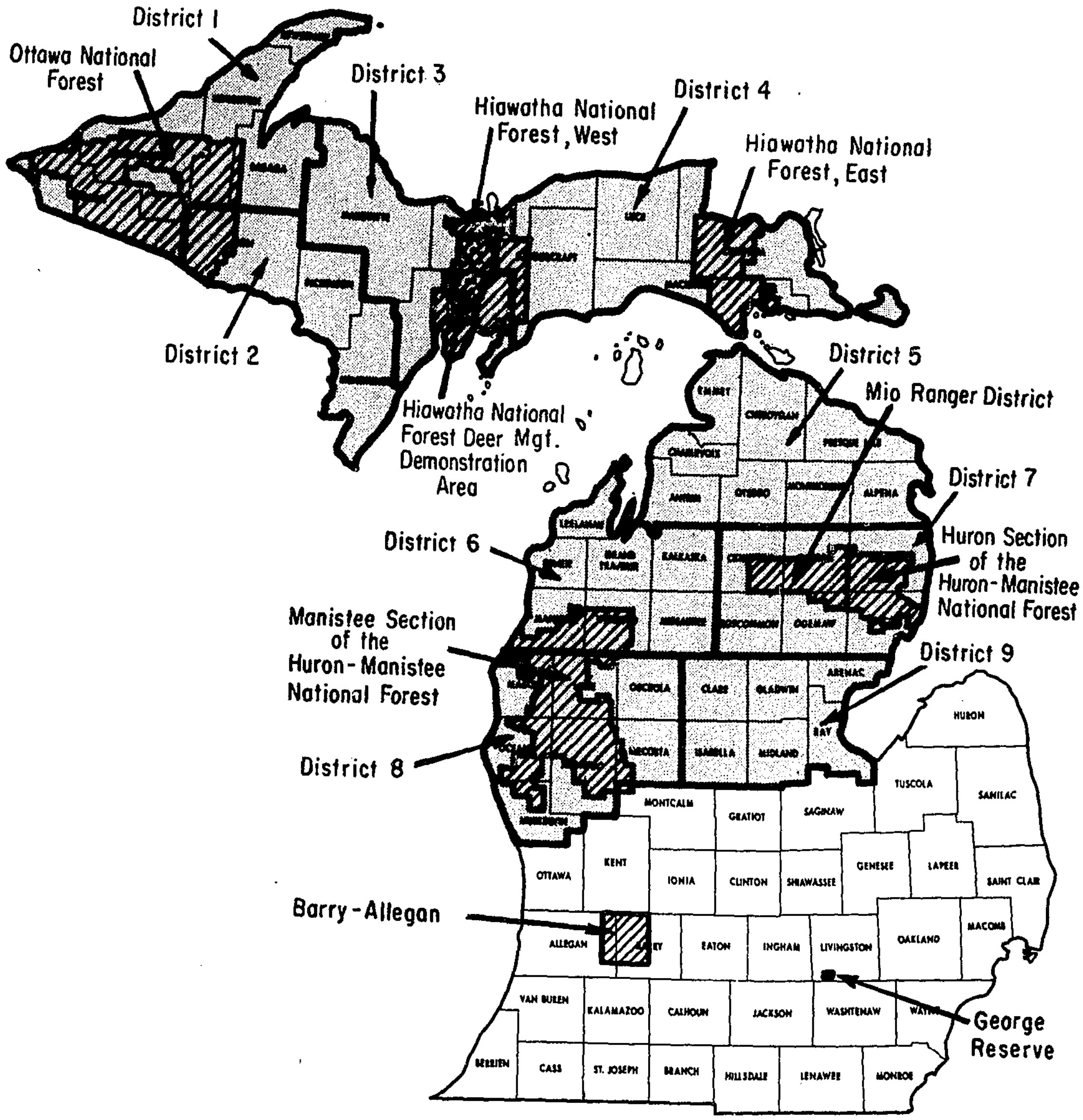

Figure 3. Locations of deer pellet group surveys, 1959-1964.

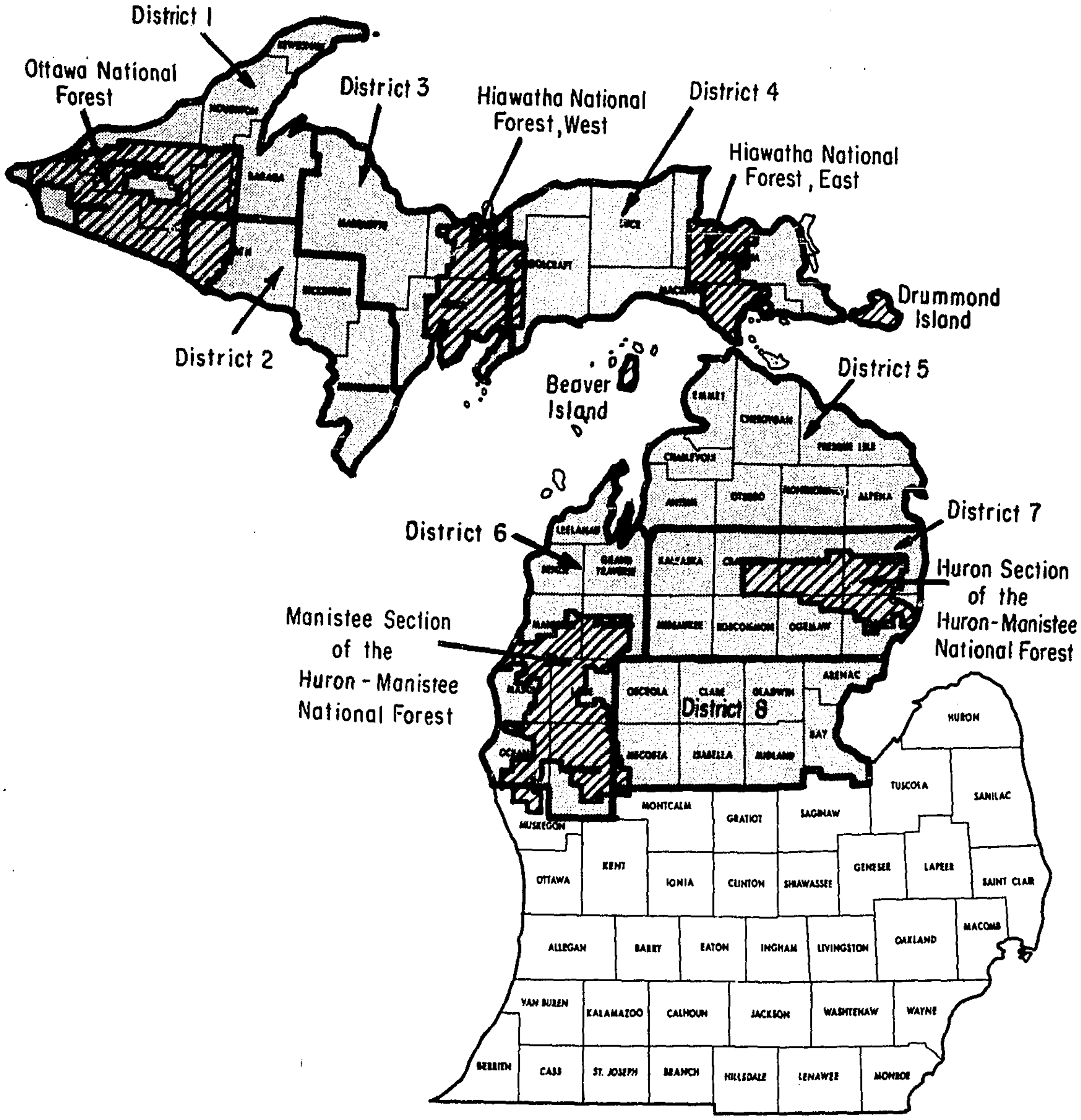

Figure 4. Locations of deer pellet group surveys, 1965-1969.

descriptive reports which give survey results.

In 1966, the Michigan Conservation Commission contracted the Research Triangle Institute of Durham North Carolina, to audit the Department's procedures for estimating deer populations and deer kill (Research Triangle Institute 1966). Their personnel reviewed sampling and computational procedures as well as the estimates given in available reports. No new analyses were conducted.

As an employee of the Michigan Department of Natural Resources, I have been involved with pellet group surveys every year since their inception in the Lower Peninsula in 1953. I participated in the first experimental survey on the George Reserve that year and in operational surveys in northern Lower Michigan from 1953 through 1957. In 1958 I became the technical supervisor of all such surveys. This included sample design, selection of courses, conducting briefing sessions, editing returned survey cards, and preparing and distributing survey results within the time structure necessary for setting annual regulations. Carl L. Bennett, Jr. assisted me from 1964 to 1969. I conducted experimental surveys on the George Reserve from 1958 to 1963.

As a biometrician with the Game Division and later the Research and Development Division, I also instigated the 1958 Cusino enclosure experimental survey and new research studies on defecation rates in 1959.

The present study will appraise the pellet group technique as it has been used in Michigan, suggest modifications for future surveys and point out areas needing future research. Unfortunately, time overlaps and feedback between research and application make it difficult to develop a logical and even presentation. The data base encompasses all research and survey work done through 1969. Original records were examined whenever possible. I also did an extensive survey of the literature and pertinent findings from other studies are cited. No attempt will be made here to delve into deer herd dynamics.

II. THE PELLET GROUP TECHNIQUE

Terminology

All living animals excrete wastes resulting from digestive and metabolic processes. In the Cervidae and some other ruminants, each defecation occurs as a group of discrete, elongated or rounded objects (Murie 1954). A large number of terms have been used to refer to mammalian defecations: feces, fecal matter, dung, spoor, sign, droppings, manure, scat, and many colloquialisms. Understandably, wildlife biologists have come to refer to defecations of the deer family, and those of other animals whose defecations are similar, by the euphemism "pellet groups." Each of the small components is called a "pellet." Pellets are also used to refer to defecations of the Leporidae (hares and rabbits), the Erethizontidae (porcupines), and others which ordinarily do not deposit clusters of pellets at one time.

Sample counts of deer defecations have commonly been called pellet group surveys.

Historical background

Seton (1925) urged the study of feces as a means of learning about the habits, food and whereabouts of mammal species. His observation that, "Normally, the white-tailed deer evacuates every hour of its active life, which may mean 20 or more times a day" may have planted the seed for a new census method.

Later, several workers used pellet counts in studies of rabbit populations (Taylor 1930, Vorhies and Taylor 1933, Hendrickson 1936, and MacLulich 1937). Ruhl (1932) suggested use of pellet counts for big game species and even anticipated that there would be difficulties in determining the age of pellets and establishing a deposition period.

The Interstate Deer Herd Committee (1946) gives credit to the Cooperative Wildlife Research Units for first using deer pellet group counts in 1938. Bennett, English, and McCain (1940) also carried out surveys that year in Pennsylvania. Since then the technique has received wide acceptance. At present it is perhaps the most used and recommended deer census method in the northern and western states. Neff (1968) lists 57 references on the pellet group method, mostly concerned with mule or white-tailed deer, but in addition he refers to elk (Cervus canadensis), moose (Alces alces), Barbary sheep (Ammotragus lervia), domestic sheep (Ovis aries), and beef cattle (Bos taurus). Uses of fecal counts to gauge animal abundance have ranged from small mammals in Wisconsin (Emlen et al. 1957) to African elephants (Loxodonta africana) (Wing and Buss 1970) and from red deer (Cervus elaphus) in Russia (Yurgenson 1963) to red deer, fallow deer (Dama dama), sheep, chamois (Rupicapra rupicapra), brush-tailed possum (Trichosurus vulpecula), domestic pig (Sus scrofa), domestic goat (Capra hircus), and wild (European) rabbit (Oryctolagus cuniculus) in New Zealand (Riney 1957).

Basic concepts

Basically the pellet group system represents a systematic application of the experienced hunter's method of reading "sign" to gauge the abundance of game (Bennett et al. 1940). The idea is that the quantity of pellet groups which are found is directly related to the number of deer that are present. Quantifying this relationship, however, involves a number of factors. Taylor and Williams (1956) observed that the number of pellets of the European rabbit seen on the ground at any given time depend upon:

(1) the number of rabbits present
(2) the average rate at which rabbits have been productin pellets over a period prior to the counting

(3) the rate at which pellets disappear due to such factors as weather, bacteria, stock, etc.
(4) the efficiency of the observer.

It is a trivial change to substitute deer for rabbits. In this regard, Michigan pellet group surveys have been predicated on several assumptions:

(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 extablished relative to the deposition period

The current paper essentially investigates the validity of these assumptions.

Since complete counts of anything which is very numerous or which occurs over a large area are virtually impossible, some form of sampling is necessary for pellet group surveys. Actually, only in the case where deer are confined in small pens for short periods can complete counts be made. Even here sampling may be the preferred approach. As Deming (1960) points out, a sample is not a last resort, but is usually the best way to do a job.

Michigan studies have always employed carefully defined plots of known size which are distributed in some fashion over the area of interest. Except for certain research studies, the ultimate sampling unit has been 1/50-acre plots. Sampling designs have varied among the several surveys and will be discussed under the appropriate section.

The deposition period in Michigan work has been bounded by the autumnal fall of leaves and the mean date of the survey. Surveys are carried out in the spring soon after the snow disappears and in as short a time span as possible.

The calculation of deer numbers from pellet group utilizes the algorithm:

$$\text{deer population} = \frac{\text{mean pellet groups per plot} \times \frac{1}{\text{plot size}} \times \text{size of area}}{\text{deposition period} \times \text{defecation rate}}$$

For a given survey, plot size, area, deposition period, and defecation rate have been considered fixed, the only variable being the mean number of groups per plot. Actually both deposition period and defecation rate are also subject to variation and their importance will be discussed in later chapters.

Additional applications of fecal studies

Study of fecal material can also provide other sorts of information besides measuring abundance. Although these other uses have not been employed extensively in Michigan, a brief account is given below as an aid to planning possible multipurpose surveys in the future.

Adams (1957) proposed using pellets to study food habits of herbivores and later several workers applied this technique to deer, for example: Lay (1965), Zyznar and Urness (1969), and Segelquist, Ward, and Leonard (1969). Short and Remmenga (1965) reported that fecal cellulose content seemed to have predictive value in estimating range forage consumed. They suggest that samples of pellet groups could be collected during population surveys for chemical assay to estimate plant tissue eaten from the range. Petrides, Golley, and Brisbin (1969) discuss determination of food energy flow in large herbivores and point out that food energy not utilized by the animal becomes defecated wastes. Severinghaus and Cheatum (1956) report that the winter range of deer was studied by putting red and blue dye into soybean molasses cakes which colored the droppings. Kindel (1960) tested a number of dyes for use in marking ruminant feces to trace animal movements. Nellis, Jenkins and Marshall (1967) fed and injected 65_{Zn} into rabbits, opossums, foxes, and bobcats (species names not given). When injected, the radioactive zinc was detectable for over a year. When fed to fox, opossum, and bobcat, it was detectable in the feces for about a month. McCaffery and Creed (1969) and Shafer and Liscinsky (1968) used the numbers of pellet groups in various cover types as an indication of relative deer use. Samuel and Trainer (1969) analyzed pellets picked up on regular pellet group surveys in Wisconsin for information on the prevalence and distribution of several endoparasites of deer. Finally, fecal examination might be useful to obtain information about age composition. Pellets of young fawns are obviously smaller than those of adults, but to date this approach has been little studied, nor have any workers reported sex differences in deer droppings as Bailey (1956) concluded are present in wild turkeys (*Meleagris gallopavo*).

III. GENERAL METHODOLOGY

The following sections explain the sources of the data which are evaluated in later chapters.

Determination of defecation rates

Rates of daily pellet group deposition were investigated with penned animals at the Cusino and Houghton Lake Wildlife Research Stations during 1953, 1954, and 1959.

At Cusino, defecation rates of one adult male, two adult females and one female fawn were studied for a total of 73 deer-days in April and early May of 1953. The deer were fed a hardwood-conifer diet made up largely of sugar maple (Acer saccharum) and northern white cedar (Thuja occidentalis) which simulated late winter conditions for this area. Other species - red maple (Acer rubrum), hemlock (Tsuga canadensis), aspen (both quaking, Populus tremuloides, and bigtooth, P. grandidentata), and willow (Salix sp.) - were also fed, but consumed in low quantities. Pellet groups were counted and removed every 24 to 72 hours depending on weather conditions. All counts were converted to rates per 24 hours.

Much more extensive work at Cusino was carried out in 1954. Twelve pens of three deer each, half adults and half fawns, were studied. All but one deer, an adult buck, were females. A pen of adults and a pen of fawns constituted the samples for each of six different diets of natural browse. Eight counts on each pen were made between January and April. Each count was made approximately 24 hours following a snowfall of sufficient depth - about 4 inches - to obliterate signs of all previous deposition. On February 27, counts of pellets were made for selected groups in each pen.

The control diet consisted of nine browse species - white cedar, balsam fir (Abies balsamea), hemlock, red maple, sugar maple, yellow birch (Betula lutea), paper birch (B. papyrifera), black ash (Fraxinus nigra), and red-osier dogwood (Cornus stolonifera) - fed in unlimited quantities, simulating a white cedar deer yard in excellent condition. The swamp conifer diet simulated a medium condition deer yard where white cedar is moderately abundant. It included nine species of which tamarack (Larix laricina), balsam fir, paper birch, red maple, and the moderate amounts of white cedar supplied, were the species consumed the most. The swamp hardwood diet consisted of eight deciduous species commonly found around the periphery of deer yards and simulated a browsed-out white cedar deer yard. Red maple, paper birch, aspen, and American elm (Ulmus americana) comprised the bulk of the browse eaten. The hemlock-hardwood diet consisted of the 10 major species found in the northern hardwoods type. Red maple, aspen, American elm, along with hemlock, the only conifer included, were preferred. The fire succession diet consisted of jack pine (Pinus banksiana), red maple, black cherry (Prunus serotina), aspen, paper birch, and five shrubs - species commonly found profusely sprouting or seeding following fires. The final diet was mixed conifer - upland hardwood consiting of white pine (Pinus strobus), balsam fir, white spruce (Picea glauca), red maple, paper birch, aspen, yellow birch, and sugar maple.

At Houghton Lake in 1954, seven counts were made on four deer on 3 successive days in late May. Information on the sex, age, or diet of these deer is not available.

In 1959 at the Cusino Station, 20 deer were fed one of two diets. Varying numbers of counts were made on each deer within the overall period from January 7 to April 24. Both diets control and swamp conifer, were essentially the same as those in 1954. Generally three deer were kept in a pen. Prior to pellet counts, each deer was moved individually to a special pen for 2 days and then returned. Pellet groups were counted at either 24 or 48-hour intervals. Longer counts were converted to 24-hour rates and each received the same weight as one 24-hour count.

Studies at Houghton Lake in 1959 involved 11 deer in seven pens on three different diets. Diets were composed of one of three test species plus a combination of five to seven other browse plants that are associated with it. Test species constituted 50 per cent of the diet and the remaining 50 per cent consisted of approximately equal amounts of the other species. Adjustments were made in amounts fed to insure that associated species made up no more than 50 per cent of the food consumed. The diets used were sweet fern (Comptonia peregrina), aspen, and willow. Counts were made from January 28 to March 5. Pens were cleared of pellet groups prior to each rate determination and counts were made 24 hours later. In some instances, fresh snowfall was used instead of clearing.

Also in 1959, a study was carried out in a 6-acre enclosure near Houghton Lake. The cover type was a typical white cedar swamp association and was used by deer as a wintering area (Dead Stream deeryard). Inmate crews had enclosed an area 6 chains by 10 chains with a 7 1/2-foot fence in the winter of 1951-52 for use in a cedar topping study (Harger, 1954). Four deer - adult buck, adult doe, buck fawn, and doe fawn - were released into the area January 7, 1959 and were removed in the spring. Following transfer of the deer, biologists counted pellet groups on 60 transects 396 feet by 3 feet from June 23 to 25. Transects ran completely across the enclosure. Those counted were selected at random with replacement.

Weathering of pellet groups

Studies were undertaken at both Cusino and Houghton Lake Wildlife Research Stations to determine the longevity of pellet groups in several situations. In addition, researchers hoped to develop some guidelines with which to judge the age of pellet groups.

In the square-mile Cusino enclosure, observations were made of the rate of decomposition and vegetative coverage of naturally deposited pellet groups at varying intervals up to 5 years. Recently dropped groups in various cover types were marked with numbered wooden stakes. A detailed description of each group and its surroundings was recorded at every visit. Summer groups were observed more closely the first year to study their rate of decomposition. All groups extant at the last visit were examined the following spring or early summer to note their appearance at the usual time of pellet group surveys.

The first groups were marked during the summer of 1953, and ultimately 318 groups were considered during the 5-year study period. Groups deposited in summer or early autumn (pre-leaf fall) numbered 123, while post-leaf fall examples totaled 195. Observations on many groups were terminated as soon as the groups became completely covered by vegetation, but others were continued to investigate the durability of individual pellets in the duff.

At Houghton Lake, workers utilized a different study technique. Pellet groups were collected from penned deer and placed in selected cover types. On September 1, 1953 three groups were set out in each of five types - oak (Quercus sp.), jack pine, open grass and sedge, aspen, and conifer swamp. Three examinations were made at weekly intervals. At the end of 24 days the study was replicated with a new series of groups.

Sixty more groups were distributed February 25 and March 7 and 10, 1954-30 in an upland aspen site and 30 in a swamp conifer stand. About one-half of the groups placed in each location were collected from deer fed a jack pine-oak diet and the remainder a balsam fir-northern white cedar diet. All groups were re-examined once on May 16, 1955.

<u>Experimental field trials</u>

Experimental pellet group surveys were conducted on two large deer enclosures. One of these, the Edwin S. George Reserve near Pinckney, covering 1.8 square miles, is owned by the University of Michigan and operated as an outdoor laboratory for ecological studies. The other, a square mile enclosure at the Cusino Wildlife Research Station near Shingleton, is used for deer population and range research by the Michigan Department of Natural Resources. Ten surveys (1953-56, 1958-63) were carried out at the George Reserve and five (1953-56, 1958) at the Cusino enclosure. Herd size is quite accurately known on each area and this enables comparisons between results of pellet group surveys and actual populations.

With areas in this size range, it is impractical to select plots wholly at random. Travel must be primarily by foot. Hence, to facilitate locating plots, systematic sampling designs were used for the most part.

On the George Reserve the sampling plan consisted of establishing plots at uniform distances on lines which crossed the area. In University research and in this study, sample plots were located with the aid of aerial photographs on which 5-chain intervals have been inscribed in a grid pattern. During the first 3 years, plots were systematically located on every other north-south grid line with a 4-chain spacing between plots. Every fifth plot was marked by a permanent stake with a designated number. The plots were circular and 1/50-acre in size (16.7 feet in diameter). A new sample was selected in 1956 in a similar fashion, except that plots were not staked. In addition, plots were changed to a rectangular format (12 feet x 72.6 feet).

From 1958 to 1963 a stratified design was used primarily to spread samples across the whole area as outlined by O'Toole (1964). The Reserve was divided into six east-west belts 20 chains deep. Two east-west transect lines were then selected at random within each belt (the northernmost belt being very small, had only one line in some years). Plots were placed 4 chains apart on each line, beginning at a randomly selected starting distance (up to 5 chains) from the main central road or the boundary fence. Plots were the same as in 1956, but each was deflected 45° to the right of the direction of travel. Major cover-type boundaries in the Reserve are orientated in a north to south fashion, hence, east to west lines cut across cover types.

Total plots numbered about 280 in every year except 1956 when about 240 were set up. All plots were spaced by pacing and lines run using a hand compass. Generally the work was done in 1 or 2 days depending on the number of men involved. Usually the survey required 11 to 15 man-days. For the most part, two-man crews were used, and personnel were nearly all regular Game Division biologists. The major deviation was in 1956 when one Game Division biologist and five University of Michigan students completed the counts in 2 days.

Until 1955, crews simply aided each other in counting groups. Seemingly low counts in 1955, however, prompted a recheck of 13 plots by two men 19 days after the original survey. Beginning in 1958 a concurrent recheck system was used. Each man searched one-half of the plot, then rechecked his partner's counts on the other half. Metal disks were often used to mark counted groups so recheckers could readily determine which groups were missed on the first count.

Leaf fall dates were determined by the local District Game biologist. Oaks were especially troublesome on the Reserve, since their leaves fall intermittently from fall through spring. Equally disturbing were the large areas of marsh and upland grass where leaves were not present as a guide to pellet group age. In such instances, teams simply had to judge the age of the groups present. At briefing sessions held the first morning of each survey, crews were provided with some guidelines to use in aging pellet groups and were given "pep talks" on the importance of diligent effort. On the final six surveys, both old and new groups were tallied, and cover types for each plot were recorded.

In the Cusino enclosure a 10 chain x 10 chain grid has been established for study purposes. Numbered posts occur every 5 chains in each line - a total of 153. The lines are partially brushed out and marked with paint on trees between posts.

In 1953, three circular 1/50-acre plots were placed in conjunction with each post. One used the post as plot center, another was staked 40 feet due west and the third 40 feet due east. In 1954, 1955, and 1956 the central plot was eliminated because of potential bias due to human disturbance in using the lines as travel lanes. In all cases, estimates were based on the sum of the two or three plots at each post.

The 1956 Cusino survey was easily the most painstaking ever carried out in Michigan. In the fall of 1955, each plot was searched two or more times and the groups found were recorded. External characteristics and the exact location on the ground were entered on charts for each group so that it could be identified later without disturbing or marking the groups in any manner. Checks were spaced to cover the leaf fall period and until snow cover prevented further examination. The following spring, as soon as the snow cover was gone, two experienced game biologists not connected with the previous fall's survey, each surveyed about half of the plots. They marked all pellet groups found with metal disks. Different colored disks were used to indicate whether they felt each group was deposited prior to or after leaf fall. Finally, all plots were resurveyed using original plot records and the disks present to arrive at the best possible count.

In 1958 a stratified random sampling design was used. Each 2 1/2-acre block (5 chains x 5 chains) was assigned to one of four deer density classes, based on the results of previous surveys. These blocks were the primary sampling units and 100 were selected at random within strata. The number selected per stratum was an optimum allocation based on previous survey data. Each selected block was sub-sampled by a north-south line of three 1/50-acre rectangular plots. The starting point for each line was selected at random. The sum of the three plots constituted the data analyzed.

With the exception of 1956, old groups were not tallied by crews. In 1953 and 1954, crews removed groups from the plots after counting.

Manpower for the enclosure's surveys consisted of biologists from the research station, usually assisted by inmates. In most years, the survey required about 4 to 5 crew-days to complete; a crew consisting of two men. In 1958 all courses were run by two men, a biologist and an inmate, each checking the work of the other in the usual manner.

Population estimates were calculated as outlined in Chapter II. Weighted defecation rates for each area were developed from herd composition data. Chapter IV explains the origin of these rates.

No unbiased variance estimators are available for systematic sampling, however, Yates (1960) gives formulae for some approximations (usually inflated). Kish (1965) points out that a systematic sample, in many cases, can be accepted for practical purposes as a good approximation of random sampling. He indicates, though, this practice may also produce variances which are high because of induced stratification effects. For ease of computation I chose to compute means and variances for the 1953 to 1956 surveys on both areas as if they were simple random samples. Later surveys were analyzed as stratified random samples. Counts for individual 1/50-acre plots on the George Reserve entered the computations, while the sum of the two or three plots at each location constituted the Cusino data. Only estimates of sampling error in counting pellet groups were considered. No attempt was made to include variance components due to deposition rate or deposition period which were considered fixed insofar as population estimates were concerned. Limits of 2 standard errors of the mean were calculated for all surveys. Since $t_{.05} \approx 2$ in the range of degrees of freedom encountered here, such limits are approximately 95 per cent confidence intervals.

Cochran (1963) indicates that the normal approximation is generally satisfactory even with markedly skewed distributions unless very exact statements of limits are needed. Validity of this assumption was investigated for pellet counts. Negative binomial distributions were fitted to these data by the method of maximum likelihood (Bliss 1953).

Extensive surveys

Procedures for extensive surveys have gradually evolved over a number of years to a rather efficient operation. They are presented in some detail for the benefit of other workers who may wish to adopt them for similar surveys.

The 1953 surveys utilized a systematic design wherein five sections (square miles) were sampled in each full geographic township. Sections were arbitrarily selected in approximately a "five of spades" pattern, favoring accessibility and public ownership. Each section was in turn sub-sampled by a "course" of five circular, 1/50-acre plots located 8 chains apart in a cardinal direction. Plot locations were determined by means of hand compass and pacing. Course lines turned at right angles if formidable barriers (lakes, rivers, military bases, etc.) were encountered. Plot centers were marked by numbered wooden stakes.

To facilitate rapid location and relocation, all course lines were begun from driveable roads where possible. Workers were instructed to check maps and aerial photos of selected sections, beginning from the NW corner and proceeding clockwise around the perimeter of the section until a driveable road was located. On-site inspection of roads was often necessary to determine actual driveability. If no useable road was present, east-west or north-south roads crossing the section were selected in turn. Lacking suitable roads, workers drove as close as they could to the section and walked the shortest distance to the section line. For each course, a random number from one to nine was selected to determine how far to drive (tenths of a mile) along the access road before starting the course line. Plot 1 was 8 chains from the starting point. Courses were searched by state or federal game biologists working alone. Plots on two of the units were also searched in 1954.

Based on the results of the 1953 surveys, a two-stage, stratified random sampling plan was developed in 1954 and used with modification henceforth. Sections (square miles) constituted the primary stage. Local game biologists assigned each section to one of five strata of expected deer abundance during the over-winter period: stratum I, colored red on the stratification maps, over 50 deer/square mile; stratum II, colored yellow, 35 to 50: stratum III, colored brown, 20 to 35, stratum IV, colored blue, 5 to 20; and stratum V, uncolored, 0 to 5. Fractional sections were included if at least half was present. Overall sample sizes were set by available manpower. Dispensing of the primary stage sample over the various strata was by optimum allocation (Cochran 1963). Sections within each stratum were picked using tables of random numbers (Rand Corporation 1955). The second stage sample in each selected section consisted of eight 1/50-acre plots arranged in a straight line 5 chains apart. Location of the course line within each section followed the 1953 practices, except Plot 1 was 5 chains from the starting point.

Beginning with the 1956 surveys, plots were changed to the rectangular shape with the center line set at 45° to the right of the line of travel. Midpoints of each end of the plot were marked with wooden stakes. A plastic clothesline was stretched between the stakes while counts were made. An additional feature was the introduction of a system of rechecking one-fifth of the courses, selected at random, by research biologists.

Beginning in 1959 two-man crews were used and the concurrent recheck system was employed. The first plot was randomly located 0 to 5 chains from the starting point. The nine northern game districts formed separate sampling units with 60 courses in each. Additional courses were established within the Huron-Manistee National Forest boundary and in some game districts to provide more precise estimates. Except in two districts, plots were established in the spring of 1959 and resurveyed the following 5 years. All plots in Districts 7 and 8 were staked in September 1958 and cleared of all pellet groups.

Game districts in the northern Lower Peninsula were reduced from five to four in 1965. New stratification maps were drawn up and new samples were selected in all districts. Population levels for Strata I to IV were modified as follows: Stratum I 35 deer/square mile, Stratum II 25 to 35, Stratum III 15 to 25, and Stratum IV 5 to 15. The basic sample size was kept at 60 courses per district. Plots were staked in the spring of 1965 and searched each year through 1969. A major change involved starting from a randomly selected corner to initiate location procedures rather than always beginning at the northwest. Furthermore, new instructions allowed no offsetting of course lines. Plots falling in permanent bodies of water were assumed to have zero groups. Plots accessible to deer, but not able to be searched by crews, were assigned the average of the plots which were counted. If none of the eight plots on a course could be reached, it was dropped from the survey. Examples of troublesome sites included Air Force bases, flooded marshes and river basins, freshly plowed fields, sheep pastures, and private land where the owner refused access.

IBM mark-sense cards were used to record field data on the 1953 and 1954 surveys. Problems with erasures and bent and water-soaked cards prompted a change to Royal-McBee keysort cards for all subsequent surveys. Recently, Patton and Casner (1970) have reported good results with IBM Port-A-Punch cards but these have not been tried in Michigan. All original records are on file in Lansing.

Game biologists residing in various parts of the state were instructed to keep annual records of local leaf fall conditions. Each year note is made of the date when most (80 to 90 per cent) of the leaves have fallen. For a given survey unit, the deposition period was considered to extend from the leaf fall date to the mean date that survey courses were searched.

Means and variances were computed from course totals only, which is the appropriate analysis when the main objective is the estimation of a total. This is true even when, as here, the second stage sample is systematic (Cochran 1963, Eberhardt 1963, Kish 1965). Because of the generally small sampling fractions used, finite population corrections were ignored. Confidence limits of 2 standard errors as per cent of the mean (approximately 95 per cent) were calculated.

Average over-winter populations were computed as given in Chapter II. Conversion of these estimates to fall (pre-hunting season) and spring (pre-fawning) populations was accomplished by taking into account deer killed during hunting seasons and other mortality during the deposition period. Losses were removed instantaneously on dates believed to be weighted averages. The third and fourth days of the hunting season were used for the legal harvest in the northern Lower Peninsula and Upper Peninsula respectively. Other fall and early winter losses were removed December 1 and late winter and spring losses on March 1 in both peninsulas.

Mail surveys to samples of deer license purchasers are conducted each year by the Department of Natural Resources to estimate the legal kill (Eberhardt and Murray 1960, Bennett et al. 1966, Ryel 1970). Because final sales figures for hunting licenses are not available when pellet group surveys are completed, previous results utilized preliminary estimates of legal harvests. Final kill data have been used here to prepare revised population estimates for all surveys.

Estimates of losses other than legal kill were obtained from stratified random sample surveys carried out in northern Michigan during some years. These involved crews searching sample plots of ground and determining cause and approximate time of death for all carcasses found (Whitlock and Eberhardt 1956, Ryel and Bennett 1962). In later surveys, dead deer searches were combined with pellet groups surveys to reduce manpower requirements. Northern biologists were asked to estimate losses in their districts for those years when surveys were not made. Not included in mortality estimates are deer shot illegally and removed during the pellet deposition period. Hence, actual fall populations are slightly higher and spring populations slightly lower than the estimates given.

Using computations similar to those carried out by Eberhardt (1960), an average herd composition following the hunting season was obtained. These are expected to be close to the averages for the entire over-winter period, since the bulk of hunting season losses usually occurs within a month of the leaf fall date. The Upper Peninsula herd averaged about 15 per cent adult bucks, 49 per cent adult does, 19 per cent buck fawns, and 17 per cent doe fawns. A weighted pellet deposition rate of 13.47 groups per deer-day was used for estimates (see Chapter IV for the source of these defecation rates). Similarly, the average northern Lower Peninsula composition was 9 per cent adult bucks, 52 per cent adult does, 22 per cent buck fawns and 17 per cent doe fawns, resulting in a weighted deposition rate of 13.37. Original population estimates were calculated using a standard rate of 12.7 statewide. All estimates given here are based on revised defecation rates.

IV. DETERMINATION OF DEFECATION RATES

The assumption that deer defecate a fixed number of groups per deer per day is an integral part of the technique whether pellet group counts are used as an index of relative abundance or as a population estimator.

Background

The deer is a ruminant. Feeding studies by Mautz (1969) revealed that, in general, food is consumed on a regular and frequent basis and materials are passed from the rumen at a regular rate. He reported that in two adult males the passage time of natural diets averaged 30.1 and 40.6 hours through the entire alimentary tract. Zyznar and Urness (1969) found in studies of both mule and white-tailed deer that normal time lapse from feeding to evacuation, as indicated by presence of basic funchsin dye, was about 36 hours for a number of forage species.

About half of the dry weight of natural deer foods is defecated. For example, Mautz and Petrides (1967) found digestibility of the dry matter in northern white cedar to be 52.45 per cent. In later studies, Mautz (1969) found digestibility coefficients of dry matter to be 50.70, 49.42 and 54.17 per cent in quaking aspen, bluegrass (*Poa pratensis*), and staghorn sumac (*Rhus typhina*) respectively. Ullrey et al. (1967) found corresponding coefficients for northern white cedar and jack pine to be about 41 per cent each.

Previous studies

Essentially two ways have been used to determine the defecation rate of deer. One involves controlled studies of penned deer; the other, counts made in large enclosures with free-ranging deer. There are advantages and disadvantages to each system.

For example, the use of penned deer enables one to study individuals on specific diets and make periodic counts covering known time intervals. The disadvantages are: (1) confined deer often trample and scatter pellets, (2) penned animals are probably less active than free-ranging deer, (3) the diet is restricted to the foods which are provided, (4) it is expensive to house and feed individual deer, and (5) only relatively docile individuals can be used, which ordinarily means few males.

In large corrals deer can be more active, can select their own food (within limits), and are less liable to trample or scatter pellet groups. Furthermore, the simulation is closer to that of an actual field survey. That is, factors which may affect disappearance of pellet groups in the wild may also be at work in large range pens. The disadvantages are: (1) it is difficult to make complete counts and sampling may be necessary, (2) it is usually possible to make counts only once at the end of the yarding season, (3) if multiple deer are used, possible sex and age differences cannot be studied, (4) the food consumed is unknown, and (5) deer may die or be removed without the knowledge of the investigator.

In spite of the widespread use of the technique, all early census estimates were based on a single study of mule deer defecation rates (Rasmussen and Doman 1943). Michigan studies, begun in 1953 and discussed in detail here, evidently were only the second such study and to date apparently the only studies dealing with white-tailed deer.

The first available data for determining defecation rates, were obtained by Rasmussen and Doman (1943) in 1941. Although not actually given in the paper, rates can be calculated from the information presented. They worked with mule deer in a 741-acre fenced area in Utah. An average of 172 animals, both fawns and adults, was present during the study period. Counts were made on 123 circular 1/100-acre plots in August, September and October; apparently the pellets present were removed during each count. The weather was hot and dry with little green forage available. The determination of known deer-days of use was based on all deer present. McCain (1948) computed an overall average of 12.7 groups per deer-day from these data, the so-called "McCain Index." Rogers, Julander and Robinette (1958), speculating on the Rasmussen and Doman study, suggested that the defecation rate, as derived, was probably low since fawns born in late June and early July would have defecated less while receiving milk than those feeding strictly on forage. In addition, some of the small fawn groups may have been missed on the August counts. Still later, Julander, Ferguson and Dealy (1963) computed an overall mean of 12.6 from these same data, giving the August mean as 11.1, September as 13.1, and October as 13.5.

Dasmann and Taber (1955) studied a population of black-tailed deer (O. h. columbianus) on a 400-acre chaparral area in California. Actual populations on the area were unknown but estimated from four census methods, including pellet group counts. Five pellet counts were made over a period of 18 months on 50 circular, 100-square foot plots, located at random. At each visit, pellet groups were counted and removed. They concluded that defecation rate must have varied with diet and gave tentative defecation rates as follows: April-June on sprouting brush - 10.0, July-October on dormant brush - 13.0, and November-March on green herbaceious feed - 17.0.

Rogers et al. (1958) studied confined mule deer during five winters in Colorado. A series of deer-tight, contiguous pastures varying from 90 to 190 acres and stocked with from 3 to 40 deer were used. Adults made up 60 per cent of the deer involved, but sex composition is not given. After removing the deer in the spring, pellet groups were counted on sample plots placed along line transects. The average defecation rate was 15.21 ± 6.97 per cent (95 per cent confidence limits). The range was 12.82 to 20.52. Smith (1964) points out, however, that they used the wrong weighing factor - pellet groups counted instead of deer-days - in their computations and concludes that 15.01 is a better estimate.

Smith (1964) studied defecation rates of mule deer over a 12-year period beginning in 1947, using both individually penned animals and paddocks stocked with known numbers of deer. Winter defecation rates for penned animals on natural forage were 16.9 for fawns, 13.0 for yearlings, and 10.6 for older deer. His analyses showed the higher defecation rate for fawns to be significantly different than those observed in older animals. Data are not given by sex. For all deer in paddocks, the over-winter average was 13.2 groups per day.

In Arizona, Neff (1964) reported the defecations of one adult mule deer (sex unknown) on dormant browse for two periods of 7 and 7 1/2-days in February to be 13.0 and 13.9 groups per day. McKean (1965) studying mule deer in Colorado, counted pellet groups deposited in five small paddocks for a 20-day period in each of three successive winters. The paddocks were established on pine-juniper range and deer ate natural food. The overall defecation rate was determined to be 13.2, but he noted that rates were usually higher in the lightly stocked paddocks than those with relatively more deer. Neither the sex nor the age of the animals used is given.

Hines (1963) studied the defecation rate of 15 black-tailed deer in Oregon in a 340-acre enclosure from December to May. Deer fed on natural foods and dropped an average of 18.5 pellet groups per deer-day.

Coprophagy

It is well established that members of the Lagomorpha frequently reingest their own fecal pellets (coprophagy). For example, Meyers (1955) has observed it in the European rabbit in Australia, Hamilton (1955) in the swamp rabbit (Sylvilagus polustus) in Florida, Geis (1957) in the cottontail (Sylvilagus floridanus) in Michigan, and Bookhout (1959) in the snowshoe hare (Lepus americanus) also in Michigan. Bailey (1969) found about 30 per cent of the pellets produced by penned cottontails were of the soft type which are normally reingested. There is no evidence, however, that deer reingest their own pellets. Being ruminants, they would presumably not be able to extract much additional sustenance from fecal matter. Short, Medin and Anderson (1965) show that deer have a relatively small rumen coupled with a relatively high basal metabolic rate. Since the digestion of fibrous foods requires a long retention time, the small dimensions of the deer rumen would seem to preclude extensive fiber digestion. Hence, I conclude that coprophagy is not a factor in deer pellet group surveys.

Results of Michigan studies

Results of penned studies will be reported here. Surveys on the Cusino enclosure and the George Reserve will be discussed in detail in Chapter VII.

Tables 38 to 41 present the pertinent results of the penned studies by sex and age. Results for all determinations were adjusted to a deer-day basis (one deer for 24 hours) and all analyses were made on the adjusted data. Included are records for all deer or pens of deer of the same type which were deemed "good counts" by the personnel present, a total of 263 determinations involving 60 deer. Not listed in these tables are (1) the 1954 Houghton Lake data because the kind of deer used was not reported, (2) one pen with an adult buck and two adult does in the 1954 Cusino study, (3) records for six adult does at Cusino in 1959 which were injured in transfer between pens or became ill during the trials, and (4) one pen with a fawn of each sex in the 1959 Houghton Lake study.

Before proceeding into a more detailed discussion, I would like to point out some of the weaknesses inherent in the data. Obviously, the deer involved were not a random sample of any natural population, nor even representative in terms of sex or age. Deer were not assigned to pens or diets at random. Counts were made at irregular intervals based on weather, work schedules, and convenience of the workers. Deer diets were constructed by workers to simulate natural diets, but were not based on observations of the diet of wild deer. My hope is that, nonetheless, the data are similar to those that might have been obtained by more appropriate methods. No better information seems to exist. Consequently, with reservations, I have carried out some statistical computations as if the implied assumtions were satisfied.

The 1954 Houghton Lake study produced an average of only 11.79 pellet groups per deer-day. Results of other studies will be discussed in four sections, which consider differences between sex and age, differences between diets, differences in time of year, and result of a large corral study.

<u>Sex and age differences</u>

I have used a simple breakdown into four sex and age categories since exact ages were not available for many of the adult deer used and sample sizes were small for males. Fawns are defined here as animals less than one year old and, hence, adults are those one year and older. The samples are heavily weighted toward female deer, mainly because females are easier to handle in pens.

The evidence of sex and age differences is rather conflicting. An analysis of variance (two level, nested, mixed model with unequal sample sizes) on the 1953 Cusino data, Table 42, indicates no difference between kind of deer, but among individuals was significant at the $P_{.01}$ level. The average rate per individual was 13.32. Regrettably, in this analysis the average coefficients of the same variance components (EMS column) for kind of deer do not correspond at difference levels because of unequal sample sizes. Hence, no exact F test can be performed. Satterthwaite's approximation (Sokal and Rohlf 1969) can be used, but preliminary computations indicate significance would not be reached at the .05 level and I did not perform all of the necessary mathematics.

For the 1954 Cusino data, Eberhardt and VanEtten (1956) indicated highly significant differences (.01 level) between ages and also between diets. I performed a somewhat more complex analysis (three way, Model I ANOVA without replications) treating dates as a third variable. The second order interaction was used in significance testing. This assumes the added effect on σ_e^2 due to the AXBXC interaction is zero. Significance was obtained between age (.01 level) and diet (.01 level), and in addition between the diets x dates interaction (.05 level), Table 43. A significant interaction, however, raises some question about the value of testing the diets and dates main effects. Fawns averaged less groups per day on every diet. Overall fawn deposition rates were 12.10 compared to 13.24 for adults. Since only one deer in this study was a male, basically these data indicate that adult females average higher than female fawns. Absence of significant interaction between ages and diets indicates that diets did not affect daily rates of fawns and adults differently.

A re-examination of original records and reports reveals some disturbing aspects about the conduct of this latter study. Replacement deer were added to various pens to maintain the quota of three deer per pen. Actually, in only four out of the 12 pens were the same three deer present for all six counts. In seven pens, one deer was substituted and in another pen two extras were used. Eight counts were made, but only the final six were reported. The first two were conducted with inmate labor and were deemed inaccurate. Obviously, caution should be exercised in interpreting the results of these trials.

For the 1959 Cusino studies, defecation rates for eight deer on the control diet (two in each of the four sex-age groups) were compared. Analysis of variance (two-level, nested, mixed model with unequal sample sizes), Table 44, showed no difference among the kinds of deer, but a difference within kind of deer ($P<.01$). Mean defecation rate for all deer was 14.30. A similar analysis revealed similar results for six deer on the swamp-conifer diet, two adult does, one buck fawn and three doe fawns (Table 45). Here the average rate was 12.38. No other groups of deer on the same diets are available for testing. As in the 1953 Cusino study described above, unequal sample sizes in both cases preclude an exact F test of the effect of kind of deer. Again preliminary comptations indicated significance would not be reached at the .05 level even using closer approximations.

Only one of the above studies reveals significant differences in defecation rate between sex and/or age categories. This is not too surprising in light of the high variability noted in individual deer and the small sample sizes available for males. Smith (1964), working with captive mule deer in Utah, reported that fawns exhibited higher rates of defecation than adults. This is the direct opposite of 1964 Cusino data. Unfortunately, Smith did not report his data by sex. All but one of the adult deer and all of the fawns at Cusino were females.

Because of the homeostatic state of the rumen, I would expect that the range of possible defecation rates would be quite limited. Actual mean rates for individual animals reported above ranged from 8.80 to 21.38, and no significant differences in defecation rates were demonstrated between sex and age classes. Pending further study, particularly of males, I computed pooled means for each sex-age group regardless of diet. Counts made on groups of two or three deer per pen were treated as if they came from a single deer. Means and variances, weighted by degrees of freedom, were obtained in the usual fashion (Dixon and Massey 1957):

$$\bar{X}_p = \frac{n_1\bar{X}_1 + n_2\bar{X}_2 + \ldots + n_k\bar{X}_k}{n_1 + n_2 + \ldots + n_k}$$

$$s^2 = \frac{(n_1 - 1)\, s_1^{\,2} + (n_2 - 1)\, s_2^{\,2} + \ldots + (n_k - 1)\, s_k^{\,2}}{n_1 + n_2 + \ldots + n_k - k}$$

$s_{\bar{X}} = \sqrt{\dfrac{s_p^{\,2}}{n_o}}$ where n_o is the adjusted mean sample size (Snedecor 1956).

The resultant means and 95 per cent confidence intervals are:

adult bucks	15.61 ± 2.03
adult does	12.89 ± 1.60
buck fawns	14.74 ± 3.04
doe fawns	11.89 ± 1.79

Tables 38 to 41 and Figure 5 present these data in some detail. The averages obtained seem different enough to warrant computation of weighted defecation rates for field surveys using some measure of herd composition.

For the weighted defecation rates used to estimate Upper Peninsula (13.47) and northern Lower Peninsula (13.37) deer populations, confidence limits of 2 standard errors of the mean were 6.59 per cent and 6.97 per cent respectively. Using a variance approximation suggested by Deming (1964), I examined the effect on the confidence limits for population estimates due to adding a component of variation for defecation rates to that based on counting pellet groups. Results indicated only a small additional contribution. For example, the revised confidence limits for the 1969 survey in District 6 were calculated to be ±39.57 per cent (2 standard errors of the mean) compared to ±38.96 per cent when the defecation rate was considered constant.

Differences between diets

The analysis of the 1954 Cusino studies (Table 43), as mentioned above, discloses a difference between diets (P<.01). Duncan's Multiple Range test (Steel and Torrie 1960) indicated that three diets, hemlock-hardwood (mean 11.80), fire succession (mean 12.21), and mixed conifer-upland hardwoods (mean 12.36), differed (less) from the control diet (mean 14.06), at the .05 level, but not among themselves. These three diets are not a typical winter diet for a large proportion of Michigan deer. The commonest diets, swamp conifer (mean 12.76), and swamp hardwoods (mean 12.83), showed no significant difference from the control or each other.

Analysis of the 1959 Cusino data (two level, nested, mixed model ANOVAS with unequal sample sizes), Tables 46, 47, and 48, also shows no

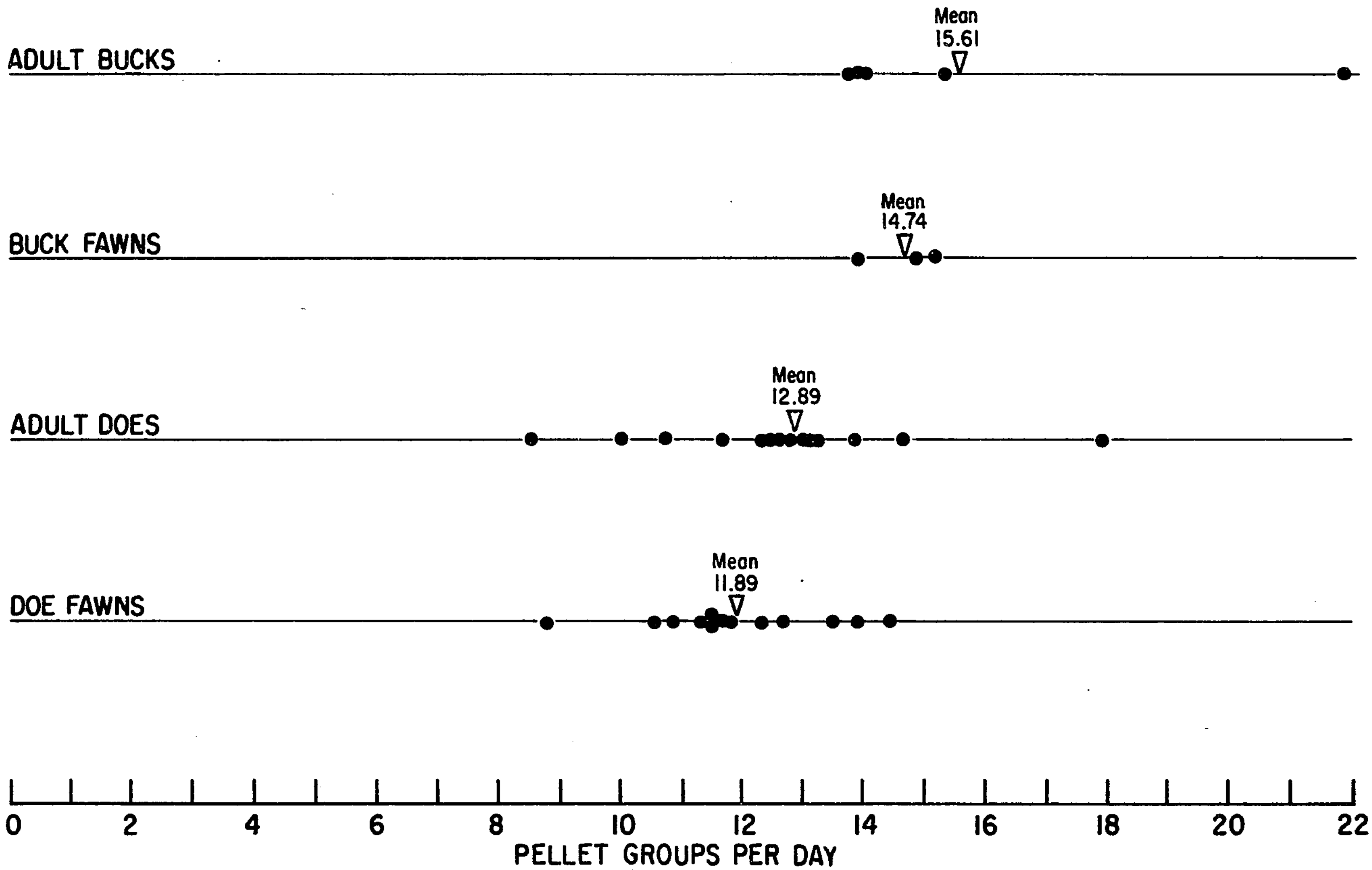

Figure 5. Defecation rates for Michigan white-tailed deer.

difference between control and swamp-conifer diets for groups of four adult does, three buck fawns and five doe fawns. Again unequal sample sizes prevent exact F tests between diets in each instance; however, it is obvious that significance would not be obtained at the .05 level by more precise methods. In the two female groups, differences were indicated between deer within diets ($P<.05$ and $P<.01$ respectively).

None of the trials at Houghton Lake lend themselves to such analyses.

I conclude from the available evidence that for deer feeding on what we believe to be the usual winter fare of wild deer, differences in diet are not a major factor influencing defecation rates. Evidently, individual differences in deer are more important than diet.

Differences between times of year

While virtually all studies of pellet deposition rate in Michigan have been conducted during late winter and early spring (see Tables 38 to 41), the mid-point of the period from leaf fall to mean survey date is mid or late January in both peninsulas. Actually the deposition period normally stretches over 6 months in the Upper Peninsula and slightly less in the northern Lower Peninsula, Figure 6.

Cowan and Long (1962) observed that adult male white-tailed deer in their studies voluntarily decreased food consumption and lost weight starting abruptly at the onset of rut, and continuing throughout the winter. In the discussion following a paper by R. L. Cowan (1962), I. McT. Cowan noted that some of his captive black-tailed deer had gone 60 days during the rut "without eating an ounce of food." Penned deer fed low nutritional diets undergo considerable weight loss and many low-diet fawns die when their weight drop exceeds about 30 per cent of their fall levels (Verme 1967).

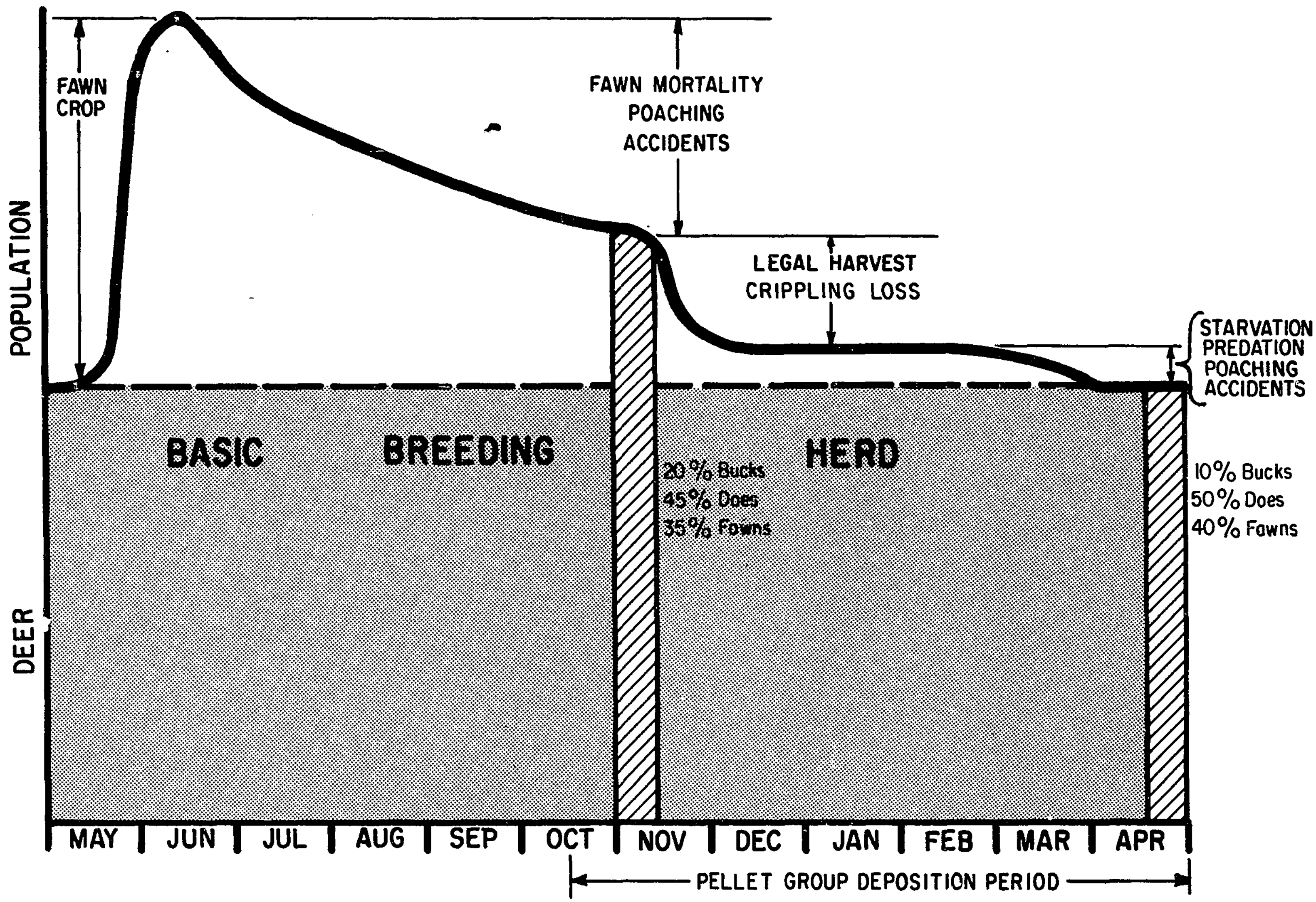

Figure 6. Diagramatic representation of a hypothetical Michigan deer herd.

Furthermore, it has long been known that deer, even on high nutritional diets fed ad libitum, undergo reduced food consuption and weight loss in mid-winter. Normally the decline starts in November and reaches a low point in February or March after which there is an increase (Davenport 1939, McBeath 1941, French et al. 1955, Magruder et al. 1957, McEwen et al. 1957, Silver and Colovos 1957, Wood, Cowan, and Norden 1962, Ozoga and Verme 1970). This has even been observed in Louisiana where cold winters are not a factor (Fowler, Newsom, and Short 1968). There is some evidence that there is an initial decrease in metabolism coincident with change to winter coat in September and that further reduction is due to onset of the rut in October or November and later still due to shorter day lengths (Silver and Colovos 1957, Silver et al. 1969, Silver 1969). Hoffman and Robinson (1966) reported a corresponding reduced function of various endocrine glands during January and February.

The concern is that there may be a corresponding decline in pellet group deposition during mid-winter when deposition studies have been carried out. If true, computed rates would be smaller than the true average rate.

Linear regression lines, defecation rates (Y) versus dates (X), were fitted to all records included in Tables 38 to 41 (except the pen of adult bucks with only two observations). Of the 35 records, only three entries, two pens of does and one doe fawn disclosed significant ($P<.05$, $P<.05$ and $P<.01$ respectively) negative slopes while one pen of does showed a significant ($P<.05$) positive slope. Three of the deer studied for defecation rates died of malnutrition. None of these showed evidence of a progressive decline in pellet deposition. Overall, about two-thirds (22) of the 35 had negative slopes and this strongly suggests at least a slight decline for most deer in mid-winter.

As noted above, analysis of the 1954 Cusino study revealed a significant diet x date interaction. This suggests there was some change in defecation rate with date in one or more of the diets.

One problem is that many of these records involve multiple deer per pen and many extend over a fairly short range of time. Nonetheless, if we look at only individual deer studied for relatively long periods, we obtain much the same results. From the 1959 investigations at Cusino and Houghton Lake, there are 13 individual deer, two adult bucks, four adult does, three buck fawns, and four doe fawns upon which counts were made in portions of three or more months. In only two instances, a doe (observation 12, Table 39) and a doe fawn (observation 12, Table 41), were slopes of linear regression lines fitted to these data significantly different ($P<.01$ and $P<.05$) from zero. However, none of the 13 have negative slopes including these two.

Intuitively one would expect that reduced intake would result in reduced fecal formation. The real question, though, is whether the rate differs, not the volume. Conflicting data are reported in the literature. Mautz (1969) studied the mean retention time of food in experimental white-tailed deer using 51-chromium as a tracer. He progressively decreased the food intake for one deer while leaving the others at ad libitum levels of feeding. He concluded that the rate of food passage was not affected significantly by the amounts of food eaten. Ullrey et al. (1964), however, noted food passage in their experimental white-tailed deer was generally slower than normal when very small amounts of food were consumed. Smith (1964) found an increase of defecation rate in mule deer with increased food consumption when rates are plotted against consumption on a per hundredweight basis.

Rogers et al. (1958) quote E. A. Hewitt of Iowa State to the effect that for livestock:

> "There is a very definite correlation with a decrease or increase in the amount of forage consumed upon the defecation rate . . . cattle usually defecate 10 to 24 times daily - more frequently if the food contains more water as in the case of succulent pasture."

Some crude data are available from both the 1954 and 1959 Cusino investigations which can be used to compare food ingested with defecation rate. All involved pens with two to four deer. Average browse consumption was reported for 3-week periods for the various pens. This can be compared with three to six pellet rate determinations per pen. unfortunately, two determinations were commonly made in the same browse period. Data for three of the 12 pens in 1954 showed significant correlations. Adults on fire succession and fawns on hemlock-hardwood showed a significant positive correlation ($P<.05$) of food consumption versus pellet deposition rate, but fawns on the control diet showed a significant negative correlation ($P<.01$). In 1959, none of five pens, with three deer in each, showed a significant correlation.

Biologists at Cusino sampled the groups present in each of 12 pens and counted the number of pellets per group on February 27, 1954. Table 1 shows a comparison of the mean pellets per group with the mean defecation rate per deer made on February 26. Data for neither age group reveals a significant correlation between the two variables.

There is evidence in the literature that switching from woody browse to lush new leafy foods results in increased defecation rates. Longhurst (1954) reported that domestic sheep in California placed on green grass after feeding on grain, stubble, and hay increased defecation rates from a mean of 13.26 to 15.50 per animal day. He also cites

Table 1

Comparison of Pellet Group Size and of Defecation Rates

in Cusino Deer, Late February, 1954

	Diet						
	Control	Swamp Conifer	Swamp Hardwoods	Hemlock Hardwoods	Fire Succession	Mixed Conifers-Upland Hardwoods	Correlation Coefficient r
Adult Does							
Mean pellets per group	73.6	71.3	94.6[1]	67.0	69.0	64.3	.27[2]
Mean groups per deer	15.0	13.6	13.3[1]	12.0	12.0	13.0	
Doe Fawns							
Mean pellets per group	49.0	62.3	67.3	52.0	67.0	63.0	-.05[2]
Mean groups per deer	14.0	12.0	14.0	11.0	12.3	10.0	

[1]One adult buck and two adult does were included in this pen, all other pens held three females each.

[2]This is a measure of the intensity of association between the two sets of means. $P_{.05}$ for 4 degrees of freedom, r = .75.

unpublished data from A. D. Smith that summer rates are higher than winter rates in penned mule deer. From studies of both mule and white-tailed deer, Zyznar and Urness (1969) conclude that coarse browse apparently passes through the digestive tract more slowly than concentrates and herbaceous foods. Mautz (1969) reported passage rate was inversely correlated with food particle size. Studies by Short, Medin, and Anderson (1966) seem to explain the mechanism involved. They found in mule deer that during the summer when the animals are feeding on succulent herbs, forbs, grasses and leaves, there is a greater rumen fermentation rate and a greater turnover of rumen contents.

What these studies seem to indicate is that defecation rates are fairly consistent in mid-winter, but with evidence for a slight decline. During this period, deer are subsisting on dormant, woody browse. Consumption of herbaceous foods apparently results in somewhat higher defecation rates. Normally this should not be a problem in the spring because surveys are usually completed before green-up. In the fall, however, deer are still able to obtain at least some herbaceous material. Hence, one might expect deposition rates then to be higher than winter, but there seems to be no way of showing this with the information at hand. I feel strongly that defecation rates need to be studied for the period from mid-October to the end of December. The diets used should simulate the mix of plant species utilized by the majority of wild deer at this time. Such studies, however, appear to be unusually difficult. Determination and collection of the proper foods for penned studies would be next to impossible. In spite of their inherent problems, the best approach might be to use rather large corrals.

Corral studies

To date, Michigan has only carried out one pellet rate determination which involved the use of a large "corral." This was the 1959 Houghton Lake study.

The four deer stocked in the 6 acres represent a deer herd of 427 per square mile. While this seems excessive, many natural populations in Michigan have exceeded this during the winter yarding period. On the average, deer yards in northern Lower Michigan occupy less than 10 per cent of the summer range (Bartlett 1950). When this study area was fenced off during the winter of 1951-52, we drove 28 deer out of the interior before the fourth side was put in place.

Nevertheless, when biologists examined the area in May the adult buck had already died. Herbert Johnson, biologist at Houghton Lake, who discovered the dead animal estimated the time of its death as late March. However, since we do not know exactly when the buck died, it greatly reduces the usefulness of the study. The adult doe was removed May 27 and the two fawns not until June 8.

Biologists making the counts had difficulty distinguishing separate groups of pellets, particularly in runways where they were often piled on top of one another. Best estimates were that a total of 2,883 groups were present on the 60 transects. This provides an estimate of 10,571 ± 531.72 (95 per cent confidence interval) for the 6 acres. If we assume the adult buck died on March 31, then the total deer days becomes 527 and the average pellet groups per deer day = 10,571 ÷ 527 = 20.06. Our other experience leads us to be surprised at this high rate.

One complicating factor was that observers were not concerned about distinguishing old groups, since the area had been deer free for 7 years.

We assumed that none of the groups deposited prior to building the fence would still be extant. However, as VanEtten and Bennett (1965) reported, some groups may persist at least as long as 5 years. Normally these would be classified as "old" by field men during the regular surveys. The author visited the enclosure a number of times in the years immediately following its construction and was impressed by the persistence of pellet groups present. We must admit, therefore, that the possibility exists that some old groups were counted, but it is difficult to believe these constituted a very high proportion.

A potentially more serious problem was that the deer were not removed in March or April when the normal yarding period ends. Furthermore, in most years the average date of the extensive deer pellet group surveys is mid-April in this area. As mentioned above, evidence suggests that switching from dormant, woody browse to lush, new growth results in increased defecation. Very likely these deer had been feeding on leafy foliage for at least 1 1/2 months. Hence, I cannot view the results of this trial as having much significance in relation to pellet group surveys.

V. DEPOSITION PERIOD

In the Rocky Mountain states, mule deer characteristically migrate between rather discrete winter and summer ranges. On a range used by deer only in the winter, workers need merely to distinguish the recent winter's pellet groups from those of the previous winter and note the time of arrival and departure of deer (McCain and Taylor 1956). In Michigan, however, the difference between summer and winter deer range is frequently ambiguous. Although deer tend to be more restrictive in their choice of winter cover, they commonly use many of the same sites throughout the year.

All Michigan work has been based on a fall-to-spring accumulation of pellet groups. Ideally, this period should be bounded by instantaneous beginning and ending points, such that each pellet group encountered could be easily assigned either within or without the period. Limitations in technology and manpower have generally precluded the ideal situation to date. Hence, less definite limits have been utilized. The autumnal fall of leaves has been used to provide a beginning reference point and the mean date of the spring survey the other bound.

LEAF FALL DATES

The premise is that the fallen leaves will blanket the ground and cover up all pellet groups deposited earlier. In northern Michigan, leaves of most deciduous trees and shrubs fall during a fairly short period. Often various combinations of hard rains, winds, and heavy, wet snows will bring down most leaves in one or two days. Leaves of some oaks and beech (*Fagus grandifolia*), however, may persist until late winter or early spring. Cropland, pasture, wild openings, marshes, and conifer stands are also potential problem areas.

While no specific studies have been carried out to explore variations in leaf fall dates, reported dates were studied to provide some indication of variability and potential problems.

Results

Records of leaf fall dates for 11 years (1959 to 1969) disclose that they have been relatively uniform within each game district (Tables 2 and 49). In most cases the range is about 2 weeks, the maximum being 27 days in old District 8. Standard errors range from .55 to 3.60 days. In every case, except old District 8 and old District 9, the range in leaf fall dates is less than 10 per cent of the average deposition period.

A simple linear correlation matrix (Table 3) of dates among the several districts suggests that their leaf fall dates show only a slight tending to covary. Significant correlations ($P<.05$) were obtained in only 7 out of 54 instances: new District 6 versus Districts 4 and 3, old District 6 versus Districts 1, 3, and 4, and District 3 versus Districts 1 and 4. Relative lack of correlation reflects vegetational and climatic differences as well as observer differences. Leaves tend to drop progressively later from north to south, but the influence of the Great Lakes precludes a regular progression. Furthermore, no regular procedures are followed by field men to determining leaf fall dates. Leaf fall dates are the result of impressions tempered by past experience and perhaps unduly weighted by conditions in the areas where each biologist lives and where he is working in mid-October. Since game districts cover several counties, leaf fall may vary somewhat from one part to another. An average date for the district is selected. At times airplane flights provide a better perspective, but such trips are generally coincidental in regard to leaf fall.

Table 2

Summary of Leaf Fall Dates by Game Districts

District	Number of years	Mean	Standard error of the mean	Range
1	11	Oct. 12	1.45	Oct. 2 - Oct. 18
2	11	Oct. 14	1.22	Oct. 8 - Oct. 21
3	11	Oct. 14	1.51	Oct. 8 - Oct. 23
4	11	Oct. 24	1.51	Oct. 17 - Oct. 31
5	11	Oct. 19	1.22	Oct. 11 - Oct. 25
Old 6	6	Oct. 23	2.03	Oct. 16 - Oct. 27
Old 7	6	Oct. 23	2.02	Oct. 18 - Oct. 31
Old 8	6	Oct. 25	3.60	Oct. 11 - Nov. 6
Old 9	6	Oct. 20	2.79	Oct. 16 - Nov. 3
New 6	5	Oct. 24	2.20	Oct. 22 - Nov. 3
New 7	5	Oct. 20	1.86	Oct. 15 - Oct. 25
New 8	5	Oct. 24	.55	Oct. 22 - Oct. 25

Table 3

Simple Linear Correlation Matrix of Leaf Fall Dates by Game Districts

District	1	2	3	4	5	Old 6	New 6	Old 7	New 7	Old 8	New 8	Old 9
1	1.00	.50	.72*	.57	.09	.88*	.56	-.27	.37	.41	-.40	-.11
2		1.00	.56	.23	.26	.67	.17	-.38	-.06	.15	-.80	-.51
3			1.00	.78**	-.01	.86*	.93*	-.22	.44	.42	-.11	-.23
4				1.00	.20	.91*	.94*	.33	.71	.52	.34	-.01
5					1.00	-.06	.75	.52	.60	-.05	-.09	-.21
Old 6						1.00		.17		.67		.08
New 6							1.00		.56		.25	
Old 7								1.00		.62		.68
New 7									1.00		.64	
Old 8										1.00		.75
New 8											1.00	
Old 9												1.00

* = P<.05
** = P<.01

Leaf fall dates do not enter the population estimator (Chapter II) per se, but only as a part of the deposition period. A variance estimate for deposition period can be obtained from the variability in the length of the yearly periods given in Table 49. Adding such a component of variation, however, has very little influence on confidence limits. As an example, approximate confidence limits (Deming 1964) for the 1969 survey in District 6 were calculated to be ±39.20 per cent (2 standard errors of the mean). This can be compared to ±38.96 per cent when both deposition period and defecation rate were assumed constant and only counts of pellet groups were considered random variables. Taking into account variance components for all three of these elements, limits of ±39.82 per cent were calculated. The additional contributions seem small enough to be safely disregarded. Hence, confidence limits reported here include only estimates of the sampling errors due to counting pellet groups.

Discussion

In my experience, where fallen leaves do not cover the ground, survey crews use matted vegetation as an equivalent reference point. Adequate snow cover to flatten ground plants, however, may not occur until some time after leaf fall, particularly in the Lower Peninsula.

In general, cover types in the Upper Peninsula seem more favorable to pellet group surveys, than in the northern Lower Peninsula (Table 4). The area covered by oak and cropland in the Upper Peninsula totals less than 5 per cent, while in the northern Lower Peninsula it comprises over one-quarter of the land area. Similarly, hardwood stands, except oak-hickory, cover nearly 60 per cent of the Upper Peninsula but only about one-third of the northern Lower Peninsula. Pine occupies less than 10

Table 4

Distribution of Major Cover Types in Northern Michigan 1966[1]

	Upper Peninsula		Northern Lower Peninsula	
	Acres	Prop.	Acres	Prop.
White pine	93,700	.0088	43,000	.0038
Red pine	234,900	.0222	325,100	.0285
Jack pine	412,300	.0390	472,100	.0415
Scotch pine			82,000	.0072
White spruce - balsam fir	872,600	.0824	193,000	.0169
Black spruce	398,700	.0377	29,400	.0026
Tamarack	115,200	.0109	40,300	.0035
Nor. white cedar	843,800	.0797	333,800	.0293
Maple-beech-birch	3,429,500	.3240	1,313,400	.1153
Oak-hickory	92,400	.0087	1,296,100	.1138
Ash-elm-cottonwood	586,100	.0554	630,500	.0554
Aspen	1,792,000	.1693	2,061,300	.1810
Paper birch	218,800	.0207	174,000	.0153
Unproductive and reserved	374,600	.0354	57,700	.0051
Cropland	246,500	.0233	1,169,400	.1027
Pasture and range	142,200	.0134	572,400	.0503
Other	731,100	.0691	2,593,900	.2278
TOTAL	10,584,400	1.0000	11,387,400	1.0000

[1]After Chase, Pfeifer and Spencer, Jr. 1970.

per cent in both regions. The only "troublesome" types where the Upper Peninsula leads, are the other conifers which total 21 per cent there compared to 5 per cent in the northern Lower Peninsula.

Leaf fall and pellet group deposition both occur on a continuum over time, while matting of fallen leaves and herbaceous plants by snow cover are essentially discontinuous events.

Workers agree that the near ideal situation occurs on northern hardwood sites in the Upper Peninsula. Here snow normally arrives in November and persists until spring breakup. Leaf fall occurs during a fairly short period and is complete. Deep snow compresses ground cover, resulting in a flat table-like appearance upon which overwintering pellets are conspicuously displayed in the spring. The early fall snow cover prevents deep frost penetration, and runoff from spring snow melt is rapidly absorbed.

While it appears that field biologists are providing fairly accurate leaf fall dates, the real problem is to decide whether a particular group was dropped before or after the selected date. In computations the assumption is made that all pellet groups deposited on the plots during the selected deposition period will persist, be found, and be identified properly on the spring survey. Furthermore, that any groups found which were dropped prior to the leaf fall date will be classified as "old" and will not enter into population estimates. The veracity of these assumptions will be considered in Chapter VI.

DATES OF SPRING SURVEYS

The dates that plots are searched in the spring are known with certainty. Ideally, counts are carried out as soon as possible after the snow disappears. Research studies on small study units present no real problems in this respect. Ordinarily they are completed in a matter of a few days. With extensive operational surveys, however, many circumstances arise which interfere with this hoped-for situation. Survey periods have ranged up to one and one-half months.

The commonest problem is that the spring thaw may proceed gradually with patches of snow remaining on north-facing slopes and in swamps for several weeks. Then too, the opposite situation - an early breakup with no precipitaion - may result in many workers being involved with forest fire control. Other hazards to efficient operation include spring snows, impassable roads, floods, and rains. A prolonged survey period may also mean new herbaceous growth will have started before counts are completed. Besides, the possible effect on pellet deposition, growing vegatation disturbs the leaf mat and makes finding and aging pellet groups more difficult.

Logically, extended counting periods might cause serious biases. For example, if high deer population areas were searched later than low population areas, overestimates would result.

Basically, our concern is with the extensive northern surveys. Records for the 94 game district surveys run from 1959 to 1969 were examined to determine ranges of survey periods. Records from a random sample of 11 of these were analyzed in more detail to determine the effects of long survey periods.

Results

Table 5 provides an overview of survey dates. The overall average length of survey periods is 24.04 days, varying from as little as 8 days for District 5 in 1965 to 45 days for District 8 in 1962. In 72 (77 per cent) instances, median and mean survey dates were within one day of

Table 5

Dates of Pellet Group Surveys by Game District

District		1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
1	Range	Apr 23-May 12	Apr 25-May 24	Apr 27-May 19	Apr 25-May 17	Apr 4-May 6	Apr 24-May 20	May 3-May 25	Apr 28-May 25	Apr 24-May 17	Apr 10-May 6	Apr 23-May 16
	Days between	20	30	23	23	33	27	23	28	24	27	24
	Mean date	May 4	May 8	May 9	May 7	Apr 23	May 5	May 15	May 12	May 4	Apr 25	May 5
	Median date	May 4	May 5	May 10	May 8	Apr 24	May 4	May 17	May 12	May 3	Apr 29	May 6
2	Range	Apr 20-May 6	Apr 25-May 27	Apr 18-May 5	Apr 26-May 15	Apr 5-Apr 17	Apr 20-May 6	Apr 28-May 25	Apr 20-May 13	Apr 17-May 5	Apr 9-Apr 24	Apr 23-May 9
	Days between	17	33	18	20	13	17	28	24	19	16	17
	Mean date	Apr 28	May 4	Apr 27	May 6	Apr 11	Apr 25	May 11	May 7	Apr 26	Apr 16	May 3
	Median date	Apr 29	May 3	Apr 28	May 7	Apr 11	Apr 25	May 12	May 8	Apr 26	Apr 17	May 5
3	Range	Apr 23-May 11	Apr 25-May 24	Apr 14-May 12	Apr 27-May 17	Apr 3-May 7	Apr 13-May 8	Apr 27-May 20	Apr 18-May 26	Apr 19-May 18	Apr 2-May 9	Apr 28-May 13
	Days between	19	30	29	21	35	26	24	39	30	38	16
	Mean date	May 2	May 8	Apr 28	May 8	Apr 16	Apr 25	May 11	May 7	May 7	Apr 16	May 4
	Median date	May 2	May 4	Apr 26	May 8	Apr 17	Apr 27	May 12	May 7	May 9	Apr 17	May 6
4	Range	Apr 21-May 11	Apr 25-May 11	Apr 14-May 9	Apr 25-May 16	Apr 16-May 10	Apr 21-May 18	May 1-May 20	Apr 16-May 13	Apr 19-May 15	Apr 16-May 7	Apr 23-May 15
	Days between	21	17	26	22	25	28	20	28	27	22	23
	Mean date	May 4	May 2	Apr 25	May 7	Apr 22	Apr 29	May 10	May 4	May 2	Apr 24	May 6
	Median date	May 5	May 2	Apr 26	May 7	Apr 23	Apr 28	May 11	May 4	May 3	Apr 24	May 7
5	Range	Apr 25-May 12	Apr 19-Apr 29	Apr 7-Apr 30	Apr 30-May 14	Apr 10-Apr 29	Apr 20-May 5	May 3-May 10	Mar 29-May 11	Apr 10-Apr 29	Apr 1-Apr 19	Apr 14-May 19
	Days between	17	11	24	15	20	16	8	44	20	19	36
	Mean date	Apr 30	Apr 26	Apr 21	May 5	Apr 18	Apr 25	May 6	Apr 21	Apr 19	Apr 9	Apr 26
	Median date	Apr 30	Apr 26	Apr 21	May 4	Apr 18	Apr 24	May 6	Apr 20	Apr 19	Apr 10	Apr 26
6[1]	Range	Apr 20-Apr 30	Apr 20-May 2	Apr 4-May 5	Apr 23-May 15	Apr 8-May 1	Apr 5-May 1	Apr 22-May 15	Apr 18-May 11	Apr 17-Apr 27	Apr 2-May 2	Apr 10-May 5
	Days between	11	13	32	23	24	27	24	24	11	31	26
	Mean date	Apr 25	Apr 26	Apr 16	Apr 29	Apr 13	Apr 18	Apr 30	Apr 25	Apr 21	Apr 17	Apr 21
	Median date	Apr 26	Apr 26	Apr 18	Apr 26	Apr 11	Apr 17	Apr 30	Apr 22	Apr 20	Apr 16	Apr 23

Table 5 (cont'd.)

District		1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
7[1]	Range	Apr 10- May 7	Apr 20- May 12	Apr 11- May 8	Apr 19- May 8	Apr 8- May 13	Apr 13- Apr 26	Apr 19- May 10	Mar 28- May 5	Apr 10- May 3	Mar 27- Apr 22	Apr 14- May 9
	Days between	28	23	28	20	36	14	22	39	24	27	26
	Mean date	Apr 24	Apr 27	Apr 15	Apr 28	Apr 18	Apr 17	Apr 29	Apr 18	Apr 15	Apr 4	Apr 23
	Median date	Apr 23	Apr 27	Apr 13	Apr 27	Apr 17	Apr 16	Apr 29	Apr 19	Apr 13	Apr 2	Apr 23
8[1]	Range	Apr 7- May 7	Apr 12- Apr 22	Apr 4- Apr 19	Apr 3- May 17	Apr 2- May 1	Mar 20- May 1	Apr 20- May 3	Mar 28- Apr 28	Apr 10- May 3	Apr 1- Apr 30	Apr 7- Apr 22
	Days between	31	11	16	45	30	43	14	32	24	30	16
	Mean date	Apr 18	Apr 19	Apr 10	Apr 11	Apr 10	Apr 11	Apr 25	Apr 10	Apr 18	Apr 9	Apr 14
	Median date	Apr 17	Apr 19	Apr 11	Apr 6	Apr 9	Apr 13	Apr 26	Apr 18	Apr 18	Apr 9	Apr 14
9[1]	Range	Apr 8- Apr 22	Apr 14- May 12	Apr 10- Apr 26	Apr 9- May 9	Apr 6- Apr 25	Mar 24- Apr 15					
	Days between	15	29	17	31	20	23					
	Mean date	Apr 14	Apr 23	Apr 15	Apr 17	Apr 19	Apr 6					
	Median date	Apr 14	Apr 23	Apr 14	Apr 16	Apr 17	Apr 9					

[1]Game District boundaries were changed in 1965.

each other suggesting symmetrical frequency distributions although not "bell-shaped." The reason for this involves the finite character of the manpower resources. As an example, Table 6 presents frequency distributions of dates for 1962 surveys.

Ranks of mean survey dates by strata for the 11 surveys are given in Table 7. Significance of these stratum ranks was tested using Friedman's test (Campbell 1967). In order to do these computations, data for stratum V and the 1962 District 5 survey were dropped and ranks recast accordingly. Results indicated there was not sufficient evidence ($\alpha = .05$) to reject the null hypothesis of no difference between strata, $.05<P<.10$.

Further tests were made to compare dates when courses were searched by stratum within each survey. Extended median tests (Mood 1950, Dixon and Massey 1957) were used to test the null hypothesis of no difference between strata ($\alpha = .05$). Table 8 presents test results for the 11 surveys. In four instances the null hypothesis was rejected, indicating some strata are different in some surveys.

The important facet of this problem at any rate, is the effect that an extended counting period has on the number of pellet groups counted. Some measure of this was obtained by adjusting all counts to a common spring date - the mean date of the survey - and computing new estimates using adjusted counts.

These computations are based on the assumptions that groups were dropped with uniform probability from a fixed leaf fall date until the date searched and that the deposition rate is constant over this time interval. Counts were then adjusted to the mean date of survey by simple proportion. To be sure, this procedure is not completely valid since

Table 6

Frequency Distribution of Courses Run by Date, 1962 Northern Surveys

Date	Game District 1	2	3	4	5	6	7	8	9	Total
April 3								2		2
4								11		11
5								12		12
6								15		15
7								3		3
8										
9								4	3	7
10								7	9	16
11								2	9	11
12									8	8
13										
14										
15										
16								1	5	6
17								1	5	6
18								2	7	9
19							1	5	7	13
20									6	6
21										
22										
23						8				8
24						7	7			14
25	2			1		10				13
26	2	2				9	12		1	26
27		2	3	2		8	14	1	4	34
28							15			15
29										
30	1		3		5	1	6			16
May 1	5	3	5	1	6		6			26
2	6	7	5	6	4	1		4		33
3	6	5	3	8	14	3	1		1	41
4	2	4	4	4	9	1	2	4		30
5					1					1
6					3					3
7	5	11	6	8	3	3	1			37
8	1	1	1	4	4	2	1		1	15
9	7	8	6	6	2	3			2	34
10	6	6	4	7	4	3				30
11	4	8	4	8	5					29
12										
13										
14		2	4							6

Table 6 (cont'd.)

Date		Game District 1	2	3	4	5	6	7	8	9	Total
May	15	3	1	5	3		1				13
	16	6		4	1						11
	17	3		3							6
	18								1		1
Total		59	60	60	59	60	60	66	75	68	567

Table 7

Ranks of the Mean Date Plots were Searched by Strata for Selected Game District Surveys

Survey	Strata				
	I	II	III	IV	V
District 1, 1965	4	2	3	5	1[1]
District 3, 1963	3	1	4	2	
District 3, 1967	5	2	4	3	1
District 4, 1969	1	2	4	3	5
District 5, 1962		1	3	2	
District 5, 1968	5	2	3.5	1	3.5
District 6, 1968	1	3	2	4	5
District 7, 1959	4	2	3	5	1
District 7, 1966	3	4	2	5	1
District 7, 1968	3.5	1	2	5	3.5
District 9, 1962	1	2	3	4	
Mean rank	3.05	2.00	3.05	3.55	2.62

[1]1 = latest date

Table 8

Extended Median Tests of Survey Dates Among Strata for Selected Game District Surveys

Survey	Degrees of freedom	χ^2	Probability of χ^2 value
District 1, 1965	3	2.76	.25 <P <.50
District 3, 1963	2	3.67	.10 <P <.25
District 3, 1967	3	5.62	.10 <P <.25
District 4, 1969	2	1.13	.50 <P <.75
District 5, 1962	2	3.78	.10 <P <.25
District 5, 1968	3	5.59	.10 <P <.25
District 6, 1968	4	17.82	P <.005
District 7, 1959	4	24.91	P <.005
District 7, 1966	2	1.04	.50 <P <.75
District 7, 1968	2	6.14	.02 <P <.05
District 9, 1962	3	14.48	P <.005

the deer herd declines from leaf fall to the time new fawns are dropped beginning in mid-May. Hence, we can expect such adjustments to overreact. Nevertheless, it provides a mathmatical routine for treating all data in the same fashion. Only discrete group counts were used, that is, fractional results were converted to whole numbers using conventional rounding methods.

Table 9 shows the results of the four surveys exhibiting significant differences in dates between strata as well as the three surveys whose survey periods extended over 40 days.

Surprisingly perhaps, the net effect of these adjustments is not great. The largest difference observed was about 3 per cent. In four out of the seven cases, the adjusted means were actually higher. The reason for this is that the strata with lower deer numbers (III and IV) were much more extensive than high strata and actually contributed much more to the stratified mean. Evidently intermediate strata tend to be searched midway in the overall survey period.

I conclude that there are differences when courses are searched in the various strata within some surveys; however, no particular pattern emerges across all surveys. Adjusting counts to simultaneous spring survey dates makes little difference in the estimates and is not recommended.

Table 9

Comparison of Survey Means from Original Records with Those Computed from Counts Adjusted to a Common Spring Survey Data for Selected Game District Surveys

Survey	Stratified mean		Change	
	Original	Adjusted	Actual	Per cent
District 6, 1968	8.2070 ±38.75%[1]	8.1842 ±37.78%	-.0228	- .28%
District 7, 1959	22.9459 ±25.36%	23.0974 ±24.54%	+.1515	+ .66%
District 9, 1962	6.6525 ±30.84%	6.5092 ±30.46%	-.1433	-2.15%
District 5, 1966	9.3762 ±30.20%	9.5514 ±30.85%	+.1752	+1.87%
District 8, 1964	6.5356 ±34.22%	6.7404 ±35.67%	+.2048	+3.13%
District 8, 1962	4.5216 ±33.81%	4.6054 ±34.94%	+.0838	+1.85%
District 7, 1968	17.9549 ±31.96%	17.7412 ±32.61%	-.2137	-1.19%

[1]Two standard errors as per cent of the mean.

VI. COUNTING AND AGING PELLET GROUPS

Without question, making accurate counts is the most important phase of the pellet group survey technique. This includes not only finding all groups present, but properly classifying those deposited prior to the deposition period and those dropped after the leaf fall date. An adjunct problem is whether all groups deposited after leaf fall are still present at the time of the spring surveys. Moreover, feces of other animals must not be mistaken for deer and vice versa.

WEATHERING OF PELLET GROUPS

Through the spring 1953 surveys, it was generally believed that most pellet groups lasted less than 1 year and nearly all those found in the spring were assumed to be new. Studies were begun in the summer of 1953 at both the Cusino and Houghton Lake Research Stations to test this hypothesis. Biologists at each station studied the longevity of pellet groups in a variety of situations. A summary of the Cusino enclosure investigations are given in VanEtten and Bennett (1965). The discussion here is based on the published data as well as on an examination of original records. Houghton Lake data are unpublished.

Pre-leaf fall groups

In the short-term studies of pellet group weathering at Houghton Lake in the fall of 1953, workers found that after 1 week all pellet groups in upland sites were rapidly decomposing and in their judgment appeared several months old. In the oak, aspen, and open sites, at least one group had completely disappeared. At 15 days further decomposition was evident and many groups had disappeared except in the conifer swamp site. At 24 days only a few individual pellets remained of groups placed in the oak site. Portions of groups remaining in the jack pine, aspen and open locations were quite decomposed and dried up, but still identifiable. In their opinion, none would have been classed as recent. Groups deposited in the swamp conifer site, on the contrary, had decomposed very little. Many of the pellets were still glossy and appeared to be only a few days old. Subsequent checks disclosed pellet groups in the cedar swamp persisting in excellent condition for over 1 1/2 years.

Of 123 groups, which had been deposited in the Cusino enclosure prior to leaf fall, 32 per cent still existed the next spring. Biologists felt that about 4 per cent might have been tallied as post-leaf fall groups by survey crews based on appearance alone. Most groups not covered by their first spring remained visible for at least 3 years, although clearly not to be confused with recent groups in later years. Some pellets were in good condition after 5 winters. Other factors being equal, groups deposited just prior to leaf fall persisted the longest. Similarly, groups dropped in open areas having a grass or moss ground cover tended to last longer. Dry, open sites seemed to favor longevity as opposed to shady, moist, and covered situations.

Post-leaf fall groups

In the 1954 spring studies at Houghton Lake, groups placed out in late winter and early spring did not weather or disappear nearly as rapidly as pre-leaf fall groups. Only one inspection of these groups was made slightly over a year after placement on May 16, 1955. The results are shown in Table 10. Although one-third of the pellet groups in the upland aspen site were visible compared to 53 per cent for those placed in a cedar swamp, a chi-square test of independence did not reject the null hypothesis at $\alpha = .05$ ($.10<P<.25$). "Visible" here was defined as being the situation where a group could be located without disturbing any living or dead vegetation. In most cases, part or all of a group

Table 10

Study of Weathering of Deer Pellet Groups
at Houghton Lake 1954-55

Diet	Date placed in field	Condition May 16, 1955: Cedar swamp site Visible	Cedar swamp site Covered	Upland aspen site Visible	Upland aspen site Covered
Balsam - cedar	Feb. 25, 1954	2	3	1	4[1]
Jack pine - oak	Feb. 25, 1954	1	2	0	3
Balsam - cedar	Mar. 7, 1954	4	2	2	4
Jack pine - oak	Mar. 7, 1954	4	2	4	2
Balsam - cedar	Mar. 10, 1954	1	4	1	4
Jack pine - oak	Mar. 10, 1954	4	1	2	3
Total balsam - cedar diet		7	9	4	12
Total jack pine - oak diet		9	5	6	8
Grand total		16	14	10	20

[1]One group had completely disappeared, all others in the study remained intact.

was leaf or grass covered. Workers thought the paucity of dead vegetation in the cedar swamp site was the principle reason that somewhat more groups were visible here.

Unfortunately, detailed records were not kept, but researchers estimated that not more than 5 per cent of the year-old groups in the aspen site and not more than 10 per cent in the cedar site would have been counted as new groups by survey crews.

Chi-square tests of independence were also performed on groups from two diets (jack pine-oak and balsam fir-northern white cedar) in each cover type to see if there was any tendency for one kind of group to remain visible more than the other. Results indicated no difference, the null hypothesis was not rejected at α = .05 level in either cover type, $.25<P<.50$ for the cedar site and $.50<P<.75$ for aspen.

At Cusino, most of the 195 post-leaf fall groups were not located until spring, hence, there is no information on over-winter weathering or disappearance. Follow-up examinations of the 195 groups revealed 53 per cent were visible the second spring, 26 per cent the third, and 20 per cent were still visible the fourth spring. Workers judged about 4 per cent would have been mistaken for recent groups in the second spring, none thereafter. Several groups of pellets under heavy cover remained solid after 5 years even though covered.

Empirical examination of the disappearance data for all 4 years indicated the relationship can be approximated by: $y = ae^{-bx}$ where y are pellet groups visible, a is the intercept, b is the slope or rate of increment expressed as a fraction, and x is the year of examination. Hence, a plot of log y against x approaches linearity (Figure 7). Here x (time) was assumed to be measured without error and regression equations

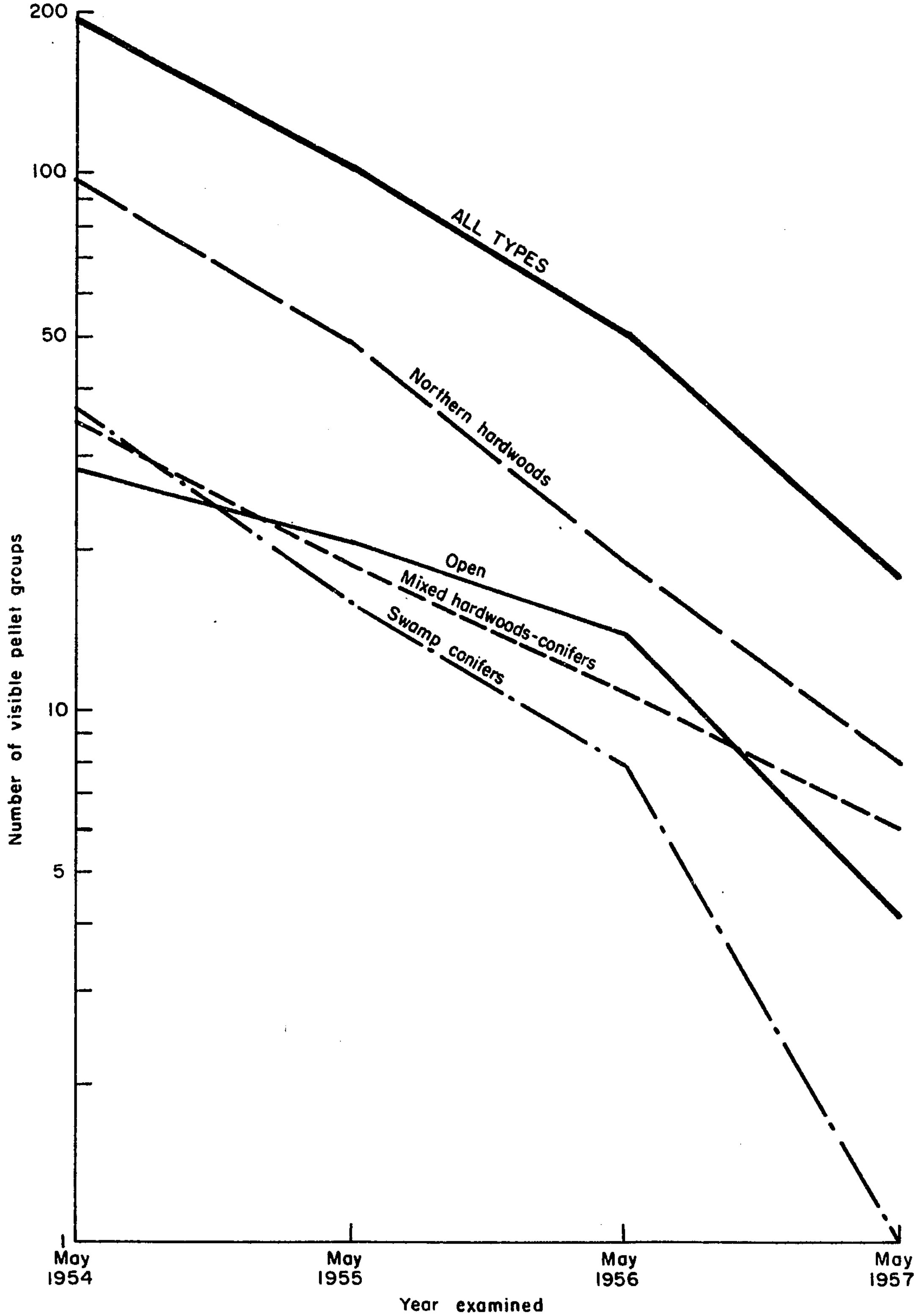

Figure 7. Disappearance of pellet groups over time in several overstory cover types. Cusino Wildlife Research Station.

could be easily calculated. The overall average disappearance rate was 54 per cent per year for these data.

Patric and Bernhardt (1960) studied deer pellet group longevity on three cover types in the Adirondacks of New York: sugar maple-beech-yellow birch, red spruce (Picea rubens)-yellow birch, and red spruce-balsam fir. They marked 60 groups from each of two successive winters and found 52 per cent and 47 per cent respectively were still visible 1 1/2 years later in June. Highly significant differences were found in relative longevity by cover types. Decomposition and/or concealment was more rapid in the sugar maple-beech-yellow birch forest type than in the types containing coniferous trees.

Cusino investigations concluded that the initial environment seemed to be the most important variable in determining how long groups remained intact. Pellets deposited in dry weather on dry sites soon became hard and virtually impervious to water. Similarly, groups deposited in the winter became desiccated, presumably through freezing. Few post-leaf fall groups showed evidence of mechanical breakup the first spring. A notable exception were groups containing large quantities of crushed black cherry pits, which decomposed readily.

In order to better evaluate the effect of various parameters on pellet group longevity, the locations for each of the Cusino groups was successively classified according to (1) overstory, (2) ground moisture conditions, (3) ground light conditions, and (4) ground cover types (Table 11). While I would have preferred knowledge of each group across all four classifications, such data are not available. In fact, because of original recording errors, the totals differ somewhat for each.

Chi-square tests of independence applied to data for the condition

Table 11

Proportion of Post-leaf Fall Deer Pellet Groups Visible in Succeeding Years in the Cusino Enclosure 1953-57[1]

Class	Proportion visible			Sample size
	Second spring	Third spring	Fourth spring	first spring
Overstory cover types				
Swamp	.43 (.03)	.20	.00	35
Hardwoods	.50 (.01)	.19	.08	98
Hardwoods and conifers	.56	.32	.18	34
Open	.75 (.18)	.50	.14	28
Ground moisture condition				
Wet	.27 (.04)	.04	.00	26
Moist	.52 (.02)	.30	.08	50
Dry	.66 (.04)	.38	.20	116
Light condition				
Abundant	.84 (.10)	.61	.32	31
Some	.51 (.03)	.25	.11	61
Little	.52 (.03)	.29	.10	90

Table 11 (cont'd.)

Class	Proportion visible: Second spring	Third spring	Fourth spring	Sample size first spring
Ground cover types				
Grasses	.60	.33	.10	10
Bracken fern and grasses	.75 (.17)	.50	.25	12
Coniferous needles	.71	.50	.25	24
Mosses and herbs	.59 (.08)	.44	.15	34
Leaves and herbs	.51	.29	.10	49
Leaves	.42 (.05)	.18	.09	55

[1]Prepared from data in VanEtten and Bennett 1965. Each of the four major classes represents essentially different sorting of the same pellet groups, although sample sizes are somewhat different. Numbers in parentheses are those judged by the senior author to have the appearance of first spring groups.

of groups in their second spring, that is, visible or concealed, for each of the four classifications showed no significant differences between ground cover types (.10<P<.25). Data for overstory types approached significance at the α = .05 level (.05<P<.10), with the major contribution being the open sites where more than the average number were visible. Analysis of data arranged by ground moisture and light conditions both indicated rejection of the null hypothesis at the α = .05 level (P<.005). Major contributions here involved wet plots where less groups than the average remained visible and again the open sites where more than the average remained visible.

Most of the effort at both Cusino and Houghton Lake has been directed towards problems with old groups. That is, how many groups deposited prior to leaf fall might be visible on succeeding spring surveys. The only Michigan study involved with the weathering and disappearance of groups dropped after leaf fall through their first spring was the 1956 Cusino enclosure survey. Results are shown diagrammatically in Figure 8.

A total of 129 new groups were marked in autumn before snow prevented further searching of the plots. When these groups were re-examined in the spring, 26 (20.2 per cent) had become so disintegrated or were covered by leaves, that they appeared old. In addition, biologists were able to "work backwards" from the groups found in the spring and, together with the autumn records, to determine that at least 869 groups had been deposited on the plots subsequent to leaf fall. Survey crews managed to find 764 (88 per cent) of these but misclassed 111 (15 per cent) as old. Actually, about equal numbers of new groups were missed as were classified as old, 105 to 111. One nebulous aspect of this study is that some groups deposited during the winter may have also disintegrated or

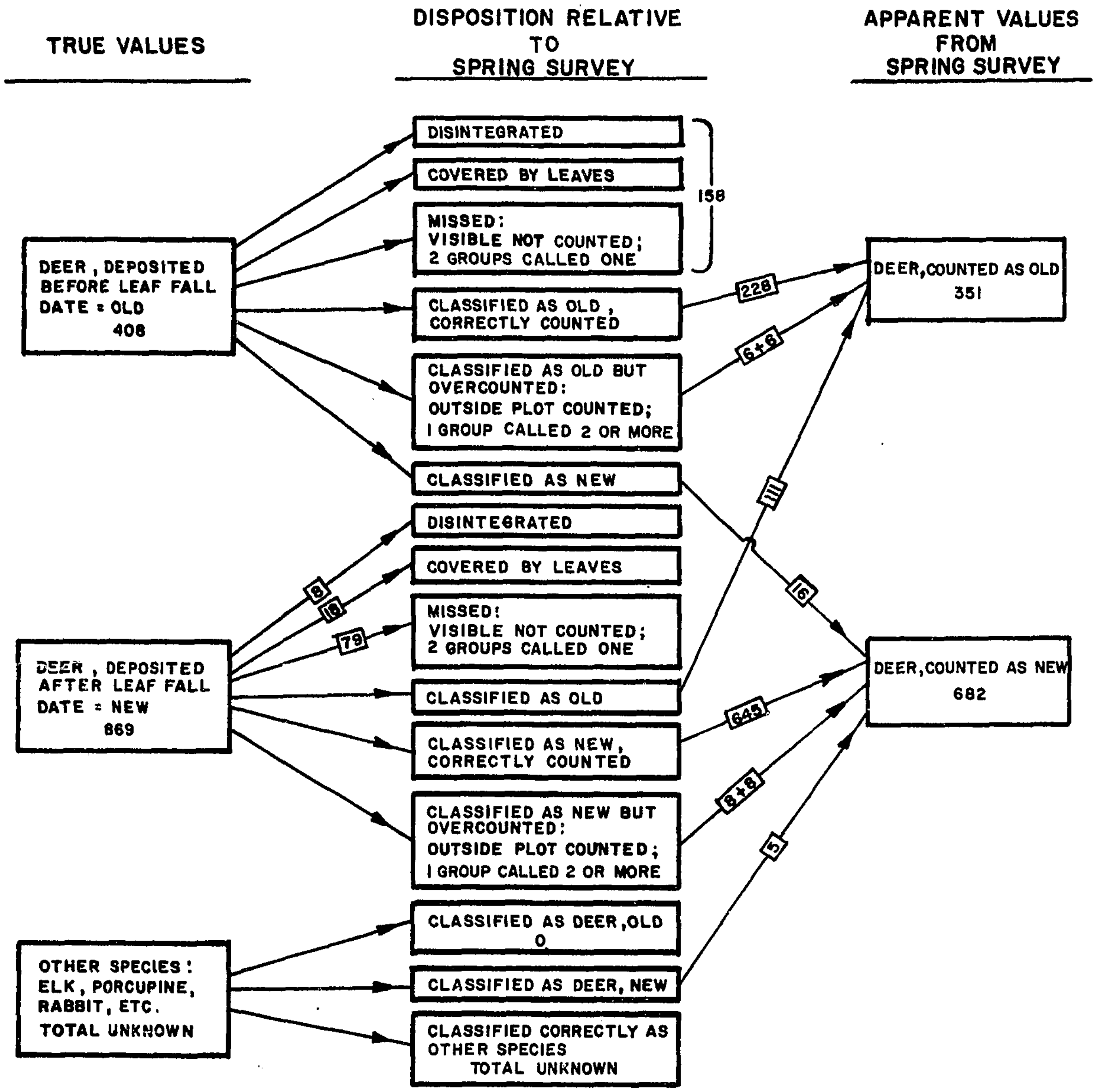

Figure 8. Model of pellet group counting; data are from the 1956 Cusino enclosure survey.

become covered and hence were missed or improperly identified in the spring.

The fall checks actually missed 104 of 408 old groups present in the spring (25 per cent). Evidently many groups became visible after ground cover was matted by winter snow, which is similar to the findings of Patric and Bernhardt (1960) in New York. On the other hand, 39 per cent of the old groups present at the time of leaf fall had disintegrated or been covered with leaves by the next spring. Errors adding to the new groups totals were very small - 16 old groups were classified as new, 8 extra groups were tallied which were really parts of other groups, and in 5 instances porcupine pellets were misidentified as deer.

Ferguson (1955), studying erosion and weathering of mule deer pellet groups on winter range in Utah, found that most groups stayed in good condition throughout the winter. The loss of groups by erosion was not important except where the ground cover was very sparse. Litter and vegetation held pellets even on slopes of 60 to 80 per cent. Shading was more important than the degree of slope for resistance to weathering.

Wallmo et al. (1962) reported that rainfall was a major cause of the disappearance of deer pellet groups (principally mule deer) in the semiarid mountains of western Texas. Mostly disappearance of groups seemed to be related to the number of "washing" rains with considerable runoff on moderate to steep slopes. Level sites and those with more ground cover showed less effect. Presumably under Michigan conditions, particularly during the winter, rainfall would not be a problem. However, we have not carried out any studies to evaluate how much heavy rain might contribute to the demise of pellets in October and November or in the early spring.

Spring and summer groups

The Cusino studies revealed that pellets deposited after green-up in the spring were often loosely formed and decomposed rapidly. Casual observations implicated insects in the rapid disintegration of some groups deposited later in the spring or summer. Similarly, workers at Houghton Lake reported insect activity associated with groups in their upland sites. In the southern part of the country, insect activity may actually preclude use of the technique. When Downing, Moore and Kight (1965) attempted to estimate the known deer population on a 776 acre enclosure in Georgia, they discovered that dung beetles (Canthon sp.) were destroying pellets quite rapidly, especially fresh ones. Use of repellents and insecticides on sample plots proved ineffective and the technique was deemed unsuitable until a better dung beetle repellent could be found. Moreover, in Utah, Ferguson (1955) found that the dung beetle (Onitlcellus californicus) was the agent most responsible for disappearance of 7 and damage to 19 out of 100 mule deer pellet groups in the spring. In a related study, Robinette, Ferguson and Gashwiler (1958) found 14 per cent of the groups studied had been completely buried by dung beetles from late March to mid-May and another 7 per cent were so damaged they would not have been recognized. Overall, 57 per cent showed at least some beetle disturbance. The findings of these studies clearly warn that the use of pellet group counts to measure deer abundance or relative deer use in the warmer months may not be valid.

Determination of pellet ages

Studies on pellet weathering revealed potentially serious problems in aging groups found on sample plots. It cannot be emphasized too strongly that the best criterion for determining the age of groups in the field is their position in relation to fallen leaves, if present. Any group partially or completely on top of leaves should be considered new. Careful searching will often reveal some new groups resting on aspen leaves but partially covered by oak leaves. The 1956 Cusino survey disclosed that many groups, classed by workers as old, were found atop fallen leaves or vegetation. Biologists were evidently misled by the appearance of the groups rather than their circumstances.

Pellet groups dropped where deciduous leaf cover is scant or nonexistent present definite problems in age assignment. As noted earlier, summer and fall groups deposited under open, dry conditions may harden and persist for long periods. Because openings are favorite feeding places for deer in autumn and spring, relatively large numbers of pellet groups are commonly found on such sites. Forbs and grasses can sometimes provide clues when alternatives are not at hand. Although their death may not conincide precisely with leaf fall in woody plants, compaction of herbaceous plants almost always occurs later and any groups found atop snow-matted vegetation will be new.

Where suitable vegetation or leaves are not present, other keys to pellet group age must be used. Eberhardt and VanEtten (1956) provide some general guidelines for use in Michigan. "Winter" pellets tend to be elongated and symmetrical, usually brownish in color and coarse in appearance. "Summer" and "fall" pellets are normally more spherical in shape, often more or less deformed, usually blackish, and finer textured. "Spring" pellets are loosely formed and decompose rapidly due to a high percentage of succulent plant material. Patric and Bernhardt (1960) in New York concluded it was unlikely that the age of white-tailed deer pellet groups could be reliably judged on the basis of condition of the individual pellets alone. Riney (1957) studied pellets from several species of captive ungulates in New Zealand and thought he could age them by the extent to which they had decayed. Fresh pellets were soft and slippery, with a surface slime. "Old" pellets were distinguished from "medium" pellets on the basis of internal decomposition. Kufeld (1968) also assigned ages to mule deer pellets in Colorado based on external appearance. Those less than 2 months old were dark brown with a lustrous finish and a hard, shell-like surface often covered with very small cracks. Pellets between 2-5 months old were described as somewhat lighter in color with the outer surface containing larger cracks and slight crumbling. Pellets older than 5 months had the outer coat broken away and the inner surface pitted and bleached grey or white. He also found pellet group size and density to be closely related to age. As time passed groups became smaller and more scattered.

Some of the more conscientious northern game biologists in Michigan routinely marked a number of groups around leaf fall time in troublesome cover types (or on actual plots) to provide themselves with a bench mark for the spring surveys. This practice has considerable merit and should be expanded.

Clearing plots and marking groups

A seemingly logical way to circumvent problems with aging pellet groups, would be to clear plots of all groups at the time of leaf fall. This approach was tried in the fall of 1958. In September all pellet group survey plots in Districts 7 and 8 were staked and cleared. Original plans called for re-examination and re-clearing shortly after the estimated leaf fall date, but lack of time and funds prevented this. Hence, clearing dates could not be used to establish definite deposition periods. Even so, we expected spring crews to find very few old groups; however, this was not the case, particularly in District 7 (Table 12). Cursory investigation pointed to three major causes. First, it is very difficult (and hard work) to remove all pellets from all groups on a 1/50th-acre area. Crews were instructed to count even one pellet as a group if no others could be located. Secondly, evidently some groups covered in the fall may become visible at a later date through decay and shifting of leaves and dead plant material. Finally, some groups were simply missed in the fall. Most vegetation in September is still standing and it greatly adds to the difficulty of finding groups. I cannot recommend this practice for Michigan surveys.

The use of tree-marking paint to spray pellet groups as they were counted has been used by some field men on our spring surveys and it shows promise. Kufeld (1968) tested several paints on mule deer pellet groups in Colorado and recommended yellow traffic-striping paint as the best. Painting has the advantage of being much faster than clearing and avoids the problems caused by not removing all individual pellets. Kufeld found that eight or nine white limestone fragments placed in the center of each group and sprayed along with the pellets to be by far the best technique. About 96 per cent of groups so marked were still identifiable after 10 1/2 months. Rain and snow seemed to have little effect on the durability. I feel we should also explore the feasibility of painting the visible groups soon after leaf fall on Michigan surveys, at least in sites where leaves will not blanket the ground.

<u>Discussion</u>

In 1953, workers assumed that most pellet groups lasted less than one year under Michigan conditions and tallied nearly all groups found

Table 12

New and Old Pellet Groups Found in the Spring With and Without "Removal" in the Fall on Surveys in Districts 7 and 8

	Year	New groups	Old groups	Prop. old
District 7	1959[1]	2,091	536	20.4%
	1960	1,697	657	27.9%
	1961	1,149	376	24.7%
	1962	1,567	316	16.8%
	1963	1,163	209	15.2%
	1964	1,367	280	17.0%
District 8	1959[1]	534	78	12.8%
	1960	573	138	19.4%
	1961	563	102	15.3%
	1962	548	65	10.6%
	1963	845	93	9.9%
	1964	793	146	15.6%

[1]Plots cleared in September, 1958.

in the spring as new. As detailed above, subsequent studies refuted this. We now know that at the time of the spring surveys many more pellet groups may be present and visible than those dropped since leaf fall. Based on the Cusino studies, in the average situation, nearly twice as many will be visible and under open conditions nearly three times as many, assuming a similar deer herd each year.

We can visualize the situation as one where groups are being constantly deposited at rates related to the season and the size, composition and diet of the deer population present. At the same time, groups on the ground are disappearing at varying rates due to a number of internal and external factors. Taylor and Williams (1956) developed a model of pellet density for the European rabbit in New Zealand assuming an exponential decay rate for pellet disappearance and a deposition rate proportional to population size. Batcheler (1971) has recently adapted this method for use with red deer in Australia. This approach may have considerable merit when and where insects (dung beetles) are active. It seems to provide a convenient way of taking into account the disappearance of groups during the deposition period.

For the type of surveys conducted in Michigan, the disappearance rate of groups during the winter has not been determined. The 1956 Cusino research showed that about one-fifth of the fresh groups marked in the late fall were leaf covered or had disintegrated by the time of the spring survey. Nevertheless, this rate would not apply to all new groups since the later the date deposited, the more likely they will survive until spring. Frigid weather normally present in mid and late winter prevents bacterial and insect activity, and to some extent mechanical breakup.

Results of these studies strongly suggest all pellet group surveys would underestimate the number of new groups actually dropped within the deposition period. During the winter, some groups will have disappeared, others will have become leaf covered, still others will have weathered enough to be called old, and many would be simply missed by crews. With the large number of old groups often present in open situations, however, misjudging the age of groups here could easily produce supernumerary counts.

Solutions to the problems of aging pellet groups would seem to lie in the following areas: (1) developing simple assay methods which could be used in the field, (2) developing more complex laboratory methods for aging pellets collected from groups of questionable longevity, (3) staking known-age pellet groups in the fall on troublesome cover types to help instruct survey crews, and (4) staking plots and painting all pellet groups visible soon after leaf fall at least on open sites.

COUNTING ERRORS

Early experience in searching for pellet groups elicited fears that a sizable proportion of groups were being missed. For example, several subdivisions of the Northern Lower Peninsula were surveyed in 1955 (Table 37), but preliminary examination of the data pointed to serious under-counting and analyses were never prepared. Hence, we took action to appraise the extent of such errors, to minimize them, and to monitor the effectiveness of quality control measures. Relevant data were obtained through both experimental surveys and follow-ups on operational surveys.

<u>Results</u>

On the 1955 George Reserve recheck of 13 plots, workers counted 25 new groups compared to 11 on the original survey, Table 13. Of course, the recheck was 19 days later and logically some additional groups might have been deposited. Workers, however, recorded only one group which was obviously very fresh. If 24 new groups were the proper number actually present on the 13 plots at the time of the original survey, then 1 additional group in 19 days does not appear unreasonable.

$$\frac{24 \text{ groups}}{181 \text{ days}} \;..\; \frac{x \text{ groups}}{200 \text{ days}} \qquad x = 27$$

Of the 13 plots, 6 had identical counts on the recheck and 7 were higher. None were lower.

The 1956 Cusino study has already been discussed above in regard to pellet weathering. At least 1,277 groups - 869 new and 408 old - were on the plots for varying time intervals following leaf fall. In the spring workers found 79 per cent of the total and 88 per cent of the new groups during the survey. Including various errors in aging and identifying groups, they reported about three-fourths as many new groups as were actually present (Table 14). VanEtten and Bennett (1965) found that the two biologists who made the initial spring searches differed at the $P_{.01}$ level in their ability to obtain accurate counts. The number of mistakes made by one biologist were independent of the number of groups present while the other individual tended to miss more groups when more were present. These findings definitely point to a need for careful selection of individuals and a system of regular rechecks.

A summary of the errors found on the 1958 George Reserve survey is given in Table 15. This necessarily differs from the 1956 Cusino study in that the "true" situation is unknown. Results represent individual deviations from the concensus of both crew members at one point in time. For example, misaging groups, the commonest mistake found at Cusino, would

Table 13

Results of Rechecking Plots in the George Reserve Following the 1955 Pellet Group Survey

Plot number	Original count New	Original count Old	Recheck New	Recheck Old
4	0	0	0	0
5	0	0	0	0
13	5	0	5	0
14	0	0	3	0
20	1	0	1	0
21	0	0	2[1]	0
22	1	0	1	0
23	2	0	3	0
24	0	0	5	2
31	0	0	1	1
41	0	0	0	0
42	2	0	3	1
51	0	0	1	0
Total	11	0	25	4
Mean	.85		1.92	

[1]Includes one obviously fresh group.

Table 14

Summary of Counting Errors on the 1956 Pellet Group Survey in the Cusino Enclosure

Pellet groups deposited prior to leaf fall - October 7, 1955		
Fall		
Counted in fall	304	
Missed in fall, but judged old in spring	104	
Total present in fall	408	
Spring		
Not counted in spring: missed, covered, or disintegrated	-158	(38.7%)
Identified as new	- 16	
New groups classified as old	+111	
One group called two or more groups	+ 5	
Outside plot counted	+ 1	
Total old counted in spring	351	(86.0%)
Pellet groups deposited after leaf fall until spring survey - mean May 15, 1956		
New groups actually present in spring	869	
Not counted - disintegrated	- 8	
Not counted - covered by leaves	- 18	
Not counted - missed	- 79	
New groups classified as old, visible	-109	
New groups classified as old, covered by leaves	- 2	
One group called two groups	+ 8	
Old groups classified as new	+ 16	
Porcupine pellets identified as new deer	+ 5	
Total new counted in spring	682	(78.5%)
New groups counted correctly	645	(74.2%)
Old groups counted correctly	228	(55.9%)

Table 15

Summary of Counting Errors on the 1958 Pellet Group Survey in the George Reserve[1]

Old groups present, but missed by first observer	67
Old groups called new groups by first observer	12
Total old groups judged to be present in spring	352
New groups present, but missed by first observer	206
New groups called old by first observer	9
One group counted as two by first observer	1
Cottontail rabbit pellets classified as new deer by first observer	3
Total new groups judged to be present in spring	1,154

[1]Based on 224 out of 279 plots actually searched by two-man crews. Data represent the sum of two independent counts of each plot.

be difficult to properly evaluate with only a spring check. Old groups appearing new to one observer would likely look new to the other. The most frequent error reported here was missing groups. The first observers failed to find about 19 per cent of the new groups and 22 per cent of the old groups judged to be present. Simply recording gross new and old group totals provides a somewhat less sensitive way of looking at counting errors. Results of seven teams of observers are shown in Table 50. Here compensation among errors produced a slight smoothing effect.

Gross results for five other surveys, 1959-63, are shown in Tables 51 to 55. Some of the apparent improvement following 1958 resulted from the transfer of one individual who was able to find only 49 per cent of the new groups in 1958. The use of metal disks and the stimulus provided by knowledge of the poor job done in 1958 also contributed to better counts on later surveys. Results suggest the average crew member missed less than 10 per cent of the groups present, although the 1958 results hinted that the close agreement is partially due to compensating errors.

I believe that it would be difficult for field crews to do a better job of counting than was practiced on these George Reserve surveys. Most participants were regular Game Division employees and motivation was relatively high, working conditions were good, public interference was lacking, only a 1 or 2 day period was involved, weather conditions were generally ideal, and the spring ground conditions were carefully watched in order to carry out the survey when conditions were near optimum. Crews often engaged in spirited competition with not a few bets involved.

In contrast with the George Reserve, many aspects of the northern operational surveys were less than ideal. Mosquitoes, black flies, hot muggy weather, rain, spring fever, wet feet, long hikes, angry bulls, angry landowners, muddy trails, sheep pastures, the jibes of associates and sportsmen, etc., were typical hazards. Since survey periods commonly dragged on for several weeks, it was difficult for anyone to sustain his enthusiasm.

The subsequent recheck system used in 1956 and 1957 proved to be of limited value basically because the rechecks were not necessarily better than the original counts. Often there was a considerable time lag before selected plots were recounted and ground conditions frequently were seriously altered by sprouting vegetation. Moreover, delays in completing rechecks caused corresponding delays in computing estimates. Tables 56 to 58 compare double counts for the two survey years, 1956 and 1957. These data represent courses from various strata in several sampling units, but plots selected for rechecks were a simple random sample of the total. For descriptive purposes only, I fitted Model II regression lines using Bartlett's three-group method (Sokal and Rohlf 1969) with the original counts as the independent variable. The slope for the Upper Peninsula in 1957 was 1.0737. However, for the Northern Lower Peninsula slopes were less than 1 both years - .7808 in 1956 and .8623 in 1957 - indicating recheckers found less than the original workers did. Some surprisingly large differences were reported. For example, 0 on the original to 44 on the recheck, and 20 on the original to 8 on the recheck.

When actually used to adjust original counts, Eberhardt (1957) found that the extremely variable results in the Northern Lower Peninsula caused an increase in sampling error, changing confidence limits from about ±20 per cent on the original to about ±30 per cent for the combined ratio estimates (Cochran 1963). Furthermore, as suggested by the comparisons made above, in two of the three survey units here in 1957, rechecks resulted in smaller estimates than original counts. Rechecks in the Upper Peninsula were much more consistent, the correction probably being largely due to missing groups. Very likely this was due in large part to the experimental use of metal disks by original searchers to mark the groups they found.

The 1966 rechecks were prompted by the surprisingly low deer populations computed from the spring survey data. We attempted to verify a feeling that an inferior job of counting had taken place. Several new, inexperienced habitat biologists did considerable work on these surveys.

In general, totals of original and recheck for Districts 6 and 8 (Table 16) were similar, with rechecks actually being slightly less. Notwithstanding, the close agreement in both instances was an artifact of compensating errors and rather important differences were found for individual courses. On the other hand, the District 7 rechecks, where Carl Bennett and the author worked, indicated over 2 1/2 times as many groups as the original counts. Without exception we found more groups than original crews on every course.

When crews originally searched each plot, all groups found by the first man on each side were marked by metal disks. Different kinds of disks were used on old and new groups. When concensus counts were obtained, however, disks were removed. Hence, rechecks represented completely independent counts, which were actually made under less favorable (more advanced) ground conditions.

While one cannot draw definitive conclusions from these data, certainly evidence of poor counting was obtained. Undoubtedly the following factors were at least in part responsible: the unusual spring

Table 16

Comparison of Original Counts with Later Rechecks on the 1966 Northern Surveys

	District 6		District 7		District 8	
	Original	Recheck	Original	Recheck	Original	Recheck
	35	31	6	10	11	9
	6	16	20	33	22	14
	13	3	0	10	11	25
	0	0[1]	7	31[2]	26	16
	0	0[1]	10	31	19	18
	0	0[1]	—	—	—	—
Total	54	50	43	114	89	82

[1]Some of the individual 1/50-acre plots on these courses were not staked by original crews and hence could not be rechecked. Totals represent comparable portions.

[2]One group judged to have been dropped since original count.

weather, poor communication between biometricians and field biologists regarding the importance of accurate counts, a number of new, inexperienced biologists acting as crew leaders, fatigue because of concurrent dead deer searches, and generally heavy work loads. Reference to Table 5 reveals that the survey periods (range) for the 1966 surveys were relatively long for every sampling unit and set records in four of the eight districts.

<u>The "Deming Method"</u>

Coincidentally, the 1966 rechecks offered an opportunity to test a method for estimating the "true" number of pellet groups present using counts made by each crew member. This suggestion was made by Walter Hendricks while engaged in an audit of Michigan's deer population and kill estimation procedures (Research Triangle Institute 1966) and is based on Sekar and Deming (1949). Conceptually, the system argues that even with two-man crews checking each other's work, very likely some groups present will be missed by both counters.

In Hendrick's notation, the total groups present, N, will be estimated by the sum of N_1 and N_2 which represent estimates for each half of a rectangular plot. Equations for these values are:

$$\frac{N_1 = n_1 n_2 \ (n_1 + n_1')}{n_1 n_2 - n_1' n_2'}$$

$$\frac{N_2 = n_1 n_2 \ (n_2 + n_2')}{n_1 n_2 - n_1' n_2'}$$

where:

N_1 = number of pellet groups on the first half-plot

N_2 = number of pellet groups on the second half-plot

n_1 = number of pellet groups found by the first man on the first half-plot

n_2 = number of pellet groups found by the second man on the second half-plot

n_1' = number of additional pellet groups found by the second man on first half-plot

n_2' = number of additional pellet groups found by the first man on the second half-plot

Combining terms gives:

$$N = \frac{n_1 n_2 \; (n_1 + n_1' + n_2 + n_2')}{n_1 n_2 - n_1' n_2'}$$

As an example, suppose the first man counts and marks 20 groups on his half of the plot and his partner finds and marks 15 on the other half-plot. They then exchange places and the second man finds two additional groups and the first man finds five. Thus we have:

$n_1 = 20$

$n_2 = 15$

$n_1' = 2$

$n_2' = 5$

$N_1 = 22.76$

$N_2 = 20.69$

$N_1 + N_2 = 43.45$ or 43

Crew members actually counted 20 + 15 + 2 + 5 = 42 groups.

Our experience with the system produced conflicting results because it is applicable only within certain restrictions, namely:

$n_1 n_2 > n_1' n_2'$ unless $n_1 = n_2 = n_1' = n_2' = 0$

$n_1 > 0$ and $n_2 > 0$ unless $n_1 = n_2 = n_1' = n_2' = 0$

In terms of application then, the first man must find at least one group on his half-plot unless there is really none there, otherwise the estimate will be undefined or zero. Furthermore, the second man's adjustments must always add to the first, otherwise the estimated total will be less than those actually found. Finally, the recheckers must not find enough additional groups to make the product of the two additional counts equal to or greater than the product of the original counts, otherwise the estimate will be undefined or negative.

Hendrick suggests that some of these difficulties can be overcome by lumping data from several plots for the same crew, but this masks the real or potential differences of finding groups in various cover types, and complicates estimating procedures.

Discussion

The relative success of these surveys has depended in very large part on the work habits, motivation, and skill of the game biologists involved. On the northern survey, they set the example for their crew members and are responsible for resolving differences in numbers and group age. Obvious as it is, this point was difficult to get across at briefing sessions. Many seemed to feel that statistical "mumbo-jumbo" could salvage a poor job.

Some personnel may have genuine eyesight problems, but in most cases missed groups can be attributed to haste and lack of concentration.

Ideally, counts should be made on bright, overcast days rather than under clear skies. Intense sunlight causes confusing patterns of light and shadow which makes pellet groups difficult to see. Recheckers should traverse their partner's half-plot in the opposite direction on sunshiny days.

On the other hand, counts during or following rain should also be avoided. Robinette, Ferguson, and Gashwiler (1958) point out fresh and older groups are often indistinguishable when wet. Riney (1957) recommends waiting at least 2 or 3 days following a rain.

Winter deer concentrations in deer yards, tree cutting operations, and heavily used runways can result in high pellet density. Problems result when survey plots fall on such sites. Not only is it difficult to sort out the different groups, but merely counting a hundred or more groups is very tedious. Often two or more groups will be intermixed and careful examination will be necessary to properly gauge the number of groups actually present. Size, shape, texture, and color can be assessed to differentiate individual groups with the reservation that pellets frequently have a slightly different hue where they have been in contact with the ground. Neff (1968) and his co-workers in Arizona concluded that adjacent groups of very similar mule deer pellets should be counted separately unless they were definitely connected by scattered pellets. Otherwise, observers who tend to be "lumpers" might make serious undercounts.

Another aspect of counting pellet groups concerns the fact that all groups deposited by deer are not in the form of neat and distinct piles of pellets. Riney noted that under zoo conditions, 26.5 per cent of red deer and 17.5 per cent of fallow deer pellet groups were "stringers." Robinette et al. (1958) found 8 per cent of 1,485 mule deer groups were "strewn-out." Unfortunately, such data are not available in Michigan, but there is ample empirical evidence that scattered groups occur here frequently in the wild. Hence, the size of the plot may affect the counts. Batcheler (1971) suggests that in general, the larger the plot the more likely that scattered pellet assemblages will be identified properly as groups.

Every group should have a chance of being counted. Robinette et al. (1958) found the mean length of 185 strewn-out mule deer groups to be 14.5

feet. If plots were "too small" none could contain half of such a group. A circular .001 acre plot, for example, could contain half of a group 14.5 feet long only if the group was strewn across the center. Michigan's plot size of 12' x 72.6' should handle most groups properly. Notwithstanding, on future surveys I recommend adopting the suggestion of Robinette and his co-workers to count a group only if its midpoint (center of gravity) falls within the plot.

On the other side of the coin, Michigan workers were instructed to count even one pellet as a group if after careful examination it could not be assigned to a nearby group. This procedure was based on the practice of Bennett et al. (1940). More recent studies of mule deer droppings by Smith (1964) and Neff (1968) and both mule and white-tailed deer by Hart (1958), recommend that a larger number of pellets be used. Neff rather arbitrarily set 30 as the minimum for his Arizona surveys while Hart used five in South Dakota. Under Michigan conditions I feel that 10 pellets would be appropriate as an interim threshold for use in future surveys, pending receipt of needed research findings.

FECAL IDENTIFICATION

Murie (1954) points out the great similarity between the droppings of many hoofed animals and the difficulty of identifying pellet groups to species.

In Michigan, we have occasional problems distinguishing the feces of porcupine (Erethizon dorsatum), snowshoe hare, and cottontail rabbit from deer; but more troublesome are elk and domestic sheep.

Pellets left by the first three animals named can usually be accurately identified, and field men are instructed in recognizing them. Both rabbit and hare droppings tend to be round, rather than oblong, and flattened from side to side rather than circular in cross-section. Porcupine pellets are usually longer than deer, of a rougher texture, often with a longitudinal groove, and usually scattered under a tree rather than in distinct groups. Frequently, cut twigs will be found lying among the pellets. At times, large piles of porcupine droppings are found at the base of a hollow tree or fallen log which an individual animal has used for a den.

Elk occur in numbers only in one area of the state, centered in the Pigeon River State Forest near Gaylord. Adult elk pellets are noticeably larger in diameter than deer and normally groups contain more pellets. Overlaps occur, however, between the droppings of small elk and large deer. Field biologists who make pellet group counts in the elk country are familiar with the droppings of both species and decide on the ground to which species questionable groups belong. Experimental elk pellet group surveys undertaken in the major elk range from 1963 to 1967 indicated about two to eight times as many deer as elk pellet groups present in the areas searched.

Domestic sheep pellet groups seem to be virtually impossible to distinguish visually from deer, and plots falling in known sheep pastures are not counted.

Howard (1967) working on western ranges where both mule deer and pronghorn (Antilocapra americana) occurred developed a simple chemical method of distinguishing pellet groups of the two species. He determined mean pH values of 6.07 for mule deer and 7.61 for pronghorn and found no overlap. Nagy and Gilbert (1968) extended this technique to mule deer and domestic sheep and found a significant difference in pH between the two, averaging 7.31 for sheep and 5.72 and 6.46 for mule deer from two different ranges.

We have not carried out similar investigations in Michigan for elk, sheep or deer pellets, nor am I aware of any such work done with white-tailed deer. This is an area offering considerable promise and should be researched.

VII. EXPERIMENTAL FIELD TRIALS

Michigan is indeed fortunate and unique in having two large deer enclosures available for deer research - the Edwin S. George Reserve in southern Lower Michigan and the Cusino enclosure in the Upper Peninsula. The two areas are quite dissimilar ecologically, geographically, and climatologically.

Neff (1968), in his literature review of the pellet group technique, reported that only Michigan and Georgia had tested pellet group counts on areas with known populations. Experimental pellet group surveys on such fenced areas allow researchers to "look up the answer in the back of the book." Georgia studies (Downing et al. 1965) were aborted when it became apparent insects were rapidly destroying pellets. Lack of similar trials is not unexpected. The cost of enclosing and maintaining even one square mile with a deer-proof fence, and the difficulty of keeping tabs on the true size of the enclosed herd are formidable obstacles.

GEORGE RESERVE

Description of the area

The George Reserve is located in southern Michigan, in Livingston County, 3 miles west of Pinckney. The following historical notes and description of the area is largely from Jenkins (1964). This property was purchased in 1927 as a country estate by Colonel Edwin S. George, a Detroit industrialist. Prior to this date the area had been occupied by 12 separate farms. Since 1927 there has been no cultivation, no lunbering, no grazing by domestic stock, no artificial feeding, no fires, and no shrub or tree planting except one small planting of white pine and red pine (*Pinus resinosa*). For the most part, only red pine survived.

The terrain ranges from rolling to rough. Glacial action produced steep-sided eskers, moraines, kettle holes, swamps, and marshes. Soils consist of loam, loamy sands, sandy loams, peats, and muck. About one-third of the area consists of open grassland, about one-third is in upland hardwoods (largely oak, _Quercus velutina_, _Q. rubra_, and _Q. alba_; hickory, _Carya glabra_, _C. ovata_; and aspen, both quaking and bigtooth), about one-tenth each is in marsh and wooded swamp (mostly tamarack, poison sumac, _Rhus vernix_, and a variety of other shrubs) and the remainder in ponds, bogs, lowland shrubs, and the pine plantation.

It became clear early in this study that the actual size of the Reserve was other than the published reports would indicate: Hickie (1937) gave "2 sections"; O'Roke and Hamerstrom (1948) "about 1,200 acres"; and Tody (1949) "1,268 acres." Several crude attempts by me to ascertain the true size stimulated Jenkins (1964) to determine that the area inside the fence is 1,146 acres with another 122 acres outside the fence. In this report I have used 1,146 as the true acreage.

The deer herd

Colonel George enjoyed seeing deer and consequently enclosed the area with a nearly deer-proof 7-foot fence and stocked it in 1928 with two bucks and four does. The deer came from Grand Island in Lake Superior near Munising, Michigan. After six breeding seasons, a deer census drive count indicated a population of 162 in December, 1933, including two found dead prior to the drive (Hickie 1937). Jenkins (1964) believes the true population at this time may have been even higher.

Deer drive counts have been conducted with University personnel and students essentially annually since 1933 (Chase and Jenkins 1962). Details about the herd and its population dynamics can be found in

Hickie (1937), Kelker (1947), O'Roke and Hamerstrom (1948), Hamerstrom and Camburn (1950), Chase and Jenkins (1962), Jenkins (1964), and Haney (1969). Since 1952, lower jaws from all deer shot or found dead have been collected.

Although many of the participants in the annual drive counts had some doubts about their accuracy, it was not until Jenkins (1964) reviewed original drive records and analyzed ages from deer jaws, that actual evidence of discrepancies come to light. Dr. Jenkins and Dr. L. Dale Fay of the Game Pathology Laboratory, Department of Natural Resources, aged all collected deer jaws from 1953 through the 1962-63 harvest, using tooth replacement and wear criteria (Ryel et al. 1960). Since that time, Dr. Dale R. McCullough (Professor in the Department of Wildlife and Fisheries) and his students have continued this task.

Jenkins (1964) described his "aging method" of determining deer populations on the Reserve as follows:

> "If the age of each deer is known the actual population during earlier years can then be reconstructed. To illustrate: If a deer was 3 1/2 years old when killed in December 1957, it must have been present as a 2 1/2-year-old in 1956; as a 1 1/2-year-old in 1955; and as a fawn in 1954."

This is essentially the "virtual population estimation procedure" developed by Fry (1949) for fisheries studies. The chief problem with the method is that it requires a wait of several years before we can be confident that most of the animals alive in a given year have died. For example, the last pellet group survey on the Reserve was carried out in 1963 and I felt it necessary to wait at least 5 years before determining the population for that year. Actually, after 1965-66, harvests produced only five deer which were alive in the spring of 1963 or before, two each in 1966-67 and 1967-68 and one in 1968-69. Jenkins indicated that during the first 11 years in which jaws were collected, only 22 deer over 4 1/2 years old were killed.

The accuracy of aging deer by the tooth replacement and wear technique varies inversely with age (Ryel et al. 1961). In recent years, a newer and more accurate technique of using annuli in the cementum has been developed (Low and Cowan 1963, Ransom 1966, Gilbert 1966). All jaws from the reserve older than 2 1/2 years were aged again by Bromley (1968) using this latter technique and population estimates were adjusted accordingly. Ages for about 20 deer were changed. In addition, my data differ slightly from those of Jenkins because of inclusion of several deer that turned up in a re-examination of old records by Dr. McCullough. Deer populations constructed from the aging method are shown in Table 17 for the period covered by pellet group surveys. More detailed information on the construction of yearly populations is given in Table 59.

The fence surrounding the Reserve prior to renovation in 1963 was only 7 feet high with a 12-inch barbed wire overhang on both sides of the top. This cannot be considered completely deer-proof and some deer were observed to jump the fence on deer drives. Jenkins' (1964) analyses, however, indicated fence jumping must have occurred only rarely and perhaps nearly always during the drives when such instances were recorded. A few deer were also observed jumping back inside the fence during or following deer drives. I have arbitrarily considered all animals leaving the Reserve and all unaged deer which were found dead to be 1 1/2 years old (median age of the herd). Deer found dead were assumed to have died on the median date of the known harvests. All deer which jumped the fence were assumed not to have returned.

University of Michigan personnel feel that the efficiency of the

Table 17

Known Deer Populations for the George Reserve Based on Aging Method

Year of survey	Deposition period	Deer on area at leaf fall	Deer days	Deer killed after leaf fall	Subtract deer days	Net total deer days	Average deer per sq. mile
1953	179	87	15,573	14	1,718	13,855	43.23
1954	182	118	21,476	42	5,175	16,301	50.02
1955	181	123	22,263	46	4,930	17,333	53.48
1956	162	125	20,250	38	4,878	15,372	52.99
1958	167	108	18,036	58	6,017	12,019	40.19
1959	165	84	13,860	17	2,126	11,734	39.72
1960	163	101	16,463	51	5,925	10,538	36.10
1961	161	87	14,007	33	3,475	10,532	36.53
1962	144	94	13,536	49	5,078	8,458	32.80
1963	153	66	10,098	13	1,570	8,528	31.13

drive counts has been much increased in later years. This is due to both the use of more participants and a better disciplined operation. A comparison between drive counts and aging estimates, Table 18, supports this feeling. Nevertheless, it is difficult to account for apparent over-estimates in drive counts which occurred in three years, particularly the difference of 16 deer in 1963. At first I was tempted to blame this on the fence renovation project in 1963 which might have allowed some deer to escape that year. An undocumented loss of deer in 1963 would also affect the reconstructed populations for previous years as well, although to a lesser extent. Inspection of the data could easily lead one to believe that such a loss occurred. University of Michigan workers, however, reported that the method used to repair and extend the height of the fence did not result in a break at any time. Furthermore, the normal behavior of deer in regard to their home ranges would seem to rule out any mass exodus even if it were possible. Another probability for deer losses would be through poaching. In the 1961-63 period the feelings of local people ran strongly against the deer harvest operations on the Reserve and this resentment may have resulted in illegal shooting and removal of deer from the Reserve. Indeed a few such instances are actually known but there is no definitive evidence that any large deer losses from poaching occurred on the Reserve during or about 1963.

During the study period, over-winter deer populations averaged 41.6 per square mile with a range from about 31 to 53. Table 19 shows the average composition of the over-winter herds together with the expected deposition rates. In pellet survey computations a weighted defecation rate of 13.79 was used.

Reference to Table 17 points up the potential problems which could

Table 18

Comparison of Deer Drive Counts with Population Estimates Based on the Aging Method for the George Reserve

Year	Date of drive count	Deer counted on drive[2]	Deer at time of drive from aging method	Difference
1952-53	Jan. 10	54	78	24
1953-54	Jan. 9	73	97	24
1954-55	Dec. 11	91	119	28
1955-56	Nov. 12	91	125	34
1956-57	Nov. 10[1]	132	153	21
1957-58	Dec. 14	110	108	- 2
1958-59	Dec. 6	74	84	10
1959-60	Dec. 5	96	99	3
1960-61	Dec. 10	73	79	6
1961-62	Dec. 9	88	84	- 4
1962-63	Dec. 1	82	66	-16

[1]Two drives were held, results for only the first are given here.
[2]Data from Jenkins (1964).

Table 19

Average Composition of the Overwinter Deer Herd on the George Reserve

Year	Proportion of deer days				Expected defecation rate
	Adult bucks	Buck fawns	Adult does	Doe fawns	
1952-53	.3874	.1289	.2849	.1988	13.98
1953-54	.2257	.1977	.3170	.2596	13.61
1954-55	.2446	.3149	.3127	.1278	14.01
1955-56	.1740	.2194	.3415	.2651	13.50
1957-58	.2891	.2163	.3451	.1495	13.93
1958-59	.1962	.3068	.2658	.2312	13.76
1959-60	.2585	.2740	.3509	.1166	13.98
1960-61	.2249	.2602	.3060	.2089	13.77
1961-62	.2120	.2454	.3502	.1924	13.73
1962-63	.2703	.1250	.3369	.2678	13.59
Average	.2483	.2288	.3211	.2018	13.79

result if the extent and timing of mortality is not considered in constructing the average over-winter populations. Similarly, attempts to determine accurate fall or spring population levels from pellet group surveys would be virtually impossible without similar knowledge. This fact, however, seems to have been overlooked by other workers and for several years these adjustments were unique to Michigan studies.

Results

Eberhardt and VanEtten (1956) reported the gross results of the first three surveys and the author (Ryel 1959a) discussed the first six in more detail. Summaries of the 1960, 1961, and 1962 surveys were given in Ryel 1960, 1961, and 1962 respectively. All of these papers, by necessity, compared survey results with deer population estimates based on drive counts, which, as we have seen, were quite inaccurate in some years.

While pellet group survey estimates compare favorably with drive-count populations for four of the first six surveys (Ryel 1959a) they fit very poorly with the more accurate population data for these and subsequent years, Table 20. The relationship between known and estimated deer population estimates is, in fact inverse. The simple linear correlation coefficient is $r = -.62$ which does not quite reach significance at the .05 level (.6319 for 8 degrees of freedom). In only three years do the estimated and known populations differ by less than 10 deer per square mile.

In addition to revisions in the size of the known deer herd, some changes were also made in survey records. Approximately a quarter of the Reserve is in cover types which are commonly flooded or soggy in the spring - bogs, marsh, lowland shrubs, and tamarack swamp (Table 21).

Table 20

Summary of Results of Deer Pellet Group Surveys on the George Reserve

Year of survey	Deposition period	New groups found	Number of 1/50 acre plots	Estimated deer per sq. mile[2]	Known deer per sq. mile	Estimated population compared to known	Apparent deposition rate
1953	179	614[1]	277	28.7 ±20.7%	43.2	- 14.5	9.14
1954	182	558	278	25.6 ±23.7%	50.0	- 24.4	7.01
1955 original	181	343	278	15.8 ±23.3%	53.5	- 37.7	4.07
1955 recheck	200			32.5[3]	53.5	- 21.0	8.39
1956	162	806	241	47.9 ±21.8%	53.0	- 5.1	12.51
1958	167	677	279	33.5 ±22.2%	40.2	- 6.7	11.49
1959	165	602	277	30.5 ±21.0%	39.7	- 9.2	10.61
1960	163	1,001	280	50.4 ±23.0%	36.1	+ 14.3	19.26
1961	161	1,115	284	55.5 ±21.6%	36.5	+ 19.0	20.94
1962	144	842	284	49.8 ±22.4%	32.8	+ 17.0	20.95
1963	153	1,430	287	75.1 ±15.2%	31.1	+ 44.0	33.28

[1]All groups were counted in 1953.
[2]Limits of 2 standard errors of mean, approximately 95 per cent confidence limits.
[3]Based on simple expansion from the results of a recheck of 13 plots.

Table 21

Cover Type Areas on the George Reserve Based on Pellet Group Surveys[1]

Year	Pond	Marsh	Lowland shrubs	Bog	Tamarack swamp	Upland grass	Pine	Mixed hardwood	Total
1963	23.0	65.1	44.7	20.5	158.5	390.6	8.2	435.6	1,146.2
1962	35.1	96.4	71.3	21.1	124.4	365.0	8.5	424.1	1,145.9
1961	29.5	75.5	37.4	53.4	87.3	419.4	8.7	434.8	1,146.0
1960	12.7	155.6	19.5	30.5	130.5	385.1	0	412.1	1,146.0
1959	31.3	117.4	27.5	31.6	117.4	405.5	4.2	411.1	1,146.0
1958	18.8	153.2	4.2	64.8	57.0	373.9	4.0	470.1	1,146.0
6-year average	25.1	110.6	34.2	37.1	112.6	390.4	4.2	431.8	1,146.0
[2]		80.2	68.8	45.8	126.1	527.1		298.0	1,146.0
[3]	5.7	114.6	19.5	154.7		455.0		396.5	1,146.0

[1]All areas in acres.
[2]From O'Roke and Hamerstrom (1948), but their data was converted to 1,146 acres.
[3]From Tody (1949), but his data converted to 1,146 acres.

Permanent ponds occupy another 2 per cent. During the first three surveys, workers generally made no effort to count groups in such areas even though deer may have used them during the over-winter period. Uncounted plots were simply ignored and estimates computed using the results from those plots which were searched. Living organisms, however, are usually not distributed at random, thus, if deer frequented wet areas more or less than the average of the other sites, computations might be considerably in error. Hence, in 1956 and 1958, crews were asked to make an extra effort to count wet plots. This strategy succeeded in reducing the proportion of uncounted plots about one-third by 1958, Table 22. Beginning in 1959 we instructed crews to attempt counts in all areas except, of course, permanent ponds. On the last five surveys the number of uncounted plots was negligible.

For the purpose of computing estimates, I assigned values for the uncounted plots. In all years, plots falling in permanent ponds were recorded as zero. For the first three surveys the same sample was utilized. Because of varying weather conditions, plots may have been counted 1, 2, or 3 years or not at all. If a wet plot had been counted at least 1 year, it provided a basis of estimating the missing year or years through linear regression methods. Plots not counted in any of the first 3 years and on all subsequent surveys (except ponds), were assigned the average of the "wet" plots for that year which were counted. Cover types were not routinely recorded until 1958; but on earlier surveys recorders usually stated the reasons why certain plots were not counted.

The net results of these manipulations actually had little effect on calculated populations, the largest difference being less than two deer per square mile, Table 23.

Table 22

Proportion of Plots Counted During Deer Pellet Group Surveys on the George Reserve

	Plots counted	Plots not counted		Total plots
		Number	Per cent	
1953	239	38	13.7	277
1954	237	41	14.7	278
1955	241	37	13.3	278
1956	223	18	7.5	241
1958	254	25	9.0	279
1959	275	2	.7	277
1960	275	5	1.8	280
1961	284	0	0.0	284
1962	284	0	0.0	284
1963	283	4	1.4	287

Table 23

Effect of Estimating Groups on Uncounted Plots for Deer Pellet Group Surveys on the George Reserve

	Unadjusted	Adjusted
1953	28.8 ±23.7%[1]	28.7 ±20.7%
1954	26.1 ±27.2%	25.6 ±23.7%
1955	15.0 ±28.1%	15.8 ±23.3%
1956	49.4 ±23.0%	47.9 ±21.8%
1958	35.4 ±22.6%	33.5 ±22.2%

[1]Deer per square mile with limits of ±2 standard errors of the mean, approximately 95 per cent confidence limits.

One of the more striking aspects of Table 20 is the rather progressive increase in apparent defecation rate. This is computed by setting the estimation equation equal to the known herd size and solving for the defecation rate necessary to produce it. Population estimates derived from the first six surveys were less than the known populations while the last four were higher. The simple linear correlation between year of the survey and apparent defecation rate, r = .87, is significantly different from 0 at the .01 level. Further study of survey data reveals a reverse progression in the proportion of pellet groups found which were classified as old, Table 24. The simple linear correlation coefficient between apparent defecation rate and the proportion of old groups for the 6 years when old groups were tallied is r = -.94 for 8 degrees of freedom, which is also highly significant (.01 level). Assuming an average of 60 per cent new groups greatly increases the accuracy of the 1960 to 1963 surveys and brings all six within 50 per cent of the known populations. This suggests that the survey inaccuracies were caused by non-random errors, in particular, mistakes in aging groups.

The studies described earlier noted that weathering of pellet groups varied with cover types, site conditions, and weather factors. I examined available weather data which might affect longevity and/or appearance of pellets. Multiple linear regression methods were used to provide an empirical prediction model for the known populations and to assess the relationships among the variables. In other words, given the pellet survey results, can gross environmental factors be used to produce a linear equation which predicts the known population?

The factors considered included:

Y = known deer population/square mile

Table 24

Observed Old and New Pellet Groups by Cover Types
on the George Reserve

Year		Marsh	Bog	Lowland shrubs	Tamarack swamp	Upland grass	Pine	Mixed hardwoods	Total	Prop. new groups
1963	New	42	10	48	195	376	48	711	1,430	95.9%
	Old	0	0	3	2	39	2	15	61	
	Total	42	10	51	197	415	50	726	1,491	
1962	New	46	1	107	142	279	6	261	842	91.0%
	Old	3	0	2	0	67	0	11	83	
	Total	49	1	109	142	346	6	272	925	
1961	New	75	78	17	18	771	1	155	1,115	88.5%
	Old	1	0	3	2	118	0	21	145	
	Total	76	78	20	20	889	1	176	1,260	
1960	New	104	23	16	89	548		221	1,001	82.7%
	Old	4	1	0	1	170		34	210	
	Total	108	24	16	90	718		255	1,211	
1959	New	58	7	13	82	212	13	217	602	75.9%
	Old	20	0	3	72	67	0	29	191	
	Total	78	7	16	154	279	13	246	793	
1958	New	36	19	1	14	198	0	409	677	78.4%
	Old	0	0	0	0	161	0	26	187	
	Total	36	19	1	14	359	0	435	864	

x_1 = estimated deer population/square mile

x_2 = degree days June to September (sums of negative departures of average daily temperatures from 65° F)

x_3 = degree days November to March

x_4 = days 1 inch or more snow on ground

x_5 = days 2 inches or more snow on ground

x_6 = days with trace or more rain April to September

x_7 = days with measurable rain April to September

Climatological data were obtained from the General Motors Proving Grounds near Milford (U. S. Department of Commerce 1952 to 1963). This, the closest regular Weather Bureau Station, is located about 18 miles northeast of the Reserve in Livingston County. Intercorrelations of these variables are shown in Table 25. None of the variables is significantly correlated with either the known or estimated deer populations, although, as noted before, they approach significance with each other at the .05 level. In addition, degree days June to September (x_2) approach a significant correlation with the estimated deer population, r = .60 (.05 level = .63 for 8 degrees of freedom).

Using stepwise regression procedures (Draper and Smith 1967), the "best" regression equation for predicting the known population level was:

$$Y = -.2028x_1 - .0083x_3 - .6449x_7 + 139.9527$$

and the ANOVA table is as follows:

source	degrees of freedom	sum of squares	mean square	F
due to regression	3	415.4159	138.4716	4.65
about regression	6	178.7941	29.7990	
Total	9	594.2090		

The calculated value of R^2 is 415.4149 = .6991 which means this model

Table 25

Intercorrelations of Weather Factors, Results of Pellet Group Surveys and Deer Populations on the George Reserve[1]

	Y	x_1	x_2	x_3	x_4	x_5	x_6	x_7
Y	1.00	-.62	-.21	.60	.41	.28	-.13	.05
x_1		1.00	-.13	-.43	-.50	-.46	-.19	-.52
x_2			1.00	.34	.46	.55	-.09	-.02
x_3				1.00	.81	.71	-.32	-.29
x_4					1.00	.95	.23	.20
x_5						1.00	.32	.24
x_6							1.00	.83
x_7								1.00

[1]See text for explanation of variables. Significance levels are:

$P_{.05} = .63$, $P_{.01} = .76$.

accounts for about 70 per cent of the variation about the mean. The calculated F is not quite significant at the .05 level, $F(3, 6, .05) = 4.76$.

The above calculations simply provide a means of explaining the way the several factors are related mathematically. In no way do they pretend to furnish an explanation of the observed phenomena. They have, however, partially satisfied my feeling that weather variations could have influenced pellet group appearance enough to cause survey crew members to make mistakes in aging many of the groups found.

The results of fitting the negative binomial distribution to the George Reserve data are shown in Table 60. Chi-square goodness-of-fit tests indicate a satisfactory fit in every year except 1961. Such computations assume simple random samples, while in reality sampling was systematic and for some years stratified. However, following the reasoning of Bowden et al. (1969), I considered these data to be similar to counts which might have been obtained from randomly located plots. Habitats were irregularly located and deer movements in relation to cover induces non-regular location of pellet groups. Locations of plots were pre-selected and independent of observer bias. The stratification used was to insure a more uniform area coverage and was not related to relative deer abundance.

The negative binomial is a two parameter distribution - the mean ($\overline{x}$) and a positive exponent (k). The value of k has been used by some ecologists as a measure of the "clumping" of populations. Relative clumping and values of k tend to vary inversely (Southwood 1966). The variance of the negative binomial is equal to $\overline{x} + \frac{\overline{x}^2}{k}$. Hence, if k was constant over the years, the mean and variance would depend only on the mean. On the Reserve, values for k ranged from .2758 to .7121 for the 10 years' data. A χ^2 test for a single pooled k value, .4119, was made according to Bliss (1953) and was rejected, .005>p. This suggests that different patterns of deer distribution may have occurred over the years. Association between ranks of k and degree days November through March and with the number of days with 1 inch or more of snow on the ground from November through April (U. S. Department of Commerce 1952 to 1963) was measured with Kendall's coefficient of rank correlation (Campbell 1967). Both associations were positive and significant, $P = .046$ and $.002<P<.005$ respectively. Intuitively, I anticipated a negative relationship, assuming more aggregation (smaller k) in years with much snow and cold weather. Further inspection indicated this was probably due to the distribution of cover types on the Reserve (Table 21). Data on pellet groups by cover types are available only for the last six surveys (Table 26). No significant associations were found between the ranks of these means, but the signs of the relationships suggest deer make heavy use of the third of the area occupied by upland grass when temperatures and snow conditions are favorable. Otherwise, they tend to use the 60 per cent occupied by trees and shrubs and marshes. These ideas are supported by field studies and casual observations by University of Michigan students and faculty (Dr. McCullough, personal communication).

CUSINO ENCLOSURE

Description of the area

The Cusino Enclosure is located in the deep snow belt of the Upper Peninsula, in Alger County, about 1/2 mile northwest of Shingleton. The area is operated by the nearby Cusino Wildlife Research Station of the Michigan Department of Natural Resources. The area has been used for studies of the ecological coaction between deer and range, deer herd

Table 26

Mean New Groups per Plot by Cover Types from Deer Pellet Group Surveys on the George Reserve

Year	Marsh	Bog	Lowland shrubs	Tamarack swamp	Upland grass	Pine	Mixed hardwood	Total
1963	2.62	2.00	4.36	5.00	3.84	24.00	6.46	4.98
1962	2.00	.20	6.29	4.90	3.03	3.00	2.46	2.96
1961	4.17	6.00	1.89	.86	7.34	.50	1.44	3.93
1960	2.97	2.88	3.20	3.07	5.71		2.15	3.58
1959	2.07	.88	1.86	3.04	2.16	13.00	2.15	2.17
1958	.97	1.19	1.00	1.00	2.18	0.00	3.56	2.43

dynamics, and deer-hunter behavior.

An area of 647 acres was enclosed with a 10-foot deer-proof fence in 1952. It can be considered a fairly representative sample of much of the eastern part of the Upper Peninsula. The following description of the area is based largely on VanEtten (1955), Eberhardt and VanEtten (1956), Arnold and Verme (1963), and VanEtten, Switzenberg, and Eberhardt (1965).

The approximate composition of cover types is: upland hardwoods (mostly sugar maple and American elm) 46 per cent; lowland hardwoods (mostly red maple and black cherry interspersed with isolated stands of balsam fir, white spruce, and hemlock) 22 per cent; upland grassland 23 per cent; and mixed conifer swamp (mostly white cedar, black spruce (*Picea mariana*), and tag alder (*Alnus incana*)) 9 per cent. A power line and a small permanent stream (Hickey Creek) bisect the area from west to east. The topography is quite level except near the creek.

The area is only about 10 miles from Lake Superior and is not far from the northern limits of the whitetail's range. Bitter cold and icy winds are the rule in the winter, although the nearby lake has some moderating effect. The snow cover commonly exceeds 3 feet in depth and usually remains for about 5 1/2 months. Average precipitation is 33 inches per year. Normally, deer are confined to deeryards of dense coniferous cover for about 120 days.

The deer herd

After fencing in 1952, all deer present were removed except three adult bucks. A new herd of 27 deer, all ear tagged, was introduced. During most of the years when experimental pellet group surveys were conducted an annual routine was followed. Each spring as many fawns as possible were captured and tagged. Drive censuses were conducted in the fall with the aid of inmate labor from a nearby corrections camp. Following the drive, the herd was reduced by controlled hunting. Approximately one-third of the fall population was removed each year. The remaining deer were live-trapped out and transferred to holding pens. Those not able to be trapped were shot. Finally, after all animals were accounted for, deer were released back in the area. Hence, the number of deer days of use during the winter was known almost exactly. The only gaps were a few animals killed by poachers and dogs during the winter. Fortunately, many of these could be accurately dated. So far as is known, only three deer have escaped. Two jumped over the fence before a final 2-foot extension was added to the top and one broke through the fence.

Over-winter populations in the enclosure for the years studied averaged 27 deer - about 18.6 per cent adult males, 46.6 per cent adult does, 17.8 per cent buck fawns, and 17.0 per cent doe fawns. Using these averages, a weighted pellet group defecation index of 13.56 was used for computations.

Results

A summary of the several surveys is presented in Table 27. Estimated populations agree somewhat better than the George Reserve results. In four of the five years, calculated confidence limits of 2 standard errors of the mean included the known population. Estimated and known means differed by less than 10 deer per square mile in every case. Only the 1955 survey produced an underestimate. As noted before, workers counted all groups found as "new" in 1953 which perhaps accounts for an overestimate that year. Most disturbing is the 1956 survey which was described in some detail earlier. The original survey data produced an

Table 27

Summary of Results of the Deer Pellet Group Surveys in the Cusino Enclosure

Year of survey	Deposition period (days)	New groups	Number of 1/50 acre plots	Estimated deer per square mile[2]	Known deer per sq. mile	Estimated compared to known	Apparent defecation rate
1953	208	1,562[1]	459	38.6 ±26.9%	28.8	+9.8	18.18
1954	205	689	306	25.9 ±31.9%	25.0	+ .9	14.06
1955	208	544	306	20.2 ±39.6%	28.1	-7.9	9.73
1956	221	685	305	24.0 ±35.3%	23.3	+ .7	13.96
1956 recheck	223	876	305	30.4 ±29.2%	23.3	+7.1	17.69
1958	203	874	297	22.2 ±18.8%	15.5	+6.7	19.39

[1]All groups were counted in 1953.
[2]Limits of 2 standard errors of the mean, approximately 95 per cent confidence intervals.

estimate within .7 deer per square mile of the known population, while the presumably more accurate recheck gave rise to an estimate 7.1 deer too high. The 1958 trial of a stratified random sample with stratification based on expected deer abundance, resulted in an estimate which was 6.7 deer higher than the known herd size. Neither old groups nor cover types were routinely tallied on these surveys, hence, trends in old-new ratios and deposition by cover types could not be appraised.

Results of fitting theoretical negative binomial distributions to observed frequency data are given in Table 61. Chi-square goodness of fit tests indicated the 1953 data departed significantly from the theoretical frequencies (.01>P>.005) while the other three surveys did not. Values for k varied from .4361 to .6623 and were well within the range obtained from the George Reserve surveys, even though the Cusino data represents the sum of three (1953) or two (1954-56) 1/50 acre plots rather than one. A χ^2 test for a single pooled value of k, .5119 (Bliss 1953), was not rejected at the .05 level (.10>P>.05), suggesting rather more consistent over-winter deer concentrations than on the George Reserve. This seems logical in view of the white-tailed deer's behavior patterns during the relatively severe winter weather here (Ozoga 1968).

DISCUSSION

The fifteen surveys reported here were carried out primarily to field test the pellet group technique against contained deer herds of known size. The record, as noted above, was not outstanding, particularly on the George Reserve. Previous chapters have discussed several potential sources of trouble in pellet group surveys, but there is no completely satisfactory explanation for these discrepancies.

One hypothesis is that defecation rates of free-ranging deer are really higher than the results of penned studies would indicate. Support for this viewpoint is provided by the 1959 Houghton Lake study of deer in a 6-acre enclosure described earlier, and from the fact that the "best" surveys on both the Cusino enclosure and the George Reserve yielded over-estimates of the known populations. The wide fluctuations in apparent defecation rates in the George Reserve and Cusino studies (Tables 20 and 27), however, suggest we are not dealing with a consistent bias in this component. Still I cannot completely rule out faulty defecation rates based on the available evidence and further research is indicated.

An alternative hypothesis would implicate aging and counting errors as being the major causes of trouble. Some evidence has been presented for the George Reserve which intimates weather factors may influence appearance of some pellets enough to confuse workers. The 1955 surveys supply additional support for interaction between counting pellet groups and a widespread phenomenon such as weather. All surveys conducted that year resulted in serious underestimates, including the only underestimate of the five Cusino surveys. Results of recounts following the 1955 George Reserve survey have been given previously. Preliminary inspection of the northern Lower Peninsula survey data revealed counts seemingly so low that analyses were never completed. The somewhat better performance of the Cusino enclosure surveys compared to those on the George Reserve seems related to the better compaction of the leaf mat and herbaceous vegetation by the deep accumulation of snow at Cusino, thereby facilitating the finding and aging of pellet groups in the spring. Furthermore, the presence of large grassy openings and the abundance of oaks on the Reserve added to the difficulties of finding and properly aging pellet groups.

An additional problem introduced by these field surveys involves chance sampling errors. With pellet group surveys we are interested chiefly in obtaining estimates of the mean with appropriate confidence intervals. Pellet count data have been treated as if they approximated random samples from normal populations. Confidence limits of 2 standard errors of the mean (about 95 per cent) were computed to compare estimated with known populations. As discussed in Chapters IV and V, components of variation due to determination of defecation rates and deposition period are evidently small enough to be regarded as negligible and were not included. Later work has indicated pellet groups are far from normally distributed and can be described rather well by several discrete contagious distributions, notably the negative binomial.

The rationale involved here is that most living organisms are not distributed at random, although at times the sampling designs used may not provide adequate data with which to show statistically significant departures from randomness. When natural populations are sampled by quadrats, the resulting sample distribution is nearly always asymmetrical with an excess of samples with low values and a few samples with very high numbers. Of course, one cannot assume exact correspondence to theoretical distributions based on samples taken from unknown populations. The best we can conclude is that the field data can be represented "adequately" by a theoretical distribution.

In the negative binomial, the smaller the value of k, the greater the aggregation of the objects being counted. Conversely, when k is "large" (about 8 or more) the distribution approaches the Poisson and hence is virtually random (Southwood 1966). Although k may be influenced by the size of the sampling unit (Cole 1946), both Bowden et al. (1969)

and McConnell and Smith (1970) found "small" k values similar to the George Reserve and Cusino data using several different plot sizes for counting mule deer pellet groups.

Thompson (1965) puts forth the idea that simple frequency of occurrence (presence or absence) could be used to estimate pellet group density, providing a value for k can be established. Such a system eliminates the need for tedious complete enumeration on each plot. McConnell and Smith (1970), however, caution that frequency counts are much less efficient than total counts. Several times the number of plots may be needed to produce estimates with the same precision. Furthermore, they report that serious biases may occur in such a system. An obvious problem would be the regular occurrence in our surveys of a few plots with extreme counts which often have a considerable influence on the mean.

Because of extreme skewness and kurtosis for distributions with $k<1$, confidence intervals are not symmetrical about the mean. With large sample sizes, Cochran (1963) indicates the normal approximation may be used for data from positively skewed populations providing sample size $>25G_1^2$ where G_1 is Fisher's measure of skewness. Examination of the George Reserve and Cusino data reveals sample sizes for most years are less than recommended. Furthermore, as Cochran shows for the Poisson distribution, while the normal approximation may produce confidence intervals which are satisfactorily close to the stated probability, in a high proportion of the statements that are wrong, the true mean is higher than the stated upper limit. We would expect the normal approximation to the negative binomial to behave in a similar fashion. Population estimates for the George Reserve surveys (Table 20), though, show four true means below the calculated confidence intervals, four above and two within (both higher than the calculated means). Similarly for the Cusino enclosure surveys (Table 27), the true mean is below the calculated confidence intervals for one year and within for four years. Of the latter, three true means are below estimated means and one is above. Of course, it should be kept in mind that in these surveys at least, we may be dealing with serious counting biases.

In addition to or in conjunction with increased sample sizes, possible solutions to more precise parameter estimation may involve changes in sample survey design or transformations. Cochran (1963) and Kish (1965) point out the usefulness of stratified random sampling in dealing with highly skewed populations. I have already discussed one such trial in the Cusino enclosure (1958 survey) and Chapter VIII will be concerned with extensive field surveys where a stratified design was used. Deming (1960) has recommended replicated subsampling for a wide variety of situations and this device appears promising for surveys on smaller units. Krefting and Shiue (1960) tested a similar technique (multiple-random-start systematic samples) on two tracts in Minnesota and Michigan and reported excellent results. Anscombe (1949) suggests two normalizing transformations for negative binomial distributions, but neither is recommended for the combination of small k and small mean present here. For analysis of variance computations, the simple transformation log (x + 1) is usually sufficient.

VIII. EXTENSIVE SURVEYS

The aim of estimating wild deer populations is to provide a sound basis for management. Initial Michigan surveys in the early 1950's were carried out in several northern areas (Table 37) with the cooperation of the U. S. Forest Service. The entire northern half of the Lower Peninsula was first surveyed in 1954 and the entire Upper Peninsula in 1957. Since 1959, both regions have been surveyed annually.

Previous chapters have considered several aspects of these extensive surveys: leaf fall dates, survey dates, and rechecks. The following discussion will emphasize various features of the sampling methods employed and make some brief remarks on the accuracy of the derived estimates. Emphasis will be on data from the 1959 to 1969 surveys.

DEER POPULATION ESTIMATES

Revised estimates for the 1959 to 1964 and 1965 to 1969 District surveys are given in Table 62. Populations presented are for the fall previous to the survey and prior to the firearm deer season. Tables 28 and 29 illustrate procedures used in generating estimates.

Only rather crude assessments as to the validity of estimates from such extensive surveys can be made since actual population sizes are unknown.

Eberhardt (1960) reported "good" agreement between pellet group counts and two independent population estimators utilizing legal kill estimates, highway losses, summer deer observations, and sex and age composition data from a sample of the legal kill. Most of his work was concerned with northern Lower Peninsula deer from 1952 to 1958.

The Research Triangle Institute (1966) compared the consistency of deer pellet group population figures, numbers of firearm deer hunters,

Table 28

Statistical Analysis of the 1962 Deer Pellet Group Survey in District 7

Stratum	Area	Area in proportion w_j	Number of courses n_j	Mean pellet groups per course $\overline{x}$	Variance of course counts s_j^2	$\frac{w_j^2 s_j^2}{n_j}$
I red	190	.0541	9	65.2222	5452.1944	1.7568
II yellow	425	.1211	12	29.2500	1032.5682	1.2649
III brown	1,544	.4399	34	15.3529	312.8166	1.7803
IV blue	1,144	.3259	10	10.7000	167.1222	1.7748
V white	207	.0590	1	0.0000	0.0000	0.0000
Total	3,510	1.0000	66			6.5768

Weighted mean groups per course $\overline{x}_{st}$ = 17.3116 ±29.63% (2 standard errors of the mean).

Table 29

Corrections for Deer Removals for the
1962 Deer Pellet Group Survey in District 7

Average over-winter population	101,590
Regular season harvest - about 10,620 deer contributing for about 18 days (Oct. 31 - Nov. 18)	
$\frac{10,620\ (18)}{179} =$	- 1,070
Other fall and early winter losses - about 2,420 deer contributing for about 31 days	
$\frac{2,420\ (31)}{179} =$	- 420
Late winter and spring losses - about 8,850 contributing for about 121 days	
$\frac{8,850\ (121)}{179} =$	- 5,980
1962 spring population	94,120
Hunting removal	10,620
Other losses	11,270
1961 fall population	116,010

and firearm deer harvests for 1958 to 1964, utilizing information for both the Upper Peninsula and northern Lower Peninsula. They reported close correspondence. In addition, they compared the results of deer drive counts on several areas in the Upper Peninsula with pellet group survey estimates for the same series of years and concluded that the trends in the two sets of estimates paralleled each other fairly closely, although the drive counts averaged somewhat higher over all years.

I explored the intensity of the relationships between fall populations and buck harvests for the figures in Table 62 using simple linear correlation. Correlation coefficients are also shown in the table. Although the size of the buck harvest each fall is influenced by factors such as hunter numbers, weather, and deer composition, logically it should exhibit at least a fair relationship with gross population size. Three of the four districts in the Upper Peninsula showed significant correlations as did the combined Upper Peninsula data. The relationship for District 2, however, was negative. Only old District 7 (1959 to 1964) exhibited a significant correlation in the northern Lower Peninsula, although the correlation for the combined northern Lower Peninsula approached significance ($.10>P>.05$).

In a similar fashion, I also investigated the relationships between the spring population estimates and the fall antlered buck harvest. Results are shown in Table 63. Correlations are somewhat better than for the previous fall data. All four districts in the Upper Peninsula, as well as the combined Upper Peninsula data, showed significant correlations. In the Lower Peninsula, old District 6 and new District 8 were also significantly correlated.

I did not consider the relation between antlerless harvests and population estimates because the magnitude of the former is manipulated through control of hunter numbers who are able to shoot antlerless deer and hence is not closely related to population size (Bennett et al. 1966).

Results of the previous and current investigations suggest extensive surveys are providing population estimates which reflect actual herd size to at least a fair degree. Computations provide further support for the hypothesis that pellet group surveys are more accurate under Upper Peninsula conditions.

DISTRIBUTION OF PELLET GROUPS

A major theoretical advantage of deer pellet group counts is that they can be based on statistical sampling techniques. Following the 1953 surveys, empirical inspection of the data disclosed rather obvious non-randomness in pellet group distribution. Cochran (1963) notes that failure of the normal approximation in highly skewed distributions is often due mostly to some extreme counts which dominate the sample mean. These counts increase the sample variance and hence decrease precision. He suggests, therefore, the use of strata in order to deal with the various frequency levels separately. Consequently, subsequent surveys employed stratified random designs.

In order to determine if the apparent non-randomness could be adequately described by the negative binomial distribution, as were the George Reserve and Cusino data, I fitted negative binomial distributions to frequency counts from the four 1953 sampling units - Lake County, Mio and Tawas Ranger Districts of the Huron National Forest, and Houghton Lake State Forest. These are the only unstratified data available from the extensive surveys. Such calculations required the assumption that plots approximated a random sample of the total area of each unit.

Recall that courses were located systematically with five 1/50-acre plots constituting a course.

Results are shown in Table 63. In one of the four units (Mio Ranger District) observed counts were significantly different (.05>P>.025) from the fitted distribution while the other three were not. The range of values for k, .2397 to .4859, were within that previously noted for George Reserve and Cusino plots. The hypothesis for a pooled value of k, .3238, was rejected (.005>P). Inspection of Table 63 suggests high means and high k values go together. Ranks of means and k's are in the same order for the four units. Bliss (1971) has also reported ecological series which exhibited similar trends. For Michigan deer a logical interpretation is simply that the more deer there are, the greater the proportion of the range that is occupied.

I conclude that the negative binomial also provides a useful way of describing frequency data from extensive surveys. Not unexpectedly, dispersion differs between areas, presumably due to habitat differences.

FIRST STAGE SAMPLES

A stratified random two-stage sampling design was first used in 1954. The Research Triangle Institute (1966) praised the design, pointing out that the selection of sample sections and location of sample courses within these sections was in accord with sound statistical practice. Furthermore, they noted that stratification allowed sampling effort to be concentrated where it provides the most information.

In our surveys, the Federal system of rectangular land surveys (Clement 1955) provides a convenient first-stage sampling unit - the section or square mile. Virtually all of Michigan was surveyed according to this system. One difficulty is that not all sections are exactly one square mile (640 acres) in area, because of the convergence of longitude lines, mistakes in the original surveys, and the large extent of water-covered areas in Michigan, including the Great Lakes and a multitude of interior lakes and streams. In most cases aberrant sections will be less than 640 acres. This tends to be compensated for by irregular land surfaces which are usually somewhat larger than the surveyed areas. Surveyed or map areas are measured as if section perimeters were completely horizontal. Since plots conform to the lay of the land, in rough terrain they will produce conservative density estimates.

When preparing strata maps, workers were instructed to count fractional sections if over half of the section was land. If sections were deemed to be exactly one-half land and water, inclusion was determined by a coin flip.

Sample allocation

First-stage samples were allocated to strata using optimum allocation (Cochran 1963). Estimates of standard deviations were based on the results of previous surveys. While pellet group count data can be represented by the negative binomial, these computations were tedious before the general availability of high speed digital computers. Hence, I developed a simplified procedure based on the relationship between the mean and variance. Similar results have also been reported by other authors when working with samples from contagiously distributed populations (Bliss 1971). This relationship is often referred to as Taylor's power law (Southwood 1966) and can be expressed by $s^2 = a\bar{x}^b$. Here s^2 is the sample variance, $\bar{x}$ the sample mean, and a and b are constants. The constant a is largely a sampling factor, and b appears to be related to the degree of aggregation. Bliss (1971) points out the power series has the added advantage that a single regression line can be fitted to data from several negative binomial distributions which could not be fitted with a common k, as is the case with our counts of pellet groups. In a recent paper, Taylor (1971) notes further that most distribution models now in use are rarely justified on a consistent theoretical basis. Therefore, he indicates it may be as well to use an empirical law that works even though its theoretical derivation is not yet clear.

As an example, values of s^2 and $\overline{x}$ from the 1959 to 1969 district surveys were transformed to logs and a linear regression line was fitted to the data: $\log s^2 = \log a + b \log \overline{x}$. The assumption was made that means were measured without error to correctly use this procedure (Model I regression). The resultant equation was: $\log s^2 = .5416 + 1.5406 \log \overline{x}$. The fit is remarkably good:

source of variation	degrees of freedom	sum of squares	mean square	F
linear regression	1	228.05131	228.05131	2017.42167***
deviations from regression	402	45.44247	.11304	(P<.001)
total	403	273.49378		

Figures 9 and 10 show the approximate location of sample courses for the 1959 to 1964 and 1965 to 1969 surveys, respectively.

Accuracy of stratification

After several years of surveying various areas, long-range plans were made in 1959 to survey each northern game district every year. Restratification and new sample selection were to be carried out about every 5 years. Actually, the first samples were selected and staked in 1959 and searched for 6 successive years. In 1965 the area was restratified and new courses selected. These were surveyed for 5 years.

Some field men have expressed concern that annual differences in deer distribution during the over-winter period would affect survey

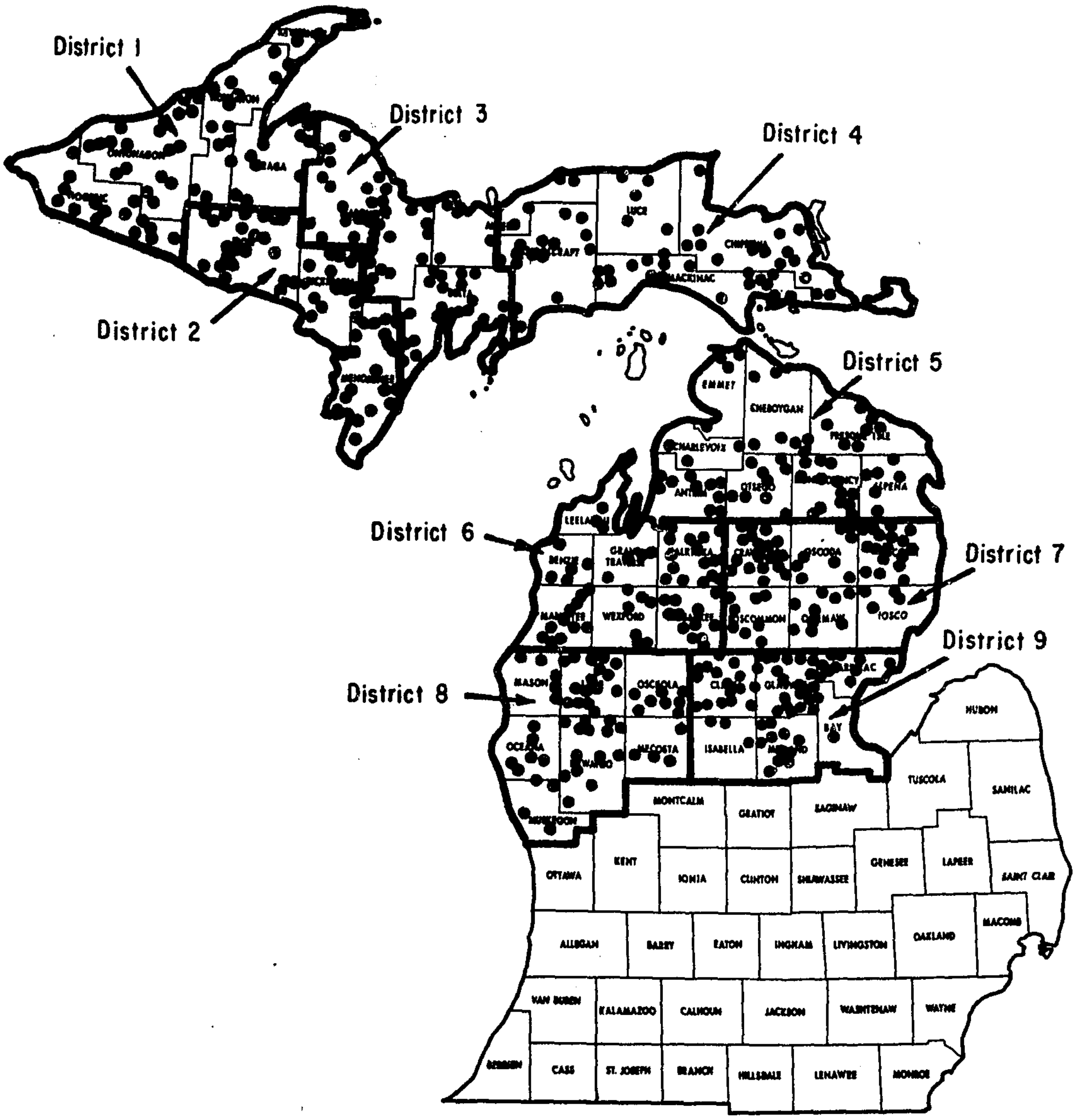

Figure 9. Location of pellet group courses 1959-1964 surveys.

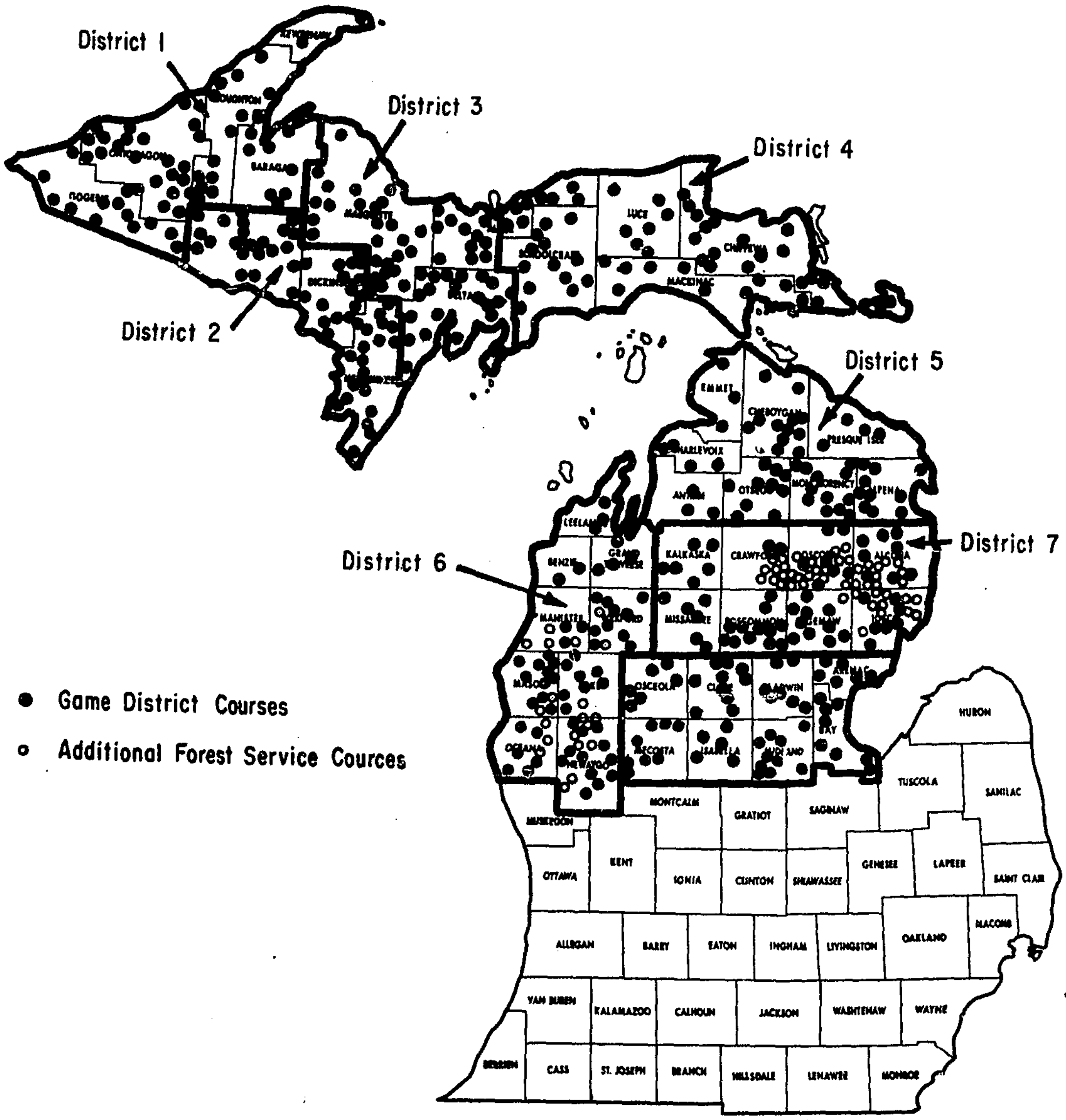

Figure 10. Location of pellet group courses 1965-1969 surveys.

results. That is, stratification was intended to reflect the average deer distributional patterns during the over-winter period. Atypical weather or timber cutting activity could conceivably result in important deviations from the expected.

The physical arguments against complete annual changes, however, seemed to outweigh those favoring it. The cost of restratification, sample selection, and establishing new plots is considerable in terms of man days. In addition, established courses become "known" by field men who can keep tabs on when they are snow-free or dry enough to be searched. Detailed information on locations is filed in district offices so that in succeeding years, courses can be more easily located. Furthermore, since there are only two or three game biologists in each district of several counties, field men cannot hope to cover more than a small proportion of the deer range each winter. Hence, their notions on current deer distribution still amount to an average based on several years' experience.

Still, if appreciable increases in precision would result when new samples were selected annually, this would provide a powerful impetus to adopt this procedure.

Table 30 shows a comparison of actual survey results with the initial stratification ranges. Comparing the relative number of times the survey results (deer per square mile) fell within the respective stratification range, I found the initial year of each series of surveys ranked well below succeeding years. Out of 17 possible, the initial years (1959 and 1965) ranked or tied for first only five times. The second years (1960 and 1966) for example, ranked first or tied for first nine times.

To study this problem further, optimum allocations were computed for each year from actual survey results, Tables 64 and 65. Chi-square

Table 30

Comparison of Actual Results with Stratification for Deer Pellet Group Surveys in Game Districts

Stratum	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
District 1											
Red I	0[1]	0	0	0	0	-	0	0	0	0	0
Yellow II	-	-	-	-	-	-	-	-	-	-	-
Brown III	+	+	+	0	+	0	0	0	-	-	-
Blue IV	0	0	0	0	0	0	0	0	-	-	-
White V	0	0	0	0	0	0	0	0	0	0	0
District 2											
Red I	0	0	-	-	-	0	-	0	-	0	-
Yellow II	0	-	-	-	-	0	+	0	0	+	-
Brown III	0	+	-	0	-	0	+	+	+	+	+
Blue IV	+	0	+	0	+	+	0	+	0	+	0
White V	0	0	0	0	0	0	0	0	0	0	0
District 3											
Red I	0	0	0	0	0	0	0	0	0	0	0
Yellow II	+	0	0	-	+	-	+	+	-	+	-
Brown III	-	0	0	0	+	-	+	+	+	+	0
Blue IV	0	0	0	0	0	0	0	0	0	0	0
White V	0	0	0	0	0	0	0	0	0	0	0

Table 30 (cont'd.)

Stratum	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
District 4											
Red I	0	0	0	-	0	-	-	-	-	-	-
Yellow II	+	+	+	+	0	0	0	-	-	0	-
Brown III	0	0	0	0	0	0	-	-	-	-	0
Blue IV	0	0	0	0	0	0	0	0	0	0	0
White V	+	+	+	0	0	0	0	0	0	0	0
District 5											
Red I							0	0	0	-	-
Yellow II	+	+	+	+	+	+	+	+	+	+	+
Brown III	+	0	0	-	-	0	-	-	0	-	+
Blue IV	0	0	0	-	0	0	-	-	-	0	0
White V							0	0	0	0	0
Old District 6							**New District 6**				
Red I							0	-	0	0	0
Yellow II	+	0	0	+	0	0	-	-	0	0	-
Brown III	0	0	0	0	0	0	+	-	0	+	0
Blue IV	0	+	+	+	+	+	0	0	0	0	0
White V	0	0	+	0	0	+	0	0	0	0	0
Old District 7							**New District 7**				
Red I	0	0	-	0	-	-	0	-	-	-	0
Yellow II	+	0	0	0	0	+	+	0	+	+	+
Brown III	0	0	0	0	0	0	+	0	+	+	+
Blue IV	+	0	+	0	0	0	0	0	+	+	0
White V	0	0	0	0	0	0	0	0	0	0	0

Table 30 (cont'd.)

Stratum	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Old District 8							**New District 8**				
Red I							0	0	0	0	0
Yellow II	0	0	-	-	0	0	+	-	-	-	0
Brown III	0	0	-	0	0	0	0	0	0	0	0
Blue IV	0	0	0	0	0	0	-	-	-	-	0
White V	0	0	0	0	0	0	0	0	0	0	0
Old District 9											
Red I											
Yellow II	+	0	-	+	0	+					
Brown III	+	0	0	0	0	+					
Blue IV	0	0	+	0	0	+					
White V	+	0	+	0	0	0					

[1]0 = within stratification range, + = above range, - = below range.

goodness of fit tests were used to provide a systematic way of rating the closeness of the actual allocation (expected) with the optimum (observed) for each year within each district. Where actual allocations to a stratum were less than 5, I combined adjacent strata. The resulting statistics are also presented in these tables.

Out of the 17 district samples, the lowest chi-square values occurred but twice in the initial year of the survey. A total of 62 of the 94 chi-square values were significant at the .05 level or less, including 11 of the 17 initial year's surveys. In only one district sample, however, (District 7 from 1959 to 1964) did all optimum allocations differ from the actual one used.

To test whether there were consistent trends in the relationships between actual and optimum allocations for the several years, I cast the chi-square values into ranks within each district sample. Friedman's test (Campbell 1967) was then used to evaluate significance of the ranked data. Results are shown in Table 31. The 1959 to 1964 surveys indicate a significant difference (.05>P>.01) while the later surveys, 1965 to 1969, do not. The years where the optimum allocations most closely resembled the actual were 1964 (sixth year) for the first samples, and 1968 (fourth year) for the second series. If stratifications were precise, the initial year would always show the best agreement with actual allocation, assuming standard deviations could be accurately predicted.

I conclude from these analyses that it would be difficult to improve precision by annual selection of the new samples. Cochran (1963) states that for estimating change, it is best to retain the same sample throughout all occasions, while for current estimates equal precision is obtained either by keeping the same sample or by changing it on every

Table 31

Ranks of Chi-square Values for Goodness of Fit Tests Comparing Actual Allocations with Optimum Allocations

Rank[1] of Chi-square Values

Sample	1959	1960	1961	1962	1963	1964	
District 1	3	4	1	6	2	5	
District 2	3	1	2	5	4	6	
District 3	3	1	2	5	4	6	
District 4	2	6	5	3	1	4	
District 5	5	6	4	3	1	2	
Old District 6	5	4	1	6	2	3	
Old District 7	2	5.5	1	4	3	5.5	
Old District 8	6	3	1	4	2	5	
Old District 9	2	3	1	4	5	6	
Totals	31	33.5	18	40	24	42.5	189

Friedman's test of differences among years, $\chi^2 = 13.84$ for 5 degrees of freedom $.05>P>.01$.

Rank of Chi-square Values

Sample	1965	1966	1967	1968	1969	
District 1	3	4	2	5	1	
District 2	4	3	2	5	1	
District 3	3	4	2	5	1	
District 4	4	2	5	3	1	
District 5	4	3	5	2	1	
New District 6	1	4	5	2	3	
New District 7	1	4	3	2	5	
New District 8	1	2	3	4	5	
Totals	21	26	27	28	18	120

Friedman's test of differences among years, $\chi^2 = 3.70$ for 4 degrees of freedom $.50>P>.10$.

[1]Rank 1 = largest value.

occasion. A third alternative is replacement of part of the sample each year, which is often the best procedure. Hence, it might be desirable to change some courses if the initial year's allocation was poor, say highly significantly different (.01>P) from the optimum.

Sample sizes and effort

Experience with early pellet group surveys in Michigan determined that about 550 courses could be searched with available manpower. The limiting factor was the biologist component. Until 1958 surveys were conducted entirely by wildlife biologists, including some university students. When two-man crews were used on later surveys, at least one was a biologist. The bulk of these were Department of Natural Resource employees, the remainder were supplied by the U. S. Forest Service.

A summary of the effort required for the northern pellet group surveys from 1960 to 1969 is given in Table 32. The total number of man-days required to complete these surveys ranged from 426 in 1969 to a high of 686 in 1966. An average of 186 different individuals worked on the surveys each year with a high of 236 in 1966. Upper Peninsula crews were able to search an average of one and three-quarters courses per day compared to about two and one-third for northern Lower Peninsula crews. Better road systems in the Lower Peninsula account for most of this difference.

In 1960, 1962, 1966, and 1967 (Upper Peninsula only) deer mortality surveys were carried out concurrently with the pellet group counts. In 1965 crews had to locate and stake new courses as well as tally groups. Such extra workloads accounted for the relatively large amount of effort required in those years. A more realistic estimate of the labor component necessary to complete pellet group surveys alone would range from about

Table 32

Effort Required for Deer Pellet Group Surveys, 1960-1969

Survey year	Upper Peninsula No. of courses	Upper Peninsula Average courses per crew-day	Northern Lower Peninsula No. of courses	Northern Lower Peninsula Average courses per crew-day[1]	Total man-days[2]	Total individuals participating
1960	238	1.39	313	2.09	660	177
1961	238	2.07	327	2.84	448	144
1962	248	1.80	331	2.10	589	205
1963	238	2.11	328	2.54	462	168
1964	239	2.08	326	2.57	472	200
1965	238	1.69	237	2.19	511	172
1966	238	1.16	235	1.68	686	236
1967	238	1.59	235	2.35	500	212
1968	268	1.73	230	2.19	507	187
1969	238	1.97	230	2.53	426	159

[1]Two men working for 1 day.
[2]One man working for 1 day.

450 to 500 man-days.

Reference to Table 62 reveals that confidence limits of 2 standard errors of the mean for Game District surveys ranged from ±25 per cent to over ±50 per cent. Analogous confidence limits for the Upper Peninsula and northern Lower Peninsula estimates ranged from about ±14 to ±22 per cent. To appreciably reduce these limits would require considerably larger sample sizes.

To illustrate approximate sample sizes needed for arbitrary levels of precision, I used data from the 1960 surveys. Estimates were obtained using a formula suggested by Cochran (1963):

$$n = \frac{\sum \frac{W_j^2 \; s_j^2}{w_j}}{\frac{d^2}{t^2} + \frac{1}{N} \sum W_j \; s_j^2}$$

where d = one-sided deviation form the mean

t = the normal deviate corresponding to the allowable probability that the error will exceed the desired margin

N = total area in square miles

W_j = proportion of total area in each stratum

w_j = proportion of total courses in each stratum

s_j^2 = estimate of S_j^2 for each stratum

The computations are based on courses being assigned to strata in the same proportions as the allocation originally used and the normal distribution is assumed within strata. Results are shown in Table 33.

Managers would prefer estimates with a precision in the ±10 per cent range but the number of courses per district necessary to achieve this level, 362 to 594 in 1960, would be out of the question with available effort. A more practical range might be limits of ±20 to 25 per cent,

Table 33

Number of Deer Pellet Group Courses Required for Various Levels of Precision[1] Based on Results of 1960 Game District Surveys

Area	± 30%	± 25%	± 20%	± 15%	± 10%	± 5%
District 1	57	81	125	217	456	1,348
District 2	46	65	101	174	362	1,034
District 3	47	68	104	180	376	1,079
District 4	64	91	140	240	493	1,338
District 5	56	80	122	209	424	1,116
District 6	79	113	173	294	594	1,518
District 7	75	106	162	272	529	1,226
District 8	47	68	105	181	378	1,086
District 9	62	89	136	231	463	1,170

[1]Limits of 2 standard errors of the mean, approximately 95 per cent confidence intervals.

Table 34

Comparison of Stratified Random Sampling with Simulated Simple Random Sampling for Selected Game District Surveys

		Stratified random sample optimum allocation	Simulated simple random sample	
Unit	Total courses	Mean	Mean	No. of courses for same precision as stratified sample
Dist. 9, 1962	67	6.6525 ±30.84%[1]	5.3088 ±42.15%[1]	127
Dist. 5, 1964	59	12.0253 ±42.56%	12.2333 ±46.10%	70
Dist. 4, 1961	59	9.7249 ±34.67%	9.8500 ±40.21%	81
Dist. 2, 1959	59	18.9238 ±29.42%	17.6833 ±28.37%	56
Dist. 5, 1966	60	9.3762 ±30.20%	10.2833 ±48.13%	152

[1]Limits of 2 standard errors of the mean, approximately 95 per cent confidence intervals.

requiring about 100 courses per district.

Effect of Stratification

Cochran (1963) supplies formulas for estimating decrease in variance due to stratification. Compared to simple random sampling this reduction depends on minimizing both the difference among stratum means and the effect of differences among stratum standard deviations. This second component also represents the advantage optimum allocation has over proportional allocation to strata.

To illustrate the advantages of stratification over simple random sampling from actual survey results, I selected five district samples at random and simulated random samples from original counts. Allocation of courses to strata was made in proportion to the relative area in each. Overall sample size was fixed at the level of the original survey (usually 60 courses). Where original allocation exceeded proportional allocation, the required number of samples were selected at random from those originally searched. Where new allocation exceeded the original, results from some or all original plots were replicated to reach the required number. The resulting "counts" were then treated as a simple random sample. The procedure used would tend to produce an under-estimate of the variance which would have resulted from a true random sample, because of the essentially proportioned allocation and the duplication of some counts. The number of courses needed to produce the same precision as the stratified survey used varied from about the same to about two and one half times as many (Table 34).

By chance, optimum allocation based on the actual results of the 1959 District 2 survey was very similar to proportional allocation. Hence, stratification provided no advantage.

I conclude that the use of stratification is worth the extra effort involved and will nearly always provide more precise estimates for the same effort. A major disadvantage, however, of stratification based on expected deer populations is that it can lead to only simple models for monitoring population changes. Since deer are herbivores, their abundance is closely related to their year-round food supplies. Thus, future research should be directed at stratifications based on vegetation which can be used to develop more complex deer herd models with predictability.

SECOND STAGE SAMPLES

General format

Since it was obviously impractical to search all of each selected section, a form of sub-sampling was used. On the 1953 surveys a design suggested by the U. S. Forest Service was employed. This consisted of five 1/50-acre plots located in a straight line 8 chains apart. Preliminary assessment of the 1953 data suggested eight plots 5 chains apart would provide a better sample. This modified design is still in use.

Rules in placement of the course line within each section have been outlined previously. A concession to efficiency advocated that courses start from driveable roads when possible. It can be seen that these procedures do not result in all parts of a section being equally likely to be searched. However, locations are preselected for each course line, thereby eliminating any personal bias by survey crews. Actual placement of each course is detailed by crews on the survey report form. These were audited in Lansing to insure that the instructions were followed, and where they were not, courses were run again.

The Research Triangle Institute (1966) in examining the sampling design remarked:

". . ., there are several advantages to using 8 such plots compared with a single plot 8 times as large. Using 8 separate smaller plots provides a greater dispersion of the sample over the section. In addition the painstaking task of searching for pellet groups can be performed more accurately on each of 8 small plots than on one large plot."

Love (1943) also reported on surveys estimating wheat yields which clearly showed that plots made up of several small scattered units had a lower standard error than single plots covering the same total area. Therefore, I recommend continued use of several small plots rather than one large one.

Plot location biases

Placing each plot at 45° to the line of travel is an attempt to reduce what I call the "easy-path bias." Since course lines are laid out by hand compass and pacing, there is a tendency for the line of travel to deviate slightly toward places that are easier to walk, and/or where longer sightings can be made with the compass. For example, one cannot walk or sight through a large tree. Hence, if the plots straddled the line of travel, they would tend to be in more open areas. Offsetting plots to the side locates them on sites which are not part of the observer's usual field of vision as he walks the course line. Similarly, Robinette et al. (1958) recommended that circular plots should be at least 100 square feet in order to reduce the effects of any proneness to place plots in more open situations.

Analyses were carried out to determine if there was any tendency for certain plot locations (1 to 8) on the course line to have more or less pellet groups. Differences might occur, for example, if deer spent less time near roads or if workers tended to do a poorer job of counting on the plots farthest from the starting point. One year was selected at random from each game district sample for the 1959 to 1964 and 1965 to

1969 surveys, a total of 17. Only data from Strata I, II, and III were used to reduce the problem of excessive zeros. Friedman's test (Campbell 1967), which utilizes ranks, was used to avoid the effect of unequal numbers of pellet groups among courses. Only one of 41 district-strata showed a significant difference (Table 35). Therefore, I conclude that there does not appear to be any consistent bias due to plot location.

Plot size and shape

Michigan researchers have not field tested various sized plots for counting pellets groups. The size of the individual plots making up the second stage units was rather arbitrarily set at 1/50-acre (871.2 square feet) in 1953 and has not changed. Workers on western deer ranges tend to use much smaller plots. Studies of Ferguson (1955), Robinette et al. (1958) and Smith (1968), working with mule deer pellet group surveys, all resulted in support for circular 100-square-foot plots.

Several authors have reported an inverse relationship between plot size and apparent density. Robinette et al. (1958) and Smith (1968), concluded this was due to the larger plots being harder to search, resulting in more missed groups. Cochran (1963) noted similar experiences in estimates of crops. This was attributed to uncertainty about the exact boundaries of the units so that boundary plants tended to be assigned to the plot if there was any doubt. Batcheler (1971), commenting on the results of mule deer pellet group studies, was convinced that the lower density on the larger plots is a consequence of greater accuracy in determining the true centers of scattered and strung-out groups as well as a tendency to count a cluster of similar groups as one group.

Greig-Smith (1957) points out that if a non-random plant population is sampled by quadrats of a size very much smaller than the average size

Table 35

Friedman's Tests on the Rank of Pellet Group Abundance by Position on Course Lines

Game District	Year	Stratum	Number of courses	Chi-square values[1]
1	1964	I	8	4.33
		II	20	3.07
		III	12	5.80
2	1961	I	22	1.74
		II	7	11.60
		III	4	1.44
3	1961	I	18	10.35
		II	7	3.06
4	1963	I	7	4.37
		II	10	5.30
		III	14	13.28
5	1960	II	17	4.16
		III	20	5.92
Old 6	1964	II	15	4.49
		III	18	5.97
Old 7	1963	II	11	4.55
		III	34	7.52
Old 8	1963	II	7	3.23
		III	17	1.79
Old 9	1960	II	6	5.58
		III	21	4.96
1	1968	I	6	2.03
		II	10	3.92
		III	21	7.11
2	1966	I	22	12.20
		III	6	1.99
3	1965	I	5	8.07
		II	9	12.57
		III	9	6.19
4	1967	II	10	2.34
		III	16	.75
5	1967	I	15	17.91*
		II	18	8.83
		III	10	4.52
New 6	1967	I	6	3.90
		II	6	3.90
		III	13	5.53
New 7	1969	II	20	2.75
		III	26	2.47
New 8	1969	II	12	4.36
		III	21	3.98

[1]Degrees of freedom = 7 for all tests. $P_{.05} = 14.07$, $P_{.01} = 18.48$

*Significant at $P_{.05}$ level

of clusters of individuals, then the variance of an observation will not be much, if any, greater than the mean (Poisson). As quadrat size increases and approaches the size of the clusters, or conversely as the density increases relative to quadrat size, the variance relative to the mean will rise sharply. He concludes the safest procedure to use for density determinations is the smallest quadrat that is practical or desirable on other grounds. Similarly, Gérard and Berthet (1971) noted for populations fitting the negative binomial distribution, greater precision was obtained by reducing plot size and increasing the number of plots.

Statistical methods for selecting optimum plot size are given by Kempthorne (1952). If the number of plots is fixed, larger plots give more information. If a fixed total area is to be searched, procedures lead to recommendation for plots as small as practical. The difficulty of obtaining a meaningful variance, however, limits the usefulness of such techniques.

The plots used on Michigan pellet group surveys were originally circular with a radius of 16.7 feet, but were changed to a rectangular shape (72.6 x 12 feet) in 1956 for two basic reasons. First, because it is easier to search under Michigan conditons. Secondly, rectangular plots are generally acknowledged to be the most efficient design (lowest variance) for sampling plant communities (Love 1943, Grieg-Smith 1957). In shrubby or wooded areas moving a rope in a circle around a fixed point takes considerable time and effort and it is difficult to keep track of which part of the plot has been searched. In the rectangular plot a double looped plastic clothes line with wire core, 72.6 feet long, was stretched from the beginning point on the line of travel, to the distal end. The line was left in place while counts were made. Only half of the plot was searched at a time by an individual. A 6-foot tape or wooden wand made a convenient device for checking whether questionable groups were within the plot boundaries. Overton and Davis (1969) commented that the Michigan plot configuration had the advantage that it could be treated as two separate plots, side by side, to study and reduce counting errors.

In conclusion, I submit that plot area and configuration should be studied under Michigan conditions. Plot size might logically vary between strata, being larger where fewer groups are expected. In the interim, however, I recommend continued use of the rectangular, 1/50-acre plot.

Optimum number of plots per course

I requested that biologists keep detailed time records on the 1958 surveys in order to obtain information with which to judge how many 1/50-acre plots to search per course line. Specifically, workers were instructed to keep track of the time between courses and the time spent running each course. "Time between courses" was defined as the time from the completion of the eighth plot of a course to the arrival at the first plot of the next course. "Time per course," then, was the time spent searching the eight plots and the travel time between these plots. Data were obtained from 87 courses in the Upper Peninsula and 91 in the northern Lower Peninsula. A summary is presented below:

	Upper Peninsula	Northern Lower Peninsula
Mean courses per day	1.9	3.1
Mean time per course	139.6 minutes	115.8 minutes
Mean time per plot, C_2	17.4 minutes	14.5 minutes
Mean travel time between courses, C_1	111.6 minutes	51.9 minutes
$\frac{C_1}{C_2}$	6.4	3.6

Cochran (1963) provides a method for computing the optimum number of subsamples per primary sample. Although the pellet survey sampling plan does not fit this situation exactly, it provides a useful approximation. Calculations depend on (1) variability within courses (plots) compared to between courses, and (2) the relation between the cost (here in terms of time) of reaching a course and the cost of obtaining data from a plot.

The equation used was:

$$\text{Optimum number of plots} = \frac{s_2 \sqrt{M}}{\sqrt{s_1^2 - s_2^2}} \sqrt{\frac{C_1}{C_2}}$$

where: M = number of plots used now, 8

s^2_1 = variance between plots (within courses)

s^2_2 = variance between courses

C_1 = cost of reaching a course (time)

C_2 = cost of measuring a plot (time)

Estimates of variances were obtained through a one-way, Model I, analysis of variance. Average ratio of $\frac{C_1}{C_2}$ were used in computations for each peninsula. Logically, C_2 values might vary directly with the number of groups found, but many of the time records supplied by field men failed to indicate the order when several courses were run on the same day. Hence, they could not be identified to strata. Analyses of the data resulted in optimum plot numbers ranging from less than two to about seven, but tending to group around four or five (Table 36). Original computations pointing to an optimum of eight plots per course, were based on the erroneous assumption that $\frac{C_1}{C_2} \approx 20$.

I recommend that the number of plots per course be reduced to five. This would allow an increase to about 75 courses per district in the Upper Peninsula and about 80 in the northern Lower Peninsula for the same overall effort.

Table 36

Estimates of the Optimum Number of Plots per Course Based on 1958 Deer Pellet Group Surveys[1]

Pellet group survey unit	Strata	Number of courses	$\frac{s_2 \sqrt{M}}{\sqrt{s_1^2 - s_2^2}}$	$\sqrt{\frac{C_1}{C_2}}$	Optimum number of plots per course
Dickinson County area	Red I	31	1.72	2.53	4.35
"	Yellow II	5	.78	2.53	1.98
"	Brown III	7	2.45	2.53	6.20
"	Blue IV	17	2.11	2.53	5.34
Alger-Delta-Schoolcraft	Red I	11	2.17	2.53	5.48
"	Yellow II	8	.58	2.53	1.47
"	Brown III	14	1.74	2.53	4.40
"	Blue IV	47	2.02	2.53	5.11
Roscommon-Oscoda-Crawford	Yellow II	22	1.73	1.90	3.28
"	Brown III	62	1.26	1.90	2.40
"	Blue IV	14	1.85	1.90	3.50
Clare-Gladwin	Yellow II	29	3.45	1.90	6.55
"	Brown III	27	1.56	1.90	2.96
"	Blue IV	28	2.47	1.90	4.68
"	White V	13	1.17	1.90	2.22
Area A-7 and A-8	Yellow II	33	1.68	1.90	3.20
"	Brown III	38	1.94	1.90	3.68
"	Blue IV	25	2.67	1.90	5.07

[1]See text for explanation of values in columns 4 and 5.

IX. SUMMARY AND CONCLUSIONS

The white-tailed deer is the most important game species in Michigan, whether measured in terms of hunter numbers or revenue received. Moreover, deer are also highly valued by the general public and especially tourists. The Michigan Department of Natural Resources is charged with management of the deer herd within guidelines set by executive and legislative branches of State government.

One of the major problems of wildlife biologists is to determine the size of the deer herd being managed. Beginning in 1953, Michigan workers have primarily relied upon pellet group counts to estimate numbers, "pellet groups" being deer defecations. Since 1953 considerable research and many experimental and operational pellet group surveys have been conducted in the State.

Use of pellet group counts as a census method is dependent upon several assumptions: deer defecate at a rather constant frequency; pellet groups persist long enough to be counted; groups can be found and counted accurately; a deposition period can be delineated; and groups found can be aged relative to the deposition period. The present paper appraises these assumptions as they affect use of the technique under Michigan conditions.

Pellet group surveys are based on standard statistical sampling techniques. Calculations of deer numbers from pellet group counts utilize the algorithm:

$$\text{deer population} = \frac{\text{mean pellet groups per plot} \times \dfrac{1}{\text{plot size}} \times \text{size of area}}{\text{deposition period} \times \text{defecation rate}}$$

For a given survey, plot size, area, deposition period, and defecation rate are generally considered fixed. The additional contributions due to adding variance components for defecation rate and deposition period were found to be small enough to be safely disregarded. At present, counts are made on rectangular, 1/50-acre plots, 72.6 feet X 12 feet in size. Both single plots and clusters of two to eight have been used.

The deer is a ruminant and food materials are passed from the rumen at a regular rate. About half of the dry weight of natural foods is defecated. Defecation rates were studied using penned deer (mostly females) being fed several diets at the Cusino Wildlife Research Station in the Upper Peninsula and at the Houghton Lake Wildlife Research Station in northern Lower Michigan. These remain the only studies carried out with white-tailed deer. The ensuing records yielded the following mean defecation rates per deer per day: adult bucks 15.61, adult does 12.89, buck fawns 14.74, and doe fawns 11.89. Ideally, indices for a given survey should be weighted by herd composition.

Groups of deer fed various winter diets showed little difference in defecation rates within sex and age classes. Although it is well known that deer undergo reduced food consumption and weight loss in mid-winter, the available data are less than decisive concerning whether there is a corresponding decrease in defecation rate.

All Michigan work has been based on a fall-to-spring accumulation of pellet groups. The autumnal fall of leaves has been used to provide a beginning reference point and the mean date of the spring survey the terminus. Examination of leaf fall dates for 11 years indicates relative uniformity within northern game districts. In most cases the range of dates was less than 2 weeks, suggesting no large source of error here.

The average time interval in the spring required to search all sample plots within a game district was 24 days. Adjusting all pellet group counts to a common spring date had little effect on estimates.

Without question, making accurate counts is the most important phase of the technique. There are two aspects involved, one is locating all groups present through diligent searching, the other is ascertaining the age of groups found relative to the deposition period. The problem of missing groups can be resolved to a large extent by using two experienced men per crew, each checking the other's work.

For survey purposes, groups dropped during the established deposition period are termed "new," while those dropped prior to the period are "old." Under Michigan conditions nearly all groups actually deposited during fall and winter will be extant in the spring. In addition, many older groups will also be visible, up to 5 years in some instances. All groups found on top of recent leaf litter should be considered new regardless of appearance. Correctly aging groups on sites devoid of fallen leaves appears to be a serious problem. Attempts to remove pellet groups from sample plots in the fall were not successful.

A group should be counted only if its midpoint falls within the plot. A minimum cluster of 10 pellets is recommended as an interim limit to define a pellet group pending the results of needed research. If possible, pellet group counts should be avoided on bright sunny days, which makes groups difficult to see in the contrasting light, or immediately following a rain, which tends to make old groups appear fresh.

Fifteen experimental surveys were conducted in two enclosed areas with known deer populations - five on the square mile enclosure at the Cusino Wildlife Research Station near Shingleton in the Upper Peninsula and ten on the 1.8 square mile E. S. George Reserve near Pinckney in the southern Lower Peninsula. For the George Reserve, population estimates from pellet group counts fit poorly with known populations. In only three of ten surveys did estimated and known populations differ by less than 10 deer per square mile. Available evidence points to mistakes in aging pellet groups as the major problem. Surveys on the Cusino enclosure showed much better agreement. Estimated and known means differed by less than 10 deer per square mile in all five trials.

Frequency distributions of pellet groups on both the Cusino enclosure and the George Reserve as well as for three of four extensive areas in the northern Lower Peninsula were satisfactorily described by fitted negative binomial distributions. The negative binomial is a non-random or "contagious" distribution defined by two parameters, the mean and a positive exponent k. The latter is considered by many to be a measure of the degree of aggregation of the population. Values for k were less than .7 in all cases studied here but differed between areas in the same year and years on the same area in one instance. Since the negative binomial distribution is tedious to work with, the relationship between means and variances provides a simple and accurate way of estimating standard deviations for sample allocation purposes. A single regression line can be fitted to data from several distributions having different k values. The equation $\log s^2 = \log a + b \log \bar{x}$ is linear and can be easily solved. Here $\bar{x}$ is the sample mean and a and b are constants.

Extensive operational pellet group surveys have been carried out in Michigan since the early 1950's. The entire northern half of the Lower Peninsula was first surveyed in 1954 and the entire Upper Peninsula in 1957. Since 1959, both regions have been surveyed annually. One year's surveys usually require about 550 man-days of effort.

A two-stage, stratified random sampling plan with optimum allocation was used. The first stage units were geographic sections (square miles). Each section was classified by field men into one of five levels of expected over-winter deer populations. Second stage sampling units (courses) consisted of eight 1/50-acre plots spaced 5 chains apart in a straight line. Courses were located within sections by restricted randomization procedures. Each 1/50-acre plot was angled at 45° to the right of the line of travel to reduce potential location biases.

Average over-winter population levels, obtained directly from pellet group counts were adjusted to provide estimates of the spring and previous fall herds by considering proportional contributions from deer known to have been removed, i.e., legal harvest and over-winter mortality.

The accuracy of extensive surveys cannot be properly appraised since real herd sizes are unknown. Available evidence indicates at least a fair agreement, although poor pellet group counting is known to have occurred on some surveys. Evidently the technique is more accurate under typical Upper Peninsula weather conditions and cover types.

For estimates of equal precision, stratified sampling resulted in considerable savings in manpower when compared to simple random sampling. Confidence limits of ±2 standard errors of the mean ranged from about ±25 to ±50 per cent for individual game district surveys, and ±14 to ±22 per cent for Upper Peninsula and northern Lower Peninsula estimates. Much larger sample sizes would be needed to appreciably reduce these limits. Stratification was not accurate enough to warrant annual selection of new samples.

No difference was found in pellet group counts by position on the course line. Analysis of time records and comparisons of within course variability and between course variability indicate optimal strategy would be to reduce the number of plots per course to five and increase the number of courses.

An unfortunate conclusion of this study is that much of the early research on the pellet group technique in Michigan and elsewhere was poorly planned. Moreover, investigations on two areas with known deer populations in Michigan revealed serious biases on some experimental surveys which would not be corrected by increased sample sizes. Obviously much work remains to be carried out.

The most critical need is to develop definitive methods for determining the age of pellet groups found in the field. A related need is a technique for separating deer defecations from those of sheep and elk. Such methods should ideally be usable on the ground, but laboratory methods would suffice if samples of questionable groups were collected. I also recommend trials of painting groups on the ground at the time of leaf fall on plots in troublesome cover types. In addition, northern wildlife biologists should stake out known age groups in the fall for reference in the spring.

Defecation rates for male deer, both adults and fawns, were based on small numbers of animals and more need to be studied. In addition, no studies of defecation rates were carried out prior to January and indices for the 2 1/2 month period following leaf fall should be examined.

Different - but not necessarily better in terms of statistical precision - sampling designs should be developed which will provide information for prediction of future herd levels. In order to accomplish this, stratifications should be vegetation-based rather than on the expected number of deer. The most efficient plot size for estimating pellet group density needs to be determined for Michigan conditions.

APPENDICES

APPENDIX A

THE MICHIGAN DEER RESOURCE

In Gilbert's (1967) words:

> "The deer is our most abundant, conspicuous, big-game mammal, ranging over three-fourths of the continent. Because deer hunting, deer killing, displaying dead deer on automobile fenders is fraught with symbolic significance, the whitetail is important to hundreds of wildlife biologists, millions of hunters, and to a multibillion-dollar deer-hunting industry."

In Michigan the white-tailed deer is the most important wildlife species and the Michigan deer hunter is, at one time, perhaps the Department of Natural Resources' best customer and severest critic. Since 1963 more people have hunted deer than any other game animal in the state. In 1969 record numbers of both firearm deer and bow and arrow deer licenses were sold, 656,853 and 65,385 respectively. About 20 per cent of all Michigan males 15-years-old or older bought a firearm deer license in 1968 (Ryel, Jamsen and Hawn 1970). In the fiscal year 1967-68, deer hunters contributed about 40 per cent of the total license revenue received by the Michigan Department of Natural Resources and 1.4 times that obtained from all types of fishing licenses. Including a portion of Federal Pittman-Robertson funds, the total income received from deer hunters was $4,114,245 (Mich. Dept. Cons. 1968).

Michigan's deer hunters harvested an average of 103,640 deer a year for the 10 year period 1960 to 1969 (Bennett et al. 1966, Ryel 1970). Following Shick's (1955) approach, the 1969 deer harvest of 109,450 deer resulted in an estimated 5,473,500 pounds of meat (at 50 pounds per deer) to hunters and their families. If we assign conservative values of $.70 per pound and $1.00 apiece for the hides, the 1968 crop was worth about

$3,940,200.

Recreationists, however, stress that the real value of hunting lies not in the deer killed, but in recreation units (e.g., hunter-days). Firearm and bow and arrow hunters totaled over 4,920,000 hunter-days in 1969.

The State of Michigan also derives substantial benefits from the deer resource indirectly through the large amount of money pumped into the economy by hunters and by summer deer-watching tourists. In addition, wild land values in northern Michigan are undoubtedly buoyed up by the presence of deer. For example, a nearby solid block of some 500 square miles in northeastern lower Michigan is occupied by deer-hunting clubs.

The 1965 National Survey of Fishing and Hunting (U. S. Dept. of Interior 1966) reported an average of $63.78 spent per big game hunter for equipment, special clothing, food, lodging, transportation and licenses. Applied to Michigan's 1969 firearm deer hunters, this would amount to about $40,224,130. Unpublished data supplied by Dr. Lewis Moncrief from his study of deer hunter attitudes (Moncrief 1970) suggested total statewide expenditures of about $39,000,000 in 1967 (565,660 hunters). Estimates were based on samples of 1967 Michigan deer license purchasers from Marquette, Alpena and Ingham counties.

A 1964 study of Michigan deer hunters revealed that the average hunting party was 3.86 persons who spent a total of $94.00 (or $24.35 per person) per hunting trip. The average round trip was 475 miles (Central Michigan University 1965). Unfortunately, the structure of the sample was such that the total number of trips made could not be determined and no statewide estimate is possible.

A sizable item, but not assessed, is the value of the satisfaction deer hunters receive over and above that which they could receive from their out-of-pocket deer hunting expenditures if the same dollar amounts were spent for other goods and services. Deer hunting is essentially a "free" sport, except for a nominal license fee. It costs no more in fees to hunt 11 hours a day for 16 days (entire season) than it does to buy a license but not hunt at all.

A study of summer tourists conducted by Central Michigan University (1965) indicated sight-seeing was the number one activity listed. Driving to observe deer is a prominent part of summertime sight-seeing in northern Michigan. When I was stationed at the Ogemaw State Game Refuge, some 50,000 people visited the Refuge in 1953 to see the captive deer and semi-tame deer herd (Ryel 1965). There were no residences within 5 miles and St. Helen and West Branch, the nearest towns, were 6 and 16 miles away respectively.

The white-tailed deer is also one of the most important ecological forces affecting composition and growth of certain northern Michigan plant communities. Heavy browsing may virtually eliminate some species of trees and shrubs, greatly reduce the abundance of others, and retard the growth of still others (Duvendeck 1952, Ryel 1953, Graham 1958).

Obviously, the State of Michigan is vitally concerned with perpetuating this valuable resource. Management is carried out by the Department of Natural Resources within guidelines set by the executive and legislative branches of the State government.

APPENDIX B - SUPPLEMENTAL TABLES

Table 37

Chronology of Deer Pellet Group Surveys in Michigan[1]

1950-52 Counts made by U. S. Forest Service personnel in certain cover types of the Ottawa National Forest (Olson 1952)

1953 Jenkins and Eberhardt (1953)

1. George Reserve
2. Cusino enclosure
3. Lake County
4. Mio Ranger District (Huron National Forest)
5. Tawas Ranger District (Huron National Forest)
6. Houghton Lake Area

1954 Eberhardt (1955)

1. George Reserve
2. Cusino enclosure
3. Lake County
4. Mio Ranger District
5. Northern Lower Peninsula

1955

1. Several sub-divisions of the Northern Lower Peninsula were surveyed, but preliminary examination of the data revealed serious under-counting and the results were never written up.
2. George Reserve
3. Cusino enclosure

1956 Eberhardt (1957)

1. Northern Lower Peninsula
2. George Reserve
3. Cusino enclosure
4. Seney-Blaney Deer Management Area (part of Schoolcraft County)

1957 Eberhardt (1957)

1. Upper Peninsula east
2. Upper Peninsula central
3. Upper Peninsula west
4. Any-deer hunting area 2 (includes most of Manistee National Forest)

[1]Pertinent references covering basic survey results are indicated.

Table 37 (cont'd.)

a. Lake County (part of area 2, but separate estimates computed)

5. Any-deer hunting areas 6, 7, 8 (includes much of Tawas and Mio Ranger Districts of Huron National Forest)

1958 Ryel (1958), Eberhardt and Ryel (1958)

1. Alger-Delta-Schoolcraft counties
2. North Dickinson County area (covers any-deer hunting area U-2 which was proposed, but not approved)

   a. Any-deer hunting areas U-3 and U-4. All of U-3 and most of U-4 is included within Alger-Delta-Schoolcraft counties.

3. Roscommon-Oscoda-Crawford counties

   a. Mio Ranger District (part of R-O-C but separate estimate computed)

4. Clare-Gladwin counties
5. Any-deer hunting areas A-7 and A-8

   a. Lake County (part of these areas but separate estimate prepared)

6. Beaver Island
7. George Reserve
8. Cusino enclosure

1959-64 Quadrats were staked in fall 1958 or spring 1959 and run for six years. Ryel (1959b), Ryel (1960), Ryel (1961), Ryel (1962), Ryel (1963), Bennett (1964)

1. Game District 1
2. Game District 2
3. Game District 3
4. Game District 4
5. Upper Peninsula - sum of Districts 1-4
6. Game District 5
7. Game District 6
8. Game District 7
9. Game District 8
10. Game District 9
11. Northern Lower Peninsula - sum of Districts 5-9
12. George Reserve (through 1963 only)
13. Huron National Forest - wholly within District 7 but additional courses were established to provide a separate estimate

Table 37 (cont'd.)

a. Mio Ranger District - a part of the Huron National Forest but a separate estimate computed

14. Manistee National Forest - part of Districts 6 and 8. Additional courses were established to provide a separate estimate
15. Estimates for other areas were also computed in some years using regular survey results

    a. Alger-Delta-Schoolcraft
    b. Ottawa National Forest
    c. Roscommon-Oscoda-Crawford
    d. Clare-Gladwin
    e. Hiawatha National Forest
    f. Marquette National Forest

1963 In addition to those listed above:

1. Barry-Allegan area (mostly the Barry State Game Area)
2. Hiawatha National Forest Wildlife Demonstration Area

1964 In addition to those listed above:

1. Hiawatha National Forest Wildlife Demonstration Area

1965-69 New quadrats were staked in spring 1965 and run for five years. Districts in Northern Lower Peninsula were realigned. Old Districts 6, 7, 8, and 9 were formed into new 6, 7, and 8, Muskegon County no longer included. Bennett (1965), Bennett (1966), Bennett (1967), Bennett (1968), Ryel (1969)

1. Game District 1
2. Game District 2
3. Game District 3
4. Game District 4
5. Upper Peninsula - sum of Districts 1-4
6. Game District 5
7. Game District 6 - includes part of old Districts 6 and 8
8. Game District 7 - includes all of old District 7 plus part of 6
9. Game District 8 - includes all of old District 9 plus part of 8
10. Northern Lower Peninsula - sum of Districts 5-8 (no longer includes Muskegon County)
11. Huron National Forest - wholly within District 7 but additional courses were established to provide a separate estimate
12. Manistee National Forest - nearly all within District 6
13. Estimates of other areas were also computed using regular survey results

Table 37 (cont'd.)

a. Ottawa National Forest
b. Hiawatha National Forest
c. Marquette National Forest

1968 In addition to those listed above:

1. Beaver Island
2. Drummond Island

Table 38

Defecation Rates for Adult Bucks in Michigan Feeding Trials

Rate determination trial	Year	Location	Diet	Deer per pen	No. of counts	Range of dates	Mean	Standard error of mean	Linear regression slope[2]	Test of regression slope = 0 t value
1[1]	1953	Cusino	Sugar maple-cedar	1	23	Apr. 2 - May 9	13.92	.6084	.0240	.4812
2	1959	Houghton Lake	Sweet fern	2	8	Jan. 28 - Mar. 5	13.96	.4467	-.0196	.5193
3	1959	Houghton Lake	Aspen	2	2	Jan. 28 - 29	14.01	.3400	-.6800	
4	1959	Cusino	Control	1	10	Feb. 3 - Apr. 3	21.38	1.0267	-.0592	1.2484
5	1959	Cusino	Control	1	10	Feb. 3 - Apr. 3	15.36	.9456	-.0650	1.5535
Total				7	53		15.61	.3834		

[1]Died on diet apparently from malnutrition.
[2]Model I regression of pellet groups/24 hours (Y) against date (X).

Table 39

Defecation Rates for Adult Females in Michigan Feeding Trials

Rate determination trial	Year	Location	Diet	Deer per pen	No. of counts	Range of dates	Mean	Standard error of mean	Linear regression slope[1]	Test of regression slope = 0 t value
1	1953	Cusino	Sugar maple-cedar	1	5	Apr. 2 - 7	12.62	.5651	-.1432	.3869
2	1953	Cusino	Sugar maple-cedar	1	12	Apr. 30 - Mar. 18	17.94	.9218	-.2940	2.0984
3	1954	Cusino	Control	3	6	Feb. 9 - Apr. 5	14.61	.5528	.0457	1.6678
4	1954	Cusino	Swamp hardwoods	3	6	Feb. 9 - Apr. 5	13.00	.2422	-.0069	.4130
5	1954	Cusino	Hemlock-hardwoods	3	6	Feb. 9 - Apr. 5	12.77	.3293	.0302	2.0132
6	1954	Cusino	Fire succession	3	6	Feb. 9 - Apr. 5	12.65	.2109	.0231	3.1627*
7	1954	Cusino	Mixed conifers-upland hardwoods	3	6	Feb. 9 - Apr. 5	13.22	.2821	.0095	.5394
8	1959	Houghton Lake	Aspen	2	8	Jan. 28 - Mar. 5	13.86	.4500	-.0816	4.1497*

Table 39 (cont'd.)

Rate determination trial	Year	Location	Diet	Deer per pen	No. of counts	Range of dates	Mean	Standard error of mean	Linear regression slope[1]	Test of regression slope = 0 t value
9	1959	Houghton Lake	Willow	1	8	Jan. 28 - Apr. 5	8.57	.5214	.0066	.2194
10	1959	Houghton Lake	Sweet fern	1	3	Feb. 26 - Mar. 5	11.77	.3048	-.1342	3.5360
11	1959	Cusino	Control	1	6	Mar. 5 - Apr. 24	10.06	.4582	-.0462	2.3910
12	1959	Cusino	Control	1	9	Feb. 5 - Apr. 24	13.10	.9383	-.0792	3.1307*
13	1959	Cusino	Swamp conifer	1	10	Jan. 10 - Apr. 22	12.46	.5565	-.0113	.7133
14	1959	Cusino	Swamp conifer	1	9	Jan. 10 - Apr. 22	10.71	.5204	.0034	.2219
Total				25	100		12.89	.1807		

[1]Model I regression of pellet groups/24 hours (Y) against date (X).
*Significant at $P_{.05}$ level.

Table 40

Defecation Rates for Buck Fawns in Michigan Feeding Trials

Rate determin-ation trial	Year	Location	Diet	Deer per pen	No. of counts	Range of dates	Mean	Standard error of mean	Linear regression slope[2]	Test of regression slope = 0 t value
1	1959	Cusino	Control	1	6	Feb. 23 - Apr. 18	15.18	.4922	-.0021	.0000
2	1959	Cusino	Control	1	4	Jan. 14 - 28	13.94	1.2387	.0766	.2706
3[1]	1959	Cusino	Swamp conifer	1	6	Jan. 7 - Mar. 12	14.83	1.5472	.0799	1.1757
Total				3	16		14.74	.6846		

[1]Died on diet after having lost 40 per cent of initial weight.
[2]Model I regression of pellet groups/24 hours (Y) against date (X).

Table 41

Defecation Rates for Doe Fawns in Michigan Feeding Trials

Rate determination trial	Year	Location	Diet	Deer per pen	No. of counts	Range of dates	Mean	Standard error of mean	Linear regression slope[2]	Test of regression slope = 0 t value
1	1953	Cusino	Sugar maple-cedar	1	8	Apr. 3 - 10	8.80	.9112	-.1643	.3871
2	1954	Cusino	Control	3	6	Feb. 9 - Apr. 5	13.50	.5060	.0496	2.3216
3	1954	Cusino	Swamp conifer	3	6	Feb. 9 - Apr. 5	12.33	.3116	-.0173	.9342
4	1954	Cusino	Swamp hardwoods	3	6	Feb. 9 - Apr. 5	12.65	.4217	-.0331	1.5249
5	1954	Cusino	Hemlock-hardwoods	3	6	Feb. 9 - Apr. 5	10.83	.5829	.0511	1.8486
6	1954	Cusino	Fire succession	3	6	Feb. 9 - Apr. 5	11.77	.3073	-.0291	2.1386
7	1954	Cusino	Mixed conifer-upland hardwoods	3	6	Feb. 9 - Apr. 5	11.50	.3864	-.0003	.0000
8	1959	Cusino	Swamp conifer	1	5	Mar. 21 - Apr. 21	11.34	1.1803	.1356	1.3749

Table 41 (cont'd.)

Rate determination trial	Year	Location	Diet	Deer per pen	No. of counts	Range of dates	Mean	Standard error of mean	Linear regression slope[2]	Test of regression slope = 0 t value
9	1959	Cusino	Swamp conifer	1	11	Jan. 7 - Apr. 21	10.53	.7265	-.0459	2.0320
10[1]	1959	Cusino	Swamp conifer	1	8	Feb. 13 - Apr. 1	14.41	.7202	-.0412	.6684
11	1959	Cusino	Control	1	10	Jan. 14 - Apr. 18	11.50	.9956	-.0436	1.6346
12	1959	Cusino	Control	1	10	Jan. 14 - Apr. 18	13.91	.7077	-.0506	3.9861**
13	1959	Houghton Lake	Sweet fern	1	6	Feb. 19 - Mar. 5	11.66	.5217	-.0842	.7128
Total				25	94		11.89	.2105		

[1]Died on diet after having lost 34 per cent of initial weight.
[2]Model I regression of pellet groups/24 hours (Y) against date (X).
**Significant at $P_{.01}$ level.

Table 42

ANOVA Table, Defecation Rates for Three Sex and Age Classes of Deer on a Hardwood-Conifer Diet, Cusino 1953

Source	Degrees of freedom	Sum of squares	Mean square	Expected mean square	F
Kind of deer A	2	312.2828	156.1414	$\sigma_e^2 + 12.5331\sigma_B^2 + 14.8125\sigma_A^2$	≃ 1.56
Deer within kind of deer B	1	99.9534	99.9534	$\sigma_e^2 + 7.0588\sigma_B^2$	12.48**
Observations within deer	44	352.3362	8.0076	σ_e^2	
Total	47	764.5724			

**Significant at $P_{.01}$ level.

Table 43

ANOVA Table, Defecation Rates for Two Sex and Age Classes of Deer on Six Diets for Six Dates between January and April, Cusino 1954

Source	Degrees of freedom	Sum of squares	Mean square	Expected mean square[1]	F
Ages A	1	23.5756	23.5756	$\sigma_e^2 + 36\Phi(A)$	41.38**
Diets B	5	36.3360	7.2672	$\sigma_e^2 + 12\Phi(B)$	12.76**
Dates C	5	7.1976	1.4395	$\sigma_e^2 + 12\Phi(C)$	2.53
Ages X diets AB	5	5.1812	1.0362	$\sigma_e^2 + 6\Phi(AB)$	1.82
Ages X dates AC	5	2.1796	.4359	$\sigma_e^2 + 6\Phi(AC)$	.77
Diets X dates BC	25	34.9792	1.3992	$\sigma_e^2 + 2\Phi(BC)$	2.46*
Diets X dates X ages ABC	25	14.2436	.5697	$\sigma_e^2 + \Phi(ABC)$	
Total	71	123.6928			

[1]This assumes the added effect on σ_e^2 of the A X B X C interaction is zero.
*Significant at $P_{.05}$ level.
**Significant at $P_{.01}$ level.

Table 44

ANOVA Table, Defecation Rates for Four Sex and Age Classes of Deer on the Control Diet, Cusino 1959

Source	Degrees of freedom	Sum of squares	Mean square	Expected mean square	F
Kind of deer A	3	466.3165	155.4388	$\sigma_e^2 + 8.08\sigma_B^2 + 15.85\sigma_A^2$	$\approx$ 2.52
Deer within kind of deer B	4	246.8220	61.7055	$\sigma_e^2 + 8.00\sigma_B^2$	8.73**
Observations within deer	57	403.0569	7.0712	σ_e^2	
Total	64	1116.1954			

**Significant at $P_{.01}$ level.

Table 45

ANOVA Table, Defecation Rates for Three Sex and Age Classes of Deer on the Swamp-Conifer Diet, Cusino 1959

Source	Degrees of freedom	Sum of squares	Mean square	Expected mean square	F
Kind of deer A	2	46.4586	23.2293	$\sigma_e^2 + 5.19\sigma_B^2 + 9.71\sigma_A^2$	$\approx$ .84
Deer within kind of deer B	3	83.4394	27.8131	$\sigma_e^2 + 12.36\sigma_B^2$	4.89**
Observations within deer	43	244.8059	5.6932	σ_e^2	
Total	48	374.7039			

**Significant at $P_{.01}$ level.

Table 46

ANOVA Table, Defecation Rates for Adult Does on the Control and Swamp-Conifer Diets, Cusino 1959

Source	Degrees of freedom	Sum of squares	Mean square	Expected mean square	F
Diets A	1	.1802	.1802	$\sigma_e^2 + 8.56\sigma_B^2 + 16.76\sigma_A^2$	$\approx$ .01
Deer within diets B	2	44.3378	22.1689	$\sigma_e^2 + 8.34\sigma_B^2$	5.21*
Observations within deer	30	127.7580	4.2586	σ_e^2	
Total	33	172.2760			

*Significant at $P_{.05}$ level.

Table 47

ANOVA Table, Defecation Rates for Buck Fawns on the Control and Swamp-Conifer Diets, Cusino 1959

Source	Degrees of freedom	Sum of squares	Mean square	Expected mean square	F
Diets A	1	.0767	.0767	$\sigma_e^2 + 5.70\sigma_B^2 + 7.50\sigma_A^2$	$\approx$ .02
Deer within diets B	1	3.6952	3.6952	$\sigma_e^2 + 4.80\sigma_B^2$	.49
Observations within deer	13	97.4961	7.4989	σ_e^2	
Total	15	101.2680			

Table 48

ANOVA Table, Defecation Rates for Doe Fawns on the Control and Swamp-Conifer Diets, Cusino 1959

Source	Degrees of freedom	Sum of squares	Mean square	Expected mean square	F
Diets A	1	5.6435	5.6435	$\sigma_e^2 + 9.40\sigma_B^2 + 21.82\sigma_A^2$	≈ .17
Deer within diets B	3	101.3271	33.7757	$\sigma_e^2 + 8.42\sigma_B^2$	5.33**
Observations within deer	39	247.2591	6.3400	σ_e^2	
Total	43	354.2297			

**Significant at $P_{.01}$ level.

Table 49

Deposition Periods for Pellet Group Surveys

Year of survey	Cusino Enclosure Leaf fall	Cusino Enclosure Mean survey date	Cusino Enclosure Deposition period	George Reserve Leaf fall	George Reserve Mean survey date	George Reserve Deposition period	District 1 Leaf fall	District 1 Mean survey date	District 1 Deposition period	District 2 Leaf fall	District 2 Mean survey date	District 2 Deposition period
1953	Oct 10	May 6	208	Nov 1	Apr 29	179						
1954	Oct 20	May 11	205	Oct 25	Apr 25	182						
1955	Oct 10	May 6	208	Oct 31	Apr 30	181						
1956	Oct 7	May 15	221	Nov 5	Apr 15	162						
1957												
1958	Oct 14	May 17	203	Oct 25	Apr 9	167						
1959				Nov 1	Apr 15	165	Oct 15	May 4	201	Oct 21	Apr 28	189
1960				Nov 1	Apr 12	163	Oct 15	May 8	206	Oct 11	May 4	206
1961				Oct 19	Mar 29	161	Oct 15	May 9	206	Oct 15	Apr 27	194
1962				Nov 5	Mar 29	144	Oct 11	May 7	208	Oct 12	May 6	206
1963				Nov 1	Apr 3	153	Oct 9	Apr 23	196	Oct 8	Apr 11	185
1964							Oct 8	May 5	210	Oct 10	Apr 25	198
1965							Oct 2	May 15	225	Oct 13	May 11	210
1966							Oct 7	May 12	217	Oct 16	May 7	203
1967							Oct 15	May 4	201	Oct 19	Apr 26	189
1968							Oct 18	Apr 25	190	Oct 18	Apr 16	181
1969							Oct 15	May 5	202	Oct 16	May 3	199
Mean	Oct 12	May 11	209	Oct 30	Apr 13	166	Oct 12	May 5	206	Oct 14	Apr 29	196

Table 49 (cont'd.)

Year of survey	District 3 Leaf fall	District 3 Mean survey date	District 3 Deposition period	District 4 Leaf fall	District 4 Mean survey date	District 4 Deposition period	District 5 Leaf fall	District 5 Mean survey date	District 5 Deposition period	District 6[1] Leaf fall	District 6[1] Mean survey date	District 6[1] Deposition period
1959	Oct 23	May 2	191	Oct 26	May 4	190	Oct 17	Apr 30	195	Oct 27	Apr 25	180
1960	Oct 19	May 8	202	Oct 27	May 2	188	Oct 11	Apr 26	198	Oct 27	Apr 26	182
1961	Oct 23	Apr 28	187	Oct 31	Apr 25	176	Oct 19	Apr 21	184	Oct 26	Apr 16	172
1962	Oct 15	May 8	205	Oct 31	May 7	188	Oct 25	May 5	192	Oct 26	Apr 29	185
1963	Oct 8	Apr 16	190	Oct 17	Apr 22	187	Oct 15	Apr 18	185	Oct 16	Apr 13	179
1964	Oct 13	Apr 25	195	Oct 19	Apr 29	193	Oct 22	Apr 25	186	Oct 18	Apr 18	183
1965	Oct 10	May 11	213	Oct 20	May 10	202	Oct 18	May 6	200			
1966	Oct 12	May 7	207	Oct 19	May 4	193	Oct 19	Apr 21	184			
1967	Oct 16	May 7	203	Oct 21	May 2	193	Oct 21	Apr 19	180			
1968	Oct 15	Apr 21	189	Oct 24	Apr 24	183	Oct 23	Apr 9	169			
1969	Oct 20	May 4	196	Oct 28	May 6	190	Oct 23	Apr 26	185			
Mean	Oct 16	May 2	198	Oct 24	May 1	189	Oct 19	Apr 24	187	Oct 23	Apr 21	180

Year of survey	Old District 7 Leaf fall	Old District 7 Mean survey date	Old District 7 Deposition period	Old District 8 Leaf fall	Old District 8 Mean survey date	Old District 8 Deposition period	Old District 9 Leaf fall	Old District 9 Mean survey date	Old District 9 Deposition period
1959	Oct 18	Apr 24	188	Oct 25	Apr 18	175	Oct 17	Apr 14	179
1960	Oct 25	Apr 27	185	Nov 6	Apr 19	165	Nov 3	Apr 23	172
1961	Oct 20	Apr 15	177	Oct 20	Apr 10	172	Oct 16	Apr 15	181
1962	Oct 31	Apr 28	179	Oct 30	Apr 11	163	Oct 26	Apr 17	173
1963	Oct 19	Apr 18	181	Oct 11	Apr 10	181	Oct 20	Apr 19	181
1964	Oct 25	Apr 17	175	Oct 25	Apr 11	169	Oct 26	Apr 6	163
Mean	Oct 23	Apr 22	181	Oct 25	Apr 13	171	Oct 23	Apr 16	175

Table 49 (cont'd.)

Year of survey	New District 6 Leaf fall	Mean survey date	Deposition period	New District 7 Leaf fall	Mean survey date	Deposition period	New District 8 Leaf fall	Mean survey date	Deposition period
1965	Oct 22	Apr 30	190	Oct 18	Apr 29	193	Oct 25	Apr 25	182
1966	Oct 22	Apr 25	185	Oct 21	Apr 18	179	Oct 24	Apr 10	168
1967	Oct 25	Apr 21	178	Oct 15	Apr 15	182	Oct 22	Apr 18	178
1968	Oct 25	Apr 17	175	Oct 24	Apr 4	163	Oct 24	Apr 9	168
1969	Nov 3	Apr 21	169	Oct 25	Apr 23	180	Oct 25	Apr 14	171
Mean	Oct 26	Apr 23	179	Oct 21	Apr 18	179	Oct 24	Apr 15	173

[1]Game District boundaries were realigned in northern Lower Michigan in 1964.

Table 50

Performance of Individuals in Counting Pellet Groups
George Reserve, 1958

Pellet Groups Found

	Observer A		Observer B		Consensus		Number of
Crew	New	Old	New	Old	New	Old	plots searched
1	84	3	84	3	84	3	25
2	73	35	77	39	82	41	38
3	31	6	44	8	45	8	30
4	37	2	42	6	47	6	20
5	95	23	102	19	124	24	42
6	39	6	65	2	79	3	34
7	84	65	79	65	116	91	35

Average proportion of consensus counted per individual New = .82
Old = .91

Table 51

Performance of Individuals in Counting Pellet Groups
George Reserve, 1959

Pellet Groups Found

	Observer A		Observer B		Consensus		Number of
Crew	New	Old	New	Old	New	Old	plots searched
1	54	25	56	26	63	26	40
2	52	8	52	8	52	8	35
3	117	5	117	5	117	5	33
4	28	94	28	94	28	94	34
5	31	10	32	11	35	11	21
6	108	13	108	12	108	13	28
7	83	22	83	21	92	23	40
8	82	10	84	10	85	10	37
9	17	1	19	1	20	1	8

Average proportion of consensus counted per individual New = .95
Old = .98

Table 52

Performance of Individuals in Counting Pellet Groups
George Reserve, 1960

Pellet Groups Found

Crew	Observer A New	Observer A Old	Observer B New	Observer B Old	Consensus New	Consensus Old	Number of plots searched
1	51	2	51	2	51	2	15
2	63	2	63	2	63	2	18
3	52	11	49	13	52	13	20
4	56	19	45	20	56	20	20
5	18	12	18	11	18	11	22
6	55	12	53	15	58	16	21
7	59	3	52	6	62	6	25
8	72	19	70	21	73	24	18
9	77	6	77	6	77	6	14
10	69	1	71	1	74	1	21
11	136	53	141	55	147	55	28
12	140	30	128	37	146	42	35
13	46	0	43	0	47	0	11

Average proportion of consensus counted per individual New = .96
Old = .93

Table 53

Performance of Individuals in Counting Pellet Groups
George Reserve, 1961

Pellet Groups Found

Crew	Observer A New	Observer A Old	Observer B New	Observer B Old	Consensus New	Consensus Old	Number of plots searched
1	168	15	170	15	186	18	24
2	56	22	53	17	60	23	25
3	48	7	52	7	54	7	35
4	62	5	62	5	62	5	28
5	84	19	84	17	93	18	21
6	48	11	45	10	49	8	19
7	93	3	100	4	109	4	30
8	82	9	77	12	83	12	32
9	73	0	78	0	83	0	29

Average proportion of consensus counted per individual New = .93
Old = .97

Table 54

Performance of Individuals in Counting Pellet Groups
George Reserve, 1962

Pellet Groups Found

Crew	Observer A New	Observer A Old	Observer B New	Observer B Old	Consensus New	Consensus Old	Number of plots searched
1	27	3	28	4	30	4	28
2	78	6	69	7	82	7	26
3	118	3	112	3	122	4	29
4	79	0	78	0	83	0	24
5	71	24	70	21	74	27	30
6	106	1	105	1	109	1	22
7	95	0	90	0	99	0	33
8	106	0	105	0	106	0	42

Average proportion of consensus counted per individual New = .94
Old = .92

Table 55

Performance of Individuals in Counting Pellet Groups
George Reserve, 1963

Pellet Groups Found

Crew	Observer A New	Observer A Old	Observer B New	Observer B Old	Consensus New	Consensus Old	Number of plots searched
1	169	6	184	7	196	7	27
2	157	1	165	1	168	1	30
3	117	5	105	2	122	5	20
4	104	4	121	3	123	4	30
5	116	8	118	8	123	9	36
6	114	8	106	8	124	9	23
7	114	15	116	17	120	17	27

Average proportion of consensus counted per individual New = .93
Old = .89

Table 56

Comparison of Original Counts with Later Rechecks
Northern Lower Peninsula Survey, 1956

Original	Recheck		Original	Recheck
0	6		11	12
0	44		11	11
0	0		13	16
0	1		13	17
0	6		14	18
0	0		14	20
1	2		19	12
1	0		23	34
1	0		28	25
4	2		61	59
6	7		70	58
7	14		99	65
9	8		186	167
10	15			
		Total	601	619

Table 57

Comparison of Original Counts with Later Rechecks
Northern Lower Peninsula Surveys, 1957

Original	Recheck	Original	Recheck
0	10	12	16
0	0	12	8
0	0	12	11
0	0	13	17
0	0	13	13
0	1	13	15
0	1	14	16
0	0	14	16
1	1	14	2
1	1	15	17
1	0	15	14
1	3	15	15
1	1	17	21
2	3	20	8
2	1	23	15
3	5	23	16
4	4	23	37
4	1	24	37
5	6	25	26
5	2	29	31
5	2	34	47
6	4	37	26
6	3	41	23
7	2	45	40
8	20	46	45
8	15	47	52
8	8	55	26
8	10	62	43
8	20	71	55
9	5	97	83
11	3		
	Total	995	923

Table 58

Comparison of Original Counts with Later Rechecks
Upper Peninsula Surveys, 1957

Original	Recheck	Original	Recheck
0	0	9	10
0	0	9	18
0	0	10	16
0	1	11	15
0	0	12	13
0	0	13	16
1	1	14	17
1	1	17	22
2	8	21	28
2	1	22	24
2	3	30	34
2	2	32	32
3	3	33	44
3	4	33	34
4	5	41	44
4	6	59	63
4	4	83	105
5	6	102	97
5	5	136	131
5	7		
		Total 730	820

Table 59

Calculation of Deer Populations for George Reserve Based on Removal and Aging Method

Year: 1952-53

Leaf fall - November 1, 1952
Deer census drive - January 10, 1953
Deer pellet group survey - April 29, 1953
Deposition period - 179 days

	Population at leaf fall deer	Population at leaf fall potential deer-days	Removals deer	Removals deer-days	Population at pellet survey	Net deer-days	Prorating unknowns
Buck fawns	10	1,790	1	123	9	1,667	1,786
Doe fawns	15	2,685	1	115	14	2,570	2,754
Yearling bucks	14	2,506	7	1,001	7	1,505	1,613
Yearling does	6	1,074			6	1,074	1,151
Older bucks	20	3,580	1	76	19	3,504	3,755
Older does	15	2,685	1	76	14	2,609	2,796
Unknown	7	1,253	3	327	4	926	
Total	87	15,573	14	1,718	73	13,855	13,855

Deer Removals in Deposition Period

Date	Buck fawn	Doe fawn	Yearling buck	Yearling doe	Older buck	Older doe	Unknown	Total
Nov. 12, 1952			1					1
Nov. 13, 1952			1					1
Nov. 29, 1952			1					1

Table 59 (cont'd.)

Date	Buck fawn	Doe fawn	Yearling buck	Yearling doe	Older buck	Older doe	Unknown	Total
Dec. 16, 1952			1					1
Dec. 17, 1952			2					2
Dec. 27, 1952	1							1
Jan. 4, 1953		1	1					2
Jan. 10, 1953							3	3
Feb. 12, 1953					1	1		2
Total	1	1	7		1	1	3	14

Year: 1953-54

Leaf fall - October 25, 1953
Deer census drive - January 9, 1954
Deer pellet group survey - April 25, 1954
Deposition period - 182 days

	Population at leaf fall		Removals		Population at pellet survey	Net deer-days	Prorating unknowns
	deer	potential deer-days	deer	deer-days			
Buck fawns	18	3,276	2	171	16	3,105	3,223
Doe fawns	25	4,550	5	473	20	4,077	4,232
Yearling bucks	9	1,638	4	643	5	995	1,033
Yearling does	14	2,548	6	597	8	1,951	2,025
Older bucks	26	4,732	14	2,184	12	2,548	2,645
Older does	20	3,640	7	612	13	3,028	3,143
Unknown	6	1,092	4	495	2	597	
Total	118	21,476	42	5,175	76	16,301	16,301

Table 59 (cont'd.)

Deer Removals in Deposition Period

Date	Buck fawn	Doe fawn	Yearling buck	Yearling doe	Older buck	Older doe	Unknown	Total
Oct. 28, 1953					2			2
Oct. 31, 1953					1			1
Nov. 4, 1953			1		2			3
Nov. 6, 1953					1			1
Nov. 11, 1953			1		4			5
Nov. 13, 1953							1	1
Nov. 14, 1953					1			1
Nov. 18, 1953			1					1
Nov. 28, 1953		1	1					2
Dec. 13, 1953					1			1
Dec. 16, 1953				1				1
Dec. 26, 1953							1	1
Jan. 2, 1954						1		1
Jan. 9, 1954							2	2
Jan. 13, 1954		1		1				2
Jan. 14, 1954		1		1	1			3
Jan. 22, 1954				1		2		3
Jan. 23, 1954	1			1		1		3
Feb. 4, 1954					1	2		3
Feb. 5, 1954	1			1				2
Feb. 23, 1954		2				1		3
Total	2	5	4	6	14	7	4	42

Table 59 (cont'd.)

Year: 1954-55

Leaf fall - October 31, 1954
Deer census drive - December 11, 1954
Deer pellet group survey - April 30, 1955
Deposition period - 181 days

	Population at leaf fall		Removals		Population at pellet survey	Net deer-days	Prorating unknowns
	deer	potential deer-days	deer	deer-days			
Buck fawns	33	5,973	6	646	27	5,327	5,458
Doe fawns	14	2,534	4	371	10	2,163	2,216
Yearling bucks	16	2,896	9	944	7	1,952	2,000
Yearling does	20	3,620	9	929	11	2,691	2,757
Older bucks	16	2,896	6	710	10	2,186	2,239
Older does	20	3,620	10	1,021	10	2,599	2,663
Unknown	4	724	2	309	2	415	
Total	123	22,263	46	4,930	77	17,333	17,333

Deer Removals in Deposition Period

Date	Buck fawn	Doe fawn	Yearling buck	Yearling doe	Older buck	Older doe	Unknown	Total
Nov. 12, 1954							1	1
Nov. 20, 1954					1			1
Nov. 26, 1954			1					1
Dec. 6, 1954					1			1
Dec. 11, 1954	2		1	2	1	1	1	8

Table 59 (cont'd.)

Date	Buck fawn	Doe fawn	Yearling buck	Yearling doe	Older buck	Older doe	Unknown	Total
Dec. 21, 1954						1		1
Dec. 22, 1954		1						1
Dec. 23, 1954			1					1
Dec. 29, 1954						1		1
Dec. 31, 1954	1							1
Jan. 8, 1955			1					1
Jan. 10, 1955		1				2		3
Jan. 14, 1955				1				1
Jan. 15, 1955				1		1		2
Jan. 17, 1955				1				1
Jan. 18, 1955	1					1		2
Jan. 22, 1955			2	1	1			4
Jan. 24, 1955					1			1
Jan. 27, 1955				1				1
Feb. 16, 1955	1		1	1				3
Feb. 18, 1955	1		1	1				3
Feb. 19, 1955					1	1		2
Feb. 20, 1955			1					1
Feb. 22, 1955		1				1		2
Feb. 24, 1955		1				1		2
Total	6	4	9	9	6	10	2	46

Table 59 (cont'd.)

Year: 1955-56

Leaf fall - November 5, 1955
Deer census drive - November 12, 1955
Deer pellet group survey - April 15, 1956
Deposition period - 162 days

	Population at leaf fall		Removals		Population at pellet survey	Net deer-days	Prorating unknowns
	deer	potential deer-days	deer	deer-days			
Buck fawns	20	3,240	1	118	19	3,122	3,372
Doe fawns	24	3,888	1	115	23	3,773	4,076
Yearling bucks	27	4,374	22	2,826	5	1,548	1,672
Yearling does	10	1,620			10	1,620	1,750
Older bucks	16	2,592	13	1,664	3	928	1,002
Older does	20	3,240			20	3,240	3,500
Unknown	8	1,296	1	155	7	1,141	
Total	125	20,250	38	4,878	87	15,372	15,372

Deer Removals in Deposition Period

Date	Buck fawn	Doe fawn	Yearling buck	Yearling doe	Older buck	Older doe	Unknown	Total
Nov. 12, 1955							1	1
Nov. 18, 1955			1		1			2
Nov. 21, 1955			2					2
Nov. 22, 1955			2					2
Nov. 25, 1955			1		1			2
Nov. 26, 1955					1			1

Table 59 (cont'd.)

Date	Buck fawn	Doe fawn	Yearling buck	Yearling doe	Older buck	Older doe	Unknown	Total
Nov. 29, 1955					1			1
Nov. 30, 1955			2		1			3
Dec. 1, 1955			2		1			3
Dec. 5, 1955			1					1
Dec. 6, 1955					1			1
Dec. 8, 1955			1					1
Dec. 9, 1955			1					1
Dec. 18, 1955					1			1
Dec. 19, 1955	1		1		2			4
Dec. 22, 1955		1	4		1			6
Dec. 27, 1955			4		2			6
Total	1	1	22		13		1	38

Year: 1957-58

Leaf fall - October 24, 1957
Deer census drive - December 14, 1957
Deer pellet group survey - April 9, 1958
Deposition period - 167 days

	Population at leaf fall		Removals		Population at pellet survey	Net deer-days	Prorating unknowns
	deer	potential deer-days	deer	deer-days			
Buck fawns	18	3,006	6	609	12	2,397	2,600
Doe fawns	13	2,171	5	514	8	1,657	1,797
Yearling bucks	22	3,674	17	1,779	5	1,895	2,055

Table 59 (cont'd.)

	Population at leaf fall		Removals		Population at pellet survey	Net deer-days	Prorating unknowns
	deer	potential deer-days	deer	deer-days			
Yearling does	14	2,338	7	737	7	1,601	1,736
Older bucks	11	1,837	5	528	6	1,309	1,420
Older does	23	3,841	16	1,618	7	2,223	2,411
Unknown	7	1,169	2	232	5	937	
Total	108	18,036	58	6,017	50	12,019	12,019

Deer Removals in Deposition Period

Date	Buck fawn	Doe fawn	Yearling buck	Yearling doe	Older buck	Older doe	Unknown	Total
Dec. 14, 1957	1	1	3	1	1	1	2	10
Dec. 21, 1957			4	1		2		7
Dec. 26, 1957	1	2	3	1	2	3		12
Dec. 28, 1957	1		2	4	2	2		11
Jan. 2, 1958	1		2			4		7
Jan. 4, 1958	2	2	3			4		11
Total	6	5	17	7	5	16	2	58

Table 59 (cont'd.)

Year: 1958-59

Leaf fall - November 1, 1958
Deer census drive - December 6, 1958
Deer pellet group survey - April 15, 1959
Deposition period - 165 days

	Population at leaf fall		Removals		Population at pellet survey	Net deer-days	Prorating unknowns
	deer	potential deer-days	deer	deer-days			
Buck fawns	23	3,795	2	246	21	3,549	3,600
Doe fawns	17	2,805	1	130	16	2,675	2,713
Yearling bucks	12	1,980	7	854	5	1,126	1,142
Yearling does	8	1,320	1	130	7	1,190	1,207
Older bucks	10	1,650	4	506	6	1,144	1,160
Older does	13	2,145	2	260	11	1,885	1,912
Unknown	1	165	0	0	1	165	
Total	84	13,860	17	2,126	67	11,734	11,734

Deer Removals in Deposition Period

Date	Buck fawn	Doe fawn	Yearling buck	Yearling doe	Older buck	Older doe	Unknown	Total
Dec. 6, 1958	1	1	3	1	2	2		10
Dec. 13, 1958					2			2
Dec. 20, 1958	1		4					5
Total	2	1	7	1	4	2		17

Table 59 (cont'd.)

Year: 1959-60

Leaf fall - November 1, 1959
Deer census drive - December 5, 1959
Deer pellet group survey - April 12, 1960
Deposition period - 163 days

	Population at leaf fall		Removals		Population at pellet survey	Net deer-days	Prorating unknowns
	deer	potential deer-days	deer	deer-days			
Buck fawns	19	3,097	3	363	16	2,734	2,887
Doe fawns	12	1,956	7	792	5	1,164	1,229
Yearling bucks	21	3,423	12	1,430	9	1,993	2,104
Yearling does	16	2,608	8	937	8	1,671	1,764
Older bucks	10	1,630	9	1,043	1	587	620
Older does	18	2,934	10	1,102	8	1,832	1,934
Unknown	5	815	2	258	3	557	
Total	101	16,463	51	5,925	50	10,538	10,538

Deer Removals in Deposition Period

Date	Buck fawn	Doe fawn	Yearling buck	Yearling doe	Older buck	Older doe	Unknown	Total
Nov. 9, 1959				1				1
Dec. 1, 1959	1							1
Dec. 5, 1959		2	4		2	1	2	11
Dec. 12, 1959		1	2	1	2	2		8

Table 59 (cont'd.)

Date	Buck fawn	Doe fawn	Yearling buck	Yearling doe	Older buck	Older doe	Unknown	Total
Dec. 19, 1959	2		4	3	2	1		12
Dec. 29, 1959		2	2	3	2	2		11
Jan. 2, 1960		2			1	4		7
Total	3	7	12	8	9	10	2	51

Year: 1960-61

Leaf fall - October 19, 1960
Deer census drive - December 10, 1960
Deer pellet group survey - March 29, 1961
Deposition period - 161 days

	Population at leaf fall		Removals		Population at pellet survey	Net deer-days	Prorating unknowns
	deer	potential deer-days	deer	deer-days			
Buck fawns	22	3,542	9	899	13	2,643	2,740
Doe fawns	15	2,415	3	293	12	2,122	2,200
Yearling bucks	16	2,576	15	1,639	1	937	972
Yearling does	5	805	3	334	2	471	488
Older bucks	9	1,449	1	102	8	1,347	1,397
Older does	17	2,737	1	99	16	2,638	2,735
Unknown	3	483	1	109	2	374	
Total	87	14,007	33	3,475	54	10,532	10,532

Table 59 (cont'd.)

Deer Removals in Deposition Period

Date	Buck fawn	Doe fawn	Yearling buck	Yearling doe	Older buck	Older doe	Unknown	Total
Nov. 6, 1960				1				1
Dec. 3, 1960			7					7
Dec. 10, 1960			3				1	4
Dec. 17, 1960	5	1	4		1			11
Dec. 20, 1960	3	1		1		1		6
Dec. 27, 1960	1	1	1	1				4
Total	9	3	15	3	1	1	1	33

Year 1961-62

Leaf fall - November 5, 1961
Deer census drive - December 9, 1961
Deer pellet group survey - March 29, 1962
Deposition period - 144 days

	Population at leaf fall		Removals		Population at pellet survey	Net deer-days	Prorating unknowns
	deer	potential deer-days	deer	deer-days			
Buck fawns	19	2,736	10	1,049	9	1,687	2,076
Doe fawns	12	1,728	4	406	8	1,322	1,627
Yearling bucks	12	1,728	7	739	5	989	1,217
Yearling does	12	1,728	8	802	4	926	1,139

Table 59 (cont'd.)

	Population at leaf fall deer	Population at leaf fall potential deer-days	Removals deer	Removals deer-days	Population at pellet survey	Net deer-days	Prorating unknowns
Older bucks	10	1,440	9	972	1	468	576
Older does	18	2,592	11	1,110	7	1,482	1,823
Unknown	11	1,584	0	0	11	1,584	
Total	94	13,536	49	5,078	45	8,458	8,458

Deer Removals in Deposition Period

Date	Buck fawn	Doe fawn	Yearling buck	Yearling doe	Older buck	Older doe	Unknown	Total
Nov. 15, 1961					1			1
Dec. 2, 1961	2	1	1	1	2	2		9
Dec. 9, 1961			1	1	1			3
Dec. 10, 1961						1		1
Dec. 16, 1961	5	1	4	1	3	3		17
Dec. 19, 1961	3	1	1	3	2	2		12
Jan. 2, 1962		1		2		3		6
Total	10	4	7	8	9	11		49

Table 59 (cont'd.)

Year: 1962-63

Leaf fall - November 1, 1962
Deer census drive - December 1, 1962
Deer pellet group survey - April 3, 1963
Deposition period - 153 days

	Population at leaf fall		Removals		Population at pellet survey	Net deer-days	Prorating unknowns
	deer	potential deer-days	deer	deer-days			
Buck fawns	7	1,071	1	123	6	948	1,066
Doe fawns	14	2,142	1	111	13	2,031	2,284
Yearling bucks	7	1,071	2	246	5	825	928
Yearling does	8	1,224	1	123	7	1,101	1,238
Older bucks	8	1,224	0	0	8	1,224	1,377
Older does	11	1,683	2	229	9	1,454	1,635
Unknown	11	1,683	6	738	5	945	
Total	66	10,098	13	1,570	53	8,528	8,528

Deer Removals in Deposition Period

Date	Buck fawn	Doe fawn	Yearling buck	Yearling doe	Older buck	Older doe	Unknown	Total
Dec. 1, 1962	1		2	1		1	6	11
Dec. 13, 1962		1						1
Dec. 18, 1962						1		1
Total	1	1	2	1		2	6	13

Table 60

Comparisons of Counts of Deer Pellet Groups with
Fitted Negative Binomial Distributions for the George Reserve

	Groups per plot	Observed	Negative binomial fit
1953	0	115	114.7
	1	34	37.5
	2	23	22.1
	3	21	15.0
	4-5	17	18.9
	6-8	15	14.8
	9+	14	17.0
	Total	239	240.0

$\overline{X} = 2.2218$ $s^2 = 16.5515$ $k = .3827$

$\chi^2 = 3.5013$ for 4 degrees of freedom, $.50>P>.25$

	Groups per plot	Observed	Negative binomial fit
1954	0	125	125.9
	1	32	34.3
	2	27	19.5
	3	17	13.0
	4-5	11	16.4
	6-8	10	12.9
	9+	15	15.5
	Total	237	237.5

$\overline{X} = 2.0380$ $s^2 = 18.2401$ $k = .3144$

$\chi^2 = 6.6505$ for 4 degrees of freedom, $.75>P>.50$

	Groups per plot	Observed	Negative binomial fit
1955	0	152	152.7
	1	36	34.1
	2	20	17.6
	3-4	15	17.9
	5+	18	20.6
	Total	241	242.9

$\overline{X} = 1.1660$ $s^2 = 6.4640$ $k = .2758$

$\chi^2 = 1.2509$ for 2 degrees of freedom, $.75>P>.50$

Table 60 (cont'd.)

	Groups per plot	Observed	Negative binomial fit
1956	0	67	73.8
	1	47	35.7
	2	27	24.0
	3	17	17.6
	4	18	13.5
	5-6	13	19.0
	7-8	10	12.3
	9-11	9	11.3
	12+	15	16.4
	Total	223	223.6

$\overline{X}$ = 3.4484 s^2 = 35.0593 k = .5635

χ^2 = 9.0072 for 6 degrees of freedom, .25>P>.10

	Groups per plot	Observed	Negative binomial fit
1958	0	100	103.1
	1	44	43.0
	2	34	26.9
	3	23	18.8
	4	10	13.7
	5-6	21	18.2
	7-9	9	14.7
	10+	13	16.1
	Total	254	254.5

$\overline{X}$ = 2.5394 s^2 = 21.2929 k = .4991

χ^2 = 7.1688 for 5 degrees of freedom, .25>P>.10

	Groups per plot	Observed	Negative binomial fit
1959	0	115	118.9
	1	60	48.3
	2	25	29.5
	3	20	20.0
	4	12	14.2
	5-6	17	18.1
	7+	26	28.6
	Total	275	277.6

$\overline{X}$ = 2.1745 s^2 = 15.1665 k = .5002

χ^2 = 4.2713 for 4 degrees of freedom, .75>P>.50

Table 60 (cont'd.)

	Groups per plot	Observed	Negative binomial fit
1960	0	74	76.5
	1	44	45.5
	2	37	32.5
	3	28	24.5
	4	21	18.9
	5	14	14.9
	6-7	22	21.3
	8-10	15	18.7
	11	20	24.0
	Total	275	276.8

$\overline{X}$ = 3.5782 s^2 = 34.1791 k = .7121

χ^2 = 2.9891 for 6 degrees of freedom, .90>P>.75

	Groups per plot	Observed	Negative binomial fit
1961	0	109	115.6
	1	54	38.6
	2	30	24.1
	3	13	17.4
	4-5	23	24.0
	6-7	9	16.0
	8-10	16	15.8
	11-15	7	14.8
	16+	23	18.1
	Total	284	284.4

$\overline{X}$ = 3.9261 s^2 = 52.4574 k = .3646

χ^2 = 17.6670 for 6 degrees of freedom, .01>P>.005

Table 60 (cont'd.)

	Groups per plot	Observed	Negative binomial fit
1962	0	123	124.3
	1	45	42.0
	2	22	25.7
	3	24	18.0
	4-5	20	24.0
	6-7	16	15.0
	8-11	21	16.9
	12+	13	18.6
	Total	284	284.5

$\overline{X} = 2.9437$ $s^2 = 31.4102$ $k = .3816$

$\chi^2 = 6.1157$ for 5 degrees of freedom, $.50>P>.25$

	Groups per plot	Observed	Negative binomial fit
1963	0	65	64.9
	1	36	39.8
	2	38	29.7
	3	24	23.5
	4	16	19.1
	5	11	15.8
	6-7	21	24.2
	8-9	23	17.3
	10-12	21	17.5
	13-17	15	16.1
	18+	13	15.4
	Total	283	283.3

$\overline{X} = 5.0530$ $s^2 = 42.0575$ $k = .6990$

$\chi^2 = 8.0841$ for 8 degrees of freedom, $.50>P>.25$

Pooled estimate of $k = .4119$. $\chi^2 = 56.3988$ for 9 degrees of freedom, $.005>P$.

Table 61

Comparisons of Counts of Deer Pellet Groups with Fitted Negative Binomial Distributions for the Cusino Enclosure

	Groups per plot	Observed	Negative binomial fit
1953	0	24	30.5
	1	17	17.0
	2	20	12.8
	3	9	10.4
	4	15	8.8
	5-6	25	14.4
	7-8	11	11.3
	9-10	4	9.1
	11-13	9	10.8
	14-17	10	10.6
	18-22	4	9.2
	23-30	6	9.0
	31+	12	12.3
	Total	166	166.2

$\bar{X} = 9.7410$ $s^2 = 263.9143$ $k = .5928$

$\chi^2 = 25.0302$ for 10 degrees of freedom, $.01>P>.005$

	Groups per plot	Observed	Negative binomial fit
1954	0	53	53.5
	1	19	22.0
	2	17	14.3
	3	11	10.5
	4	11	8.1
	5-6	14	11.7
	7-8	9	8.0
	9-11	3	7.8
	12+	13	15.0
	Total	150	150.9

$\bar{X} = 3.8800$ $s^2 = 49.5426$ $k = .4588$

$\chi^2 = 5.7479$ for 6 degrees of freedom, $.50>P>.25$

Table 61 (cont'd.)

	Groups per plot	Observed	Negative binomial fit
1955	0	55	58.3
	1	27	22.6
	2	15	14.5
	3	9	10.5
	4	8	8.0
	5-6	16	11.4
	7-9	14	10.5
	10-13	5	7.7
	14+	4	9.7
	Total	153	153.2

$\overline{X} = 3.5556$ $s^2 = 75.7749$ $k = .4361$

$\chi^2 = 8.5196$ for 6 degrees of freedom, $.25>P>.10$

	Groups per plot	Observed	Negative binomial fit
1956	0	31	34.0
	1	23	20.2
	2	14	15.1
	3	12	12.0
	4	14	9.8
	5	11	8.2
	6-7	13	12.9
	8-9	6	9.5
	10-12	11	10.0
	13-16	7	8.4
	17+	11	13.5
	Total	153	153.6

$\overline{X} = 5.7451$ $s^2 = 106.5991$ $k = .6623$

$\chi^2 = 5.4931$ for 8 degrees of freedom, $.75>P>.50$

Pooled estimate of $k = .5119$. $\chi^2 = 6.4831$ for 3 degrees of freedom, $.10>P>.05$.

Table 62

Deer Population Estimates[1] and Antlered Buck Harvests for Game Districts

Year of survey	District 1 Deer population	District 1 Confidence limits	District 1 Buck harvest prev. fall	District 2 Deer population	District 2 Confidence limits	District 2 Buck harvest prev. fall
1959	119,890	±26.16%	4,980	99,040	±29.42%	5,060
1960	125,760	±29.36%	5,930	95,080	±26.62%	6,560
1961	96,440	±32.29%	3,230	79,890	±24.54%	3,110
1962	99,930	±31.89%	4,080	68,250	±21.95%	5,360
1963	100,560	±34.49%	4,870	85,640	±21.90%	4,190
1964	93,800	±37.57%	5,460	97,580	±22.94%	5,250
1965	90,390	±31.50%	6,760	84,280	±23.63%	7,640
1966	69,540	±24.86%	3,660	87,510	±28.09%	6,220
1967	47,370	±30.21%	3,970	70,180	±29.02%	5,090
1968	46,500	±25.30%	2,230	96,140	±25.62%	3,400
1969	42,040	±30.26%	2,920	56,680	±28.70%	6,080
	r = .6712*[2]			r = -.1171		

Table 62 (cont'd.)

Year of survey	District 3 Deer population	District 3 Confidence limits	District 3 Buck harvest prev. fall	District 4 Deer population	District 4 Confidence limits	District 4 Buck harvest prev. fall
1959	90,470	±29.02%	5,190	97,300	±50.97%	7,330
1960	76,650	±27.35%	4,950	94,820	±31.51%	6,000
1961	59,410	±29.08%	4,050	93,740	±34.67%	4,540
1962	63,510	±26.92%	3,480	86,540	±47.53%	4,340
1963	77,990	±35.75%	4,120	96,180	±42.41%	4,600
1964	74,140	±39.73%	4,180	82,070	±55.93%	4,820
1965	81,180	±33.82%	4,390	73,060	±41.56%	4,780
1966	71,930	±24.87%	2,960	62,070	±45.87%	4,370
1967	58,380	±26.70%	3,260	54,560	±39.66%	3,670
1968	63,600	±28.64%	3,100	57,060	±37.57%	2,550
1969	49,270	±31.67%	2,800	70,540	±56.11%	3,030
	r = .7938**			r = .7234**		

Table 62 (cont'd.)

	District 5			Old District 6		
Year of survey	Deer population	Confidence limits	Buck harvest prev. fall	Deer population	Confidence limits	Buck harvest prev. fall
1959	110,640	±28.62%	11,000	62,480	±29.61%	6,610
1960	79,290	±29.26%	10,560	62,710	±34.90%	6,090
1961	79,000	±34.27%	6,870	62,700	±45.41%	4,610
1962	68,790	±27.44%	8,100	56,270	±28.97%	6,210
1963	92,830	±44.18%	9,060	61,900	±41.08%	6,020
1964	101,120	±42.56%	9,100	76,540	±37.77%	7,550
1965	80,110	±28.04%	10,750			
1966	82,990	±30.20%	7,970			
1967	84,190	±31.64%	10,520			
1968	91,560	±40.29%	6,750			
1969	100,580	±34.39%	8,500			
	r = .2176			r = .5844		

	Old District 7			Old District 8		
1959	154,030	±25.36%	14,670	45,590	±30.66%	6,730
1960	128,700	±32.53%	13,150	55,020	±26.90%	5,970
1961	106,280	±29.70%	9,550	40,690	±40.29%	4,890
1962	116,010	±29.63%	10,620	41,730	±33.81%	6,020
1963	108,420	±32.32%	11,910	52,540	±27.29%	6,630
1964	132,000	±28.45%	14,980	60,450	±34.22%	8,810
	r = .8401*			r = .7713		

Table 62 (cont'd.)

	Old District 9					
Year of survey	Deer population	Confidence limits	Buck harvest prev. fall	Deer population	Confidence limits	Buck harvest prev. fall
1959	64,700	±32.92%	8,010			
1960	45,580	±29.10%	5,730			
1961	47,620	±52.16%	3,050			
1962	41,420	±30.84%	5,690			
1963	44,980	±24.07%	6,470			
1964	58,620	±25.44%	7,800			
	r = .6488					
	New District 6			New District 7		
1965	79,120	±43.36%	13,790	154,090	±33.95%	20,470
1966	51,690	±38.89%	8,320	109,000	±37.71%	12,300
1967	65,460	±31.80%	8,360	164,690	±29.20%	11,170
1968	80,080	±38.75%	8,680	180,480	±31.96%	14,550
1969	78,510	±38.96%	9,940	145,500	±32.73%	11,820
	r = .5238			r = .1991		

Table 62 (cont'd.)

Year of survey	New District 8					
	Deer population	Confidence limits	Buck harvest prev. fall	Deer population	Confidence limits	Buck harvest prev. fall
1965	68,920	±38.86%	11,230			
1966	41,310	±44.82%	8,760			
1967	44,590	±43.98%	6,910			
1968	48,700	±35.30%	8,510			
1969	61,820	±42.79%	7,490			
	r = .5714					
	Total Upper Peninsula			Total Northern Lower Peninsula		
1959	406,700	±17.16%	22,560	437,430	±13.66%	47,020
1960	392,310	±14.64%	23,440	371,310	±15.49%	41,500
1961	329,480	±15.77%	14,930	336,280	±17.51%	28,970
1962	318,230	±17.65%	17,260	324,220	±14.47%	36,640
1963	360,370	±17.55%	17,780	360,660	±17.33%	40,090
1964	347,590	±19.47%	19,710	428,740	±16.53%	48,240
1965	328,910	±16.36%	23,570	382,250	±18.76%	56,240
1966	291,050	±15.31%	17,210	284,990	±19.51%	37,350
1967	230,480	±15.62%	15,990	358,930	±17.56%	36,960
1968	263,290	±14.75%	11,280	400,830	±19.30%	38,490
1969	218,540	±21.76%	14,830	386,420	±18.58%	37,750
	r = .7296*			r = .5688		

[1]Population estimates are from pellet group surveys and are for the fall (pre deer season) previous to each survey.

[2]Linear correlation coefficients for relationship of deer populations with buck harvests.

* = significant at .05 level

** = significant at .01 level

Table 63

Deer Population Estimates and Antlered Buck Harvests for Game Districts[1]

Year	District 1 Pellet estimate spring	District 1 Buck kill following fall	District 2 Pellet estimate spring	District 2 Buck kill following fall	District 3 Pellet estimate spring	District 3 Buck kill following fall
1959	100,598	5,930	87,564	6,560	76,981	4,950
1960	94,494	3,230	66,801	3,110	65,147	4,050
1961	84,468	4,080	69,712	5,360	52,363	3,480
1962	83,786	4,870	52,977	4,190	52,555	4,120
1963	83,482	5,460	73,786	5,250	69,862	4,180
1964	75,264	6,760	82,852	7,640	62,028	4,390
1965	61,474	3,660	53,357	6,220	70,403	2,960
1966	51,385	3,970	66,803	5,090	59,169	3,260
1967	37,752	2,230	56,905	3,400	48,252	3,100
1968	39,043	2,920	84,220	6,080	55,655	2,800
1969	33,018	2,670	41,973	4,410	39,993	2,440
	r = .6730*		r = .6032*		r = .6595*	

Year	District 4		Total Upper Peninsula		District 5	
1959	76,972	6,000	342,115	23,440	86,255	10,560
1960	73,119	4,540	299,561	14,930	51,335	6,870
1961	81,984	4,340	288,527	17,260	64,234	8,100
1962	76,725	4,600	266,043	17,780	50,033	9,060
1963	80,684	4,820	307,814	19,710	69,534	9,100
1964	64,396	4,780	284,540	23,570	80,026	10,750
1965	50,149	4,370	235,383	17,210	56,351	7,970
1966	51,582	3,670	228,939	15,990	62,933	10,520
1967	38,446	2,550	181,355	11,280	61,152	6,750
1968	49,305	3,030	228,223	14,830	74,104	8,500
1969	59,632	3,020	174,616	12,540	79,815	7,880
	r = .7545**		r = .8048**		r = .5116	

Year	Old District 6		Old District 7		Old District 8	
1959	47,898	6,090	117,127	13,150	34,174	5,970
1960	45,608	4,610	96,707	9,550	41,814	4,890
1961	52,712	6,210	84,518	10,620	31,875	6,020
1962	48,409	6,020	94,123	11,910	33,152	6,630
1963	49,429	7,550	79,086	14,980	41,577	8,810
1964	59,584	9,340	96,593	17,380	45,102	10,480
	r = .8761*		r = -.0070		r = .6026	

Table 63 (cont'd.)

Year	Old District 9		New District 6		New District 7	
	Pellet estimate spring	Buck kill following fall	Pellet estimate spring	Buck kill following fall	Pellet estimate spring	Buck kill following fall
1959	52,143	5,730				
1960	30,024	3,050				
1961	41,038	5,690				
1962	33,319	6,470				
1963	31,115	7,800				
1964	43,964	8,570				
1965			53,410	8,320	111,303	12,300
1966			35,728	8,360	81,897	11,170
1967			55,052	8,680	140,796	14,550
1968			62,675	9,940	145,193	11,820
1969			59,042	10,160	117,204	14,020
	r = .2236		r = .7068		r = .5047	

Year	New District 8		Total Northern Lower Peninsula	
1959			337,597	41,500
1960			265,488	28,970
1961			274,377	36,640
1962			259,036	40,090
1963			270,741	48,240
1964			325,269	56,520
1965	49,612	8,760	270,676	37,350
1966	27,793	6,910	208,351	36,960
1967	31,834	8,510	288,834	38,490
1968	35,134	7,490	317,106	37,750
1969	48,595	9,830	304,656	41,890
	r = .8117*		r = .4307	

[1]Population estimates are from pellet group surveys and are for spring (pre-breeding) herds. Harvest estimates are for the subsequent fall season.

* = significant at .05 level

** = significant at .01 level

Table 64

Comparisons of Counts of Deer Pellet Groups with Fitted Negative Binomial Distributions for Northern Surveys in 1953

Groups per plot	Observed	Negative binomial fit
Lake County		
0	239	242.4
1	61	48.8
2	28	25.4
3-4	19	26.8
5+	29	35.9
Total	376	379.3[1]

$\overline{X} = 1.2580$ k = .2397

$\chi^2 = 6.9483$ for 2 degrees of freedom, $.25>P>.10$

Groups per plot	Observed	Negative binomial fit
Mio Ranger District, Huron National Forest		
0	143	147.4
1	74	58.8
2	25	35.9
3	27	24.4
4	20	17.5
5-6	19	22.5
7-9	19	17.3
10+	13	20.6
Total	340	344.4

$\overline{X} = 2.2265$ k = .4859

$\chi^2 = 11.4968$ for 5 degrees of freedom, $.05>P>.025$

Table 64 (cont'd.)

Groups per plot	Observed	Negative binomial fit
Tawas Ranger District, Huron National Forest		
0	229	231.0
1	84	78.4
2	44	44.8
3	26	29.0
4-5	37	34.1
6-8	23	23.5
9+	16	23.8
Total	459	464.6

$\overline{X} = 1.7233$ k = .4225

$\chi^2 = 3.5654$ for 4 degrees of freedom, $.50>P>.25$

Groups per plot	Observed	Negative binomial fit
Houghton Lake State Forest		
0	269	270.3
1	75	67.5
2	29	35.7
3-4	37	37.0
5+	40	44.8
Total	450	455.3

$\overline{X} = 1.2978$ k = .3095

$\chi^2 = 2.6112$ for 3 degrees of freedom, $.50>P>.25$

Pooled estimate of k = .3238, $\chi^2 = 22.2561$ for 3 degrees of freedom, $.005>P$.

[1]Fitted totals differ slightly from observed because of rounding error.

Table 65

Comparison of Optimum with Actual Allocation
for Deer Pellet Group Surveys in Game Districts, 1959 to 1964

Unit	Stratum	Actual allocation	Optimum allocation 1959	1960	1961	1962	1963	1964
District 1	I	8	12	8	8	11	5	5
	II	20	11	12	8	13	13	14
	III	12	15	18	19	15	21	16
	IV	19	22	22	25	21	21	25
	V	1	0	0	0	0	0	0
Total		60	60	60	60	60	60	60
	χ^2 [1]		7.00*	6.40*	12.53**	4.37	10.38**	5.51
District 2	I	23	13	17	14	16	15	17
	II	7	7	5	7	4	5	5
	III	4	2	11	1	7	2	3
	IV	25	37	27	37	33	38	34
	V	1	1	0	1	0	0	1
Total		60	60	60	60	60	60	60
	χ^2		10.89**	14.43***	11.31**	7.55*	9.89**	5.50
District 3	I	18	12	12	10	17	7	9
	II	7	14	12	12	8	12	10
	III	2	0	2	5	3	3	0
	IV	33	34	34	33	32	38	41
	V	0	0	0	0	0	0	0
Total		60	60	60	60	60	60	60
	χ^2		4.81*	4.81*	10.67**	.53	11.48***	6.55*

Table 65 (cont'd.)

Unit	Stratum	Actual allocation	Optimum allocation 1959	1960	1961	1962	1963	1964
District 4	I	7	2	8	3	2	4	3
	II	10	4	6	6	5	4	5
	III	15	7	11	12	7	5	12
	IV	27	47	33	38	45	46	40
	V	1	0	2	1	1	1	0
Total		60	60	60	60	60	60	60
	χ^2		24.33***	4.56	8.81*	21.91***	24.45***	10.53**
District 5	II	17	22	22	19	23	13	10
	III	20	16	17	14	19	7	15
	IV	23	22	21	27	18	40	35
Total		60	60	60	60	60	60	60
	χ^2		2.31	2.09	2.73	3.25	21.96***	10.39**
Old District 6	II	15	17	11	5	17	9	9
	III	18	20	11	9	12	11	9
	IV	11	13	20	13	13	26	16
	V	16	10	18	33	18	14	26
Total		60	60	60	60	60	60	60
	χ^2		3.10	11.40***	29.59***	2.88	25.82***	15.42***

Table 65 (cont'd.)

Unit	Stratum	Actual allocation	Optimum allocation 1959	1960	1961	1962	1963	1964
Old District 7	I	9	18	14	6	13	4	6
	II	12	11	14	21	13	19	18
	III	34	27	29	21	26	32	32
	IV	10	9	9	18	14	11	10
	V	1	1	0	0	0	0	0
Total		66	66	66	66	66	66	66
	χ^2		10.62**	4.21*	17.18***	4.56*	6.98**	4.21*
Old District 8	II	7	6	5	4	11	9	7
	III	17	17	16	14	19	18	13
	IV	18	22	27	32	16	27	16
	V	18	15	12	10	14	6	24
Total		60	60	60	60	60	60	60
	χ^2		1.53	7.13**	16.26***	3.63	13.13**	3.16
Old District 9	II	14	9	10	8	16	15	12
	III	21	17	16	6	20	16	22
	IV	23	16	23	18	17	25	26
	V	10	26	19	36	15	12	8
Total		68	68	68	68	68	68	68
	χ^2		30.28***	10.43**	81.97***	4.40	1.84	1.12

[1]Chi-square goodness of fit tests with n-2 degrees of freedom comparing actual (expected) with optimum allocation (observed).

* = .05>P>.01
** = .01>P>.001
*** = .001>P

Table 66

Comparison of Optimum with Actual Allocation
for Deer Pellet Group Surveys in Game Districts, 1965 to 1969

Unit	Stratum	Actual allocation	Optimum allocation 1965	1966	1967	1968	1969
District 1	I	6	12	9	12	6	11
	II	10	9	15	11	16	15
	III	21	21	14	11	21	10
	IV	21	18	22	26	17	24
	V	2	0	0	0	0	0
Total		60	60	60	60	60	60
	χ^2 [1]		7.19*	6.38*	11.25**	5.17	12.47**
District 2	I	22	19	23	17	22	24
	II	2	2	1	1	1	1
	III	6	8	4	14	9	15
	IV	28	31	31	28	28	20
	V	2	0	1	0	0	0
Total		60	60	60	60	60	60
	χ^2		.94	1.30	7.39**	.63	11.52***
District 3	I	5	2	5	10	4	16
	II	9	9	5	4	9	5
	III	10	9	11	10	9	13
	IV	34	40	39	36	38	26
	V	2	0	0	0	0	0
Total		60	60	60	60	60	60
	χ^2		2.34	.72	7.78	.41	29.66***
District 4	I	3	1	1	0	1	0
	II	10	14	16	13	17	8
	III	16	22	5	21	23	36
	IV	29	23	38	25	19	16
	V	2	0	0	1	0	0
Total		60	60	60	60	60	60
	χ^2		4.62*	10.37**	2.37	9.63**	34.18***
District 5	I	15	8	9	9	5	4
	II	18	20	25	18	22	16
	III	11	17	14	17	9	25
	IV	14	15	12	16	24	15
	V	2	0	0	0	0	0
Total		60	60	60	60	60	60
	χ^2		6.82*	6.94*	5.67	11.92**	26.17***

Table 66 (cont'd.)

Unit	Stratum	Actual allocation	Optimum allocation 1965	1966	1967	1968	1969
District 6	I	6	12	4	5	4	8
	II	6	3	6	7	4	3
	III	14	23	13	13	26	16
	IV	23	19	19	25	18	29
	V	11	3	18	10	8	4
Total		60	60	60	60	60	60
	χ^2		19.80***	5.89	.67	13.52**	8.47*
District 7	I	2	0	0	0	0	1
	II	22	14	22	18	15	22
	III	27	39	27	32	37	29
	IV	7	7	11	10	8	8
	V	2	0	0	0	0	0
Total		60	60	60	60	60	60
	χ^2		9.94**	.61	2.54	7.19**	.30
District 8	I	3	6	3	4	5	2
	II	12	27	6	10	14	8
	III	22	22	42	39	35	27
	IV	11	4	1	4	2	9
	V	12	1	8	3	4	14
Total		60	60	60	60	60	60
	χ^2		36.14***	31.01***	24.41***	21.45***	3.50

[1]Chi-square goodness of fit tests with n-2 degrees of freedom comparing actual (expected) with optimum allocation (observed).

* = .05>P>.01

** = .01>P>.001

*** = .001>P

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