

Annotated Bibliography of Methodologies to Census, Estimate, and Monitor the Size of White-Tailed Deer *Odocoileus virginianus* Populations

Allan F. O'Connell, Jr.

Linda Ilse

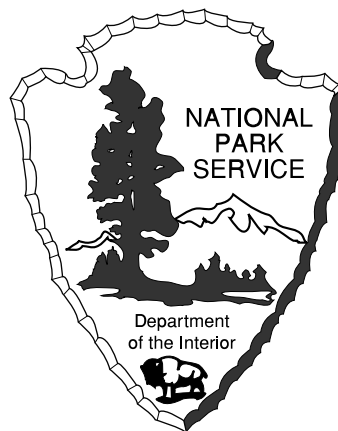
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John Zimmer

Technical Report NPS/BSO-RNR/NRTR/00-2

July 1999

**Department of the Interior
National Park Service
Boston Support Office**



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**Annotated Bibliography of Methodologies to Census, Estimate, and Monitor the
Size of White-Tailed Deer *Odocoileus virginianus* Populations**

by

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Preface

The large increase in white-tailed deer numbers over the past four decades (Porter 1991, 1996), particularly in the eastern United States, has resulted in an urgent need to determine the size of many deer populations. Toward that end, we gathered information on methods used to count and estimate deer population size. We also have provided an historical framework of how techniques have changed throughout this century. This document will not answer definitively the question of which technique is most appropriate for a specific situation; rather - citations describe the technique(s) in use, provide some pros and cons, and hopefully, guide the reader toward selecting a technique best suited for a particular situation. One must remember, however, that when evaluating the use of biological/ecological field activities there is often no substitute for trial and error.

For a general perspective, we developed a relatively short list of references on sampling techniques and estimating (biological) population size. For publications not included, we apologize, but in no way is this a reflection on the quality of work; we simply had to stop somewhere given the explosion of fish and wildlife information in recent years (Kemp 1992). We then focused our review on studies dealing only with white-tailed deer populations. We felt there was an adequate number of citations on white-tailed deer to provide a variety of options for nearly any situation. Although many of the census and monitoring techniques used on other cervid species are applicable to white-tailed deer and vis-à-vis, including citations conducted on other cervids would have resulted in a voluminous bibliography, and thus clouding our goal to focus on white-tails.

The citations in each section are listed in chronological order (earliest to most recent) and then alphabetically within each year by the first author's surname. For each citation, we have provided a short abstract and keywords. Two indices have been included: 1) a subject index - to facilitate a quick assessment of specific topics that may apply to local needs, and 2) an author index to ease locating a specific author. Most citations in this bibliography are publications in the disciplines of wildlife management, ecology, mammalogy, or zoology. Either in scientific journals or books, these documents typically can be obtained from libraries at academic institutions. A number of citations, however, have not been published and are considered gray literature ; thus, they may not be readily available. Therefore, to facilitate use of this bibliography, citations that are **not** part of a published scientific journal/book (including theses, dissertations, and agency technical reports), have been archived and are available from the following address: **NATIONAL PARK SERVICE, NATURAL SYSTEMS MANAGEMENT OFFICE, 1201 OAK RIDGE DRIVE, SUITE 350, FORT COLLINS, CO 80525, (970) 225-3585.**

We graciously thank Michael Coffey, Dr. Mary K. Foley, and Dr. H. B. Underwood for coordinating the funding process through the National Park Service white-tailed deer research initiative. Dr. Underwood is to be credited for his idea to prepare this bibliography. We thank also Dr. H. Randolph Perry of the Patuxent Wildlife Research Center in Maryland for orchestrating the final review, the Patuxent Library staff for their patience and knowledge - Lynda Garrett and Wanda Manning, and those reviewers that gave of their time to make this a much improved document. We hope that resource managers and natural resources, especially deer, everywhere will be better served by this document!

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Summary

White-tailed deer populations have increased in recent decades throughout much of the eastern United States, particularly in refuges, preserves, parks, and suburban landscapes. Management of these populations is an important issue with ecological, social, and cultural implications. Censusing or estimation of population size is fundamental to properly evaluating the status of deer relative to their local environment, and a key factor in developing a management plan. The methodologies described in this bibliography include references in the field of sampling techniques, enumerating and estimating biological population size, monitoring trends, and an extensive list of scientific literature in these fields specific to white-tailed deer. An historical account of techniques used to count and estimate the size of deer populations during the 20th century also has been provided.

White-tailed deer are widely distributed across North and Central America and have been studied in many different environments; thus, citations in this bibliography will assist resource managers and biologists in selecting a technique suitable for local conditions and a variety of project goals and objectives. Citations have been prepared in Procite format (version 4.03) with abstracts and keywords; indices for keywords and authors have been included to facilitate retrieval of information.

Introduction

Biological Populations

Estimating the size of animal populations has long been a focal point in ecology and wildlife and fishery management. Dating back to population estimates from mark-recapture experiments on fish in the 1880s and early 1900s (Peterson 1889 and Dahl 1917 in LeCren 1965) and later on waterfowl (Lincoln 1930), estimation of animal population abundance is now grounded in quantitative, statistical protocols (see Seber 1982 and Lancia et al. 1994 for detailed reviews) to insure validity of the data collected. Sophistication of current techniques and the wealth of scientific literature available create a labor-intensive task for selecting an appropriate method applicable to local conditions, species under study, or management objectives and constraints (i.e., economics). Nevertheless, the question of numbers in a population and changing trends (increasing or decreasing) of a population is fundamental to all other biological or ecological work; the importance of effectively and efficiently gathering these data cannot be understated.

White-tailed Deer

An enormous amount of scientific information is available on white-tailed deer. One of the most studied big game animals in North America (Poole 1984), white-tailed deer are native to the eastern United States and Canada, and have a long history with native Americans and European settlers to North America. Early in this century, the white-tailed deer population in North America was nearly decimated due to overharvest (Downing 1987). Passage of the Lacey Act and similar game laws in the early 1900's, coupled with intensive management throughout the first half of this century, helped to increase white-tailed deer population size. Ironically, in many parks, preserves, and now even suburban landscapes, white-tailed deer numbers have increased (Porter 1991, 1996) to where they are often considered a nuisance, public safety issue (i.e., vehicular accidents) or both. High-density deer populations have been termed *overabundant* (McShea et al. 1997), and have spawned renewed interest in deer management, albeit from a perspective often different from the state or provincial fish and game agency managing deer populations for maximum sustained yield.

Trends in Deer Monitoring

1930s through 1940s

The main focus of deer monitoring studies during the 1930s and 1940s was to develop and describe census techniques. The foundation for many of these many methods was worked out during this period and included drive counts, pellet-group counts, and estimates using harvest and sex ratio data. The first description of aerial surveys to estimate deer populations occurred in 1942 and 1944. Cruise censuses were used and refined to include flushing and cover distances. Two major modifications of the cruise census were made in 1943 and 1949, one based on timber cruising techniques, the second incorporated snow tracking into the survey. Several studies reviewed and critiqued census methods, and comparisons were made to determine relative efficiency.

1950s

During this period cruise census techniques were abandoned in favor of more quantitative techniques. In the early portion of the decade, estimates using hunter kill data and age/sex ratios became prevalent. Several models were created to predict population density, age/sex composition, and life histories of individual deer herds. The first citations of the Lincoln Index as an estimator were reported in the mid 1950s. Aerial surveys, using both fixed wing and helicopters, became more popular as a survey technique. Converting track counts from a basic index to a viable census method was reported in the early 1950's. Dead deer surveys based on winter kill and vehicle related mortality were also documented. In the latter part of the decade, several studies again compared and evaluated

census methods. The accuracy of pellet-group counts was questioned, the usefulness of spotlight surveys was examined, and drive counts were compared against track counts.

1960s

Critical examination of census techniques became the focus of studies in the 1960s. Field methods associated with track counts and deer drives were again critiqued, and the applicability of certain methods to different habitats and weather conditions was assessed. Spotlight surveys and line transect censuses were also evaluated. Pellet-group counts received the most attention during the decade, with nine separate studies based on this method. Factors such as pellet deterioration rates, sources of estimate and observer error, and comparison of plot shape and size were all tested within the context of different field conditions. Many projects compared and contrasted different census techniques on enclosed herds in an attempt to further define the most effective estimator for a particular situation. The first use of infrared scanning for population monitoring purposes was reported in 1968.

1970s

The evaluation and refinement of census techniques continued into the 1970s, as several studies examined underlying principles. Biases associated with aerial surveys, problems relating to assumptions, improving estimates from inaccurate censuses, accuracy of age/sex ratio counts, and methods of improving dead deer and transect counts were addressed in individual studies. Thermal infrared imagery developed into a major census technique and field methods and equipment used in the process were detailed in 1972. Remote sensing was compared to more traditional techniques in a 1973 thesis, and the advantages, associated biases, and relative costs of remote sensing were discussed in 1977.

New advances also were made in track and pellet-group surveys, including the advent of a plotless method of pellet-group counts as well as a system of combining track and pellet-group counts to give a more reliable estimate. A few studies dealt used census techniques to model populations. A new method, the deer trail survey, was presented in 1976, and exhaustive comparison of twelve transect survey methods was published in 1975. Spotlight surveys began to gain more attention, with evaluation studies in the late 1970s.

1980s

In the 1980s, studies continue to use a variety of census methods, favoring no single technique. Projects begin to become separated into geographic regions, with the majority of work being done in the southern states. Traditional methods were adapted and specialized for use in particular areas. Specific studies were completed on pellet-group counts in the Southeast, spotlight surveys in a number of states, and aerial surveys in Maryland and Texas. Spotlight surveys became the focus of many studies throughout the decade, whereas the use of remote sensing as a census method declined. Pellet-group and track counts were compared once again, and there was an increase in estimation of populations using harvest data. A new census technique using scent stations was developed but deemed ineffective. Refinements were made for both change-in-ratio estimators and line transect surveys. Sampling criteria were established for aerial surveys, with several studies concentrating on the use of helicopters, especially throughout the southern United States.

1990s

The 1990s have shown a general decrease in census methodology studies and an increase in population modeling through the use of capture-recapture data. Statistical analysis of survey data and the associated interpretation (e.g., pellet-group counts) has been stressed. Spotlight surveys have continued to receive attention, with in-depth assessments and refinements conducted between 1992 and 94. Further modifications were made in track, drive, and aerial censuses. Two separate studies, published in 1995 and 96, evaluated infrared thermography systems as a survey technique. Common throughout the relatively short history of deer monitoring, comparisons between methods continue, as drive censuses were compared to pellet-group and track counts.

Technique Suitability

The success of the white-tailed deer has, in large part, been attributed to the ability of the species to adapt to a variety of landscapes and conditions (Smith and Coggin 1984). This trait has also resulted in the development of a variety of population estimation and monitoring techniques, including some developed for other species and later adapted for deer. In attempting to select the most appropriate technique for a situation, goals and objectives for a project should be articulated. For example, a technique used to gather information in a detailed research project might be quite different from a management-oriented project. Physical characteristics like topography, vegetation, and climatic conditions also can have a great influence on technique selection (e.g., aerial versus ground counts).

Before proceeding with fieldwork, reference(s) of interest should be obtained and reviewed to thoroughly evaluate prospective techniques. A worthwhile, yet often neglected, approach is to conduct a pilot study that will provide insight on the applicability of techniques in a particular situation (Ratti and Garton 1994). Evaluating a technique prior to a full-scale investigation can save a great deal of time, money, and effort.

Literature Cited

- Downing, R. L. 1987. Success story: white-tailed deer. Pages 45-57 *in* Kallman, H., C. P. Agee, W. R. Goforth, and J. P. Linduska, eds. *Restoring America's wildlife 1937-1987*. U. S. Department of the Interior, U.S. Fish and Wildlife Service. U. S. Government Printing Office, Washington, DC.
- Kemp, H. T. 1992. Tapping into the fish and wildlife information explosion: commercial on-line data sources. U. S. Department of the Interior, U. S. Fish and Wildlife Service, Fish and Wildlife Leaflet No. 16. Washington, DC. 5pp.
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- LeCren, E. D. 1965. A note on the history of mark-recapture population experiments. *Journal of Animal Ecology*. 34:453-454.
- Lincoln, F. C. 1930. Calculating waterfowl abundance on the basis of waterfowl returns. U. S. Department of Agriculture Circular, No. 118. 4pp.
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- Poole, D. A. 1984. Forward. Page v *in* Halls, L. K., ed. *White-tailed deer ecology and management*. Stackpole Books, Harrisburg, PA.
- Porter, W. F. 1991. White-tailed deer in eastern ecosystems: Implications for management and research in national parks. - U. S. Department of the Interior, National Park Service Technical Report NRSUNY/NRR-91/05. Washington, DC. 57pp.
- Porter, W. F. 1996. Management of overabundant species in protected areas: the white-tailed deer as a case example. Pages 223-248 *in* Wright, R. G., ed. *National parks and protected areas: their role in environmental protection*. Blackwell Science Publishers, Cambridge, MA.
- Ratti, J. T., and E. O. Garton. 1994. Research and experimental design. Pages 1-23 *in* Bookhout, T. A., ed. *Research and management techniques for wildlife and habitats*. The Wildlife Society, Bethesda, MD.
- Seber, G. A. F. 1982. *The estimation of animal abundance and related parameters*. Macmillan Publ. Co., Inc. New York, NY. 653pp.
- Smith, R. L., and J. L. Coggin. 1984. Pages 571-600 *in* Halls, L. K., ed. *White-tailed deer ecology and management*. Stackpole Books, Harrisburg, PA.

Annotated Citations

Biological Populations

1. Hosely, N. W., Moss, A. E., Dalke, P. D., Bradder, W. E., and Ashman, R. I. 1936. **Forest wildlife census methods applicable to New England conditions. *Journal of Forestry* 34:467-471.**
Abstract: Methods and specific techniques used to census deer, grouse, snowshoe hare, and woodcock in New England were provided. Drive lines, yard area tracks, and snow-tracking were methods considered successful in enumerating deer.
Keywords: *drive census/ New England/ yard area tracks/ snow-tracking*

2. **Dice, L. R. 1941. Methods for estimating populations of mammals. *Journal of Wildlife Management* 5:398-407.**
Abstract: Methods used to estimate mammalian abundance were reviewed. A basic description of the techniques (complete counts, aerial counts, mark-release estimates, track counts, ratio estimators, pellet counts, line transects) were provided, and disadvantages or associated problems were discussed.
Keywords: *abundance estimation/ mammals/ techniques*

3. **Saugstad, S. 1942. Aerial census of big game in North Dakota. *Transactions of the North American Wildlife Conference* 7:343-356.**
Abstract: Use of aerial surveys to census big game (deer, elk, antelope) was adopted in North Dakota because drive census methods were costly, and use of pellet-groups was unsuited to much of the area. Test flights were used to determine technique, man-power, and equipment required for greatest accuracy. A light plane flown at 136.7-144.8 km/h (85-90 mph) at an altitude of 114.4 m (375 ft) allowed accurate scanning of 201.3 m (660 ft) wide strips. An experienced pilot and 2 observers were considered essential. Optimal time for deer censusing efforts in North Dakota was determined to be any period from late October-May. Most effective times of day for surveys were 1-2 hours before sunset and/or 1-2 hours after sunrise.
Keywords: *aerial survey/ big game / equipment/ North Dakota/ techniques*

4. **Morse, M. A. 1946. Censusing big game from the air. *Conservation Volunteer* 9 (52):29-33.**
Abstract: Use of aerial surveys was proposed as a viable alternative to other census methods in Minnesota. Drive censuses and roadside surveys were critiqued and a detailed account of the advantages and methodology of aerial surveys was provided. Limitations such as season, weather, and dense cover were addressed. Results from preliminary survey flights were presented for deer, moose, and caribou.
Keywords: *Minnesota/ aerial survey/ drive census/ roadside census*

5. **Hayne, D. W. 1949. An examination of the strip census for estimating animal populations. *Journal of Wildlife Management* 13:145-157.**
Abstract: A critique of the King strip census method was conducted, including descriptions of the methodology and inherent assumptions. Particularly important was the assumption that the 'average of the flushing distances observed by the investigator is a good estimate of the true average of all flushing distances throughout the population being studied' was violated in many studies. A formula to correct this systematic error was provided. Other possible sources of error and suggestions for making corrections were addressed. An appendix explaining the mathematical calculations was included.
Keywords: *assumptions/ flushing distance/ formula/ strip census*

6. **Blomquist, W. 1951. Censusing techniques. *North Dakota Outdoors* 13:6-15.**
Abstract: General census techniques were discussed, with one paragraph devoted to deer population estimation. Aerial survey was the main method, as transects were flown in both wooded and prairie habitats. Some details of the methodology were discussed, but not in depth.
Keywords: census/ aerial survey/ North Dakota
7. **Banfield, A. W. F., Flock, D. R., Kelsall, J. P., and Loughrey, A. G. 1955. An aerial survey technique for northern big game. *Transactions of the North American Wildlife Conference* 20:519-532.**
Abstract: Recommendations for conducting aerial surveys to census big game in northern regions were discussed. Consideration was given to aircraft, flight patterns, transect width, segregated counts, use of aerial photographs, and data analysis. Suggestions relevant to caribou, walrus, musk-oxen, wolves, moose, and mountain goats were included, but most suggestions were applicable to a variety of species including white-tailed deer.
Keywords: aerial survey/ aircraft/ statistical analysis/ flight pattern/ transect/ Canada
8. **Hanson, W. R. 1963. Calculation of productivity, survival, and abundance of selected vertebrates from sex and age ratios. *Wildlife Monographs* #9. 66 pp.**
Abstract: Methods for estimating productivity, survival, and abundance using sex and age ratios were evaluated. Interactions of sex ratios, unequal survival and productivity, and calculation of sex ratios from age ratios were also addressed. Mathematical calculations rather than actual data collection were the focus of discussion; conditions and assumptions relevant to calculations were also included.
Keywords: abundance estimation/ age ratio/ productivity/ sex ratio/ survival
9. **Rupp, R. S. 1966. Generalized equation for the ratio method of estimating population abundance. *Journal of Wildlife Management* 30:523-526.**
Abstract: A simplified explanation of the ratio method to estimate population abundance was reviewed. Equations and derivations were presented with examples to demonstrate usefulness.
Keywords: equation/ population dynamics/ ratio
10. **Bergerud, A. T. 1968. Numbers and densities. Pages 21-42 in F.B. Golley and H.K. Buechner, eds. A practical guide to the study of the productivity of large herbivores. *International Biological Programme Handbook, No. 7. Blackwell Science Publishers. Oxford, England.***
Abstract: This chapter on population estimation included discussions of minimum standards, distribution patterns, sampling techniques, variance, direct counts, transect counts, ground counts, change-in-ratio, and indices. Descriptions and applicability for specific techniques were provided. Methods of reducing variance in estimates included (1) stratification of the population, (2) sampling during periods of homogeneous dispersion and (3) increasing sampling units.
Keywords: census/ techniques/ ungulates/ variance
11. **Eberhardt, L. L. 1968. A preliminary appraisal of line transects. *Journal of Wildlife Management* 32:82-88.**
Abstract: Biases associated with line transects were discussed. Models of line transect surveys were classified according to detectability based on behavior/response of both animal and observer. Sighting distance and right angle distance for individual observations were recommended.
Keywords: assumptions/ bias/ behavior/ flushing distance/ right angle distance

12. **Neff, D. J. 1968. The pellet-group count technique for big game trend, census, and distribution: a review. *Journal of Wildlife Management* 32:597-614.**
Abstract: Factors that affected the pellet-group census method were examined: (1) size and shape of sample plot, (2) distribution of sample units, (3) sampling intensity, (4) defecation rate, and (5) observer bias. Observer bias was the greatest source of error. However, period of deposition, map acreage vs. ground acreage, deterioration/loss of pellet-groups, and species identification of pellet-group were cited as sources of error. A review of experimental evaluation of pellet-group counts, including comparison with known deer populations and comparison with other census techniques was provided.
Keywords: bias/ error/ observer/ pellet-group
13. **Johnson, N. L., and Smith, H., Jr., eds. 1969. New developments in survey sampling. John Wiley & Sons, Inc. New York, NY. 732 pp.**
Abstract: This publication covers all aspects of survey sampling. Topics like mark-recapture, ratio and regression estimators, accuracy and precision, inference, randomness, and stratification were discussed. For those interested in the fundamentals of sampling populations, this document provided a variety of presentations from leading scientists in the field.
Keywords: survey sampling/ theory/ sampling errors
14. **Jolly, G. M. 1969. Sampling methods for aerial censuses of wildlife populations. *East African Agriculture and Forestry Journal (Special Issue)* 34:46-49.**
Abstract: Methods of "enumerating animal populations from the air" that included direct observation and photography were discussed. Various sample strategies (e.g., transects, sample versus census) were examined, including associated statistics.
Keywords: aerial census/ direct observation/ ratio method/ stratification/ photography/ transect
15. **Jolly, G. M. 1969. The treatment of errors in aerial counts of wildlife populations. *East African Agriculture and Forestry Journal (Special Issue)* 34:50-56.**
Abstract: Bias of numerical estimates was placed into one of three categories: consistent errors in counting, faulty sampling methods, and methods of obtaining the final estimate from sample counts. The effects of error were discussed and the appropriate statistical calculations were provided.
Keywords: aerial count/ bias/ counting errors/ observer
16. **Caughley, G. 1970. Eruption of ungulate populations, with emphasis on Himalayan Thar in New Zealand. *Ecology* 51:53-72.**
Abstract: The process and causes underlying eruptions in ungulate populations were reviewed from two perspectives, eruptions following liberation (change in the environment [habitat or food] and causes of eruptive liberation. Although much of the available scientific information on various ungulate species was reviewed, considerable detail focused on a population of Himalayan Thar in New Zealand. Using Thar as a model, evidence was found supporting population increases linked to changes in habitat or food.
Keywords: eruptions/ Himalayan Thar/ population dynamics/ ungulates/ New Zealand
17. **Lewis, J. C. 1970. Wildlife census methods: a resume. *Journal of Wildlife Diseases* 6:356-364.**
Abstract: An overview of wildlife census problems, schemes, and techniques was provided. Basic census methods discussed included direct counts, methods dependent on animal signs and related objects, mark-recapture methods, change-in-population and rate of capture methods, and harvest evaluation. Techniques for specific animals included bats, carnivores, miscellaneous small mammals, birds, and deer. Costs of the basic census and selection of the most appropriate technique were addressed.
Keywords: census/ techniques/ direct counts/ harvest evaluation/ change-in-population/ rate of capture/ economic costs/ mammals / birds

18. **Manly, B. F. J. 1970. A simulation study of animal population estimation using the capture-recapture method. *Journal of Applied Ecology* 7:13-39.**
Abstract: The Fisher and Ford, Jolly, and Manly and Parr capture-recapture methods of population analysis were evaluated using computer simulations. Results indicated the Fisher and Ford method was most appropriate when mortality rates were near constant and not age-dependent. The method was particularly useful with small sample sizes. The Jolly method was deemed less sensitive to age-dependent mortality rates than Fisher and Ford, but high infant mortality could result in biases. The Manly and Parr method was more sensitive to sample size than the former 2 methods, and use was recommended with large sample size and age-dependent mortality rates. Attention was given to assumptions inherent in each method.
Keywords: assumptions/ mark-recapture/ mortality rate/ sample size/ Jolly / Fisher and Ford / Manly and Parr
19. **Caughley, G., and Goddard, J. 1972. Improving estimates from inaccurate censuses. *Journal of Wildlife Management* 36:135-140.**
Abstract: A method of calculating more reliable estimates of abundance from negatively biased data was presented. Means and variances from sets of counts at 2 levels of survey efficiency were incorporated into simultaneous equations to derive the improved estimate.
Keywords: bias/ observability/ simultaneous equations
20. **Caughley, G. 1974. Bias in aerial survey. *Journal of Wildlife Management* 38:921-923.**
Abstract: Effects of strip width, altitude, and speed on observability in aerial surveys were the focal points of discussion. Ameliorating biases by refining techniques and by incorporating correction factors was discussed. A simple method was suggested for estimating bias.
Keywords: altitude/ bias/ observability/ speed/ strip census
21. **Caughley, G. 1974. Interpretation of age ratios. *Journal of Wildlife Management* 38:557-562.**
Abstract: Computer simulations were used to assess efficacy of age ratios in reflecting population dynamics. Age ratios, when used alone, revealed little about population dynamics and were ineffective in estimating abundance or density.
Keywords: age ratio/ population dynamics/ rate of increase
22. **Pendergast, G., Horstman, L., and Dorey, L. R. 1974. Population surveys of ungulates. *Biological Report Series, Volume 25. Canadian Arctic Gas Study Limited and Alaskan Arctic Gas Study Company. Calgary, Alberta. 47 pp.***
Abstract: This study was conducted in an attempt to assess potential effects of construction on several species of ungulates, including white-tailed deer. Aerial surveys were flown along a pipeline route from the Northwest Territories south into Alberta. Transects were split so that half were along stream routes and half were in uplands. White-tailed deer were sparse throughout the study area, and only one was sighted over the entire length of all transects. Typical deer habitat was described.
Keywords: Northwest Territories/ Alberta/ aerial survey/ moose/ mule deer/ caribou/ bighorn sheep/ elk/ line transect sampling/ mammals
23. **Anderson, D. R., Laake, J. L., Cain, B. R., and Burnham, K. P. 1976. Guidelines for line-transect sampling of biological populations. *Journal of Wildlife Management* 43:70-78.**
Abstract: A clear and thorough description of line-transect sampling for population estimation was provided. Definitions, assumptions, and concepts are provided. Applications to immotile and motile populations were also addressed. Field procedures were emphasized and include detailed descriptions of measurements and methods of searching, survey design, and recommendations. Six figures clearly illustrate several survey designs.
Keywords: assumptions/ concepts/ data collection/ line transect sampling/ survey design

24. **Dzieciolowski, R. 1976. Estimating ungulate numbers in a forest by track counts. *Acta Theriologica* 21:217-222.**
Abstract: Drives and track counts were evaluated as census techniques for roe deer, red deer, and wild boars. Track counts were more effective in censusing roe deer and wild boar than for red deer. A better understanding of spatial distribution of animals was recommended as a requisite of effectively using the track count census method.
Keywords: forest/ Poland/ track count/ ungulates
25. **Norton-Griffiths, M. 1976. Further aspects of bias in aerial census of large mammals. *Journal of Wildlife Management* 40:368-371.**
Abstract: Possible psychological sources of negative observer bias in aerial censusing were examined using multiple regression. Fatigue was the most apparent source of observer error, followed by time of day that the census was conducted. Boredom was cited as another source of error, albeit less apparent in this study due to the short transects. Investigators recommended that these factors be considered when planning aerial censuses.
Keywords: aerial survey/ observer/ bias/ psychological effects
26. **Caughley, G. 1977. Analysis of vertebrate populations. John Wiley & Sons, Inc. New York, NY. 234 pp.**
Abstract: The book includes all aspects of population analyses, but 2 chapters were devoted to censusing techniques. In chapter 4, 3 types of abundance measurements: (1) number of animals in a population, (2) absolute density (animals/unit area), and (3) relative density (density of 1 population relative to another) were discussed. A flow chart and description were provided to assist in selecting the most appropriate technique. A separate chapter was devoted entirely to mark-recapture techniques of censusing including assumptions, variations, and interpretation of results.
Keywords: abundance estimation/ density/ mark-recapture/ population dynamics
27. **Eberhardt, L. L. 1978. Assessing variability in population studies. *Journal of Wildlife Management* 42:207-238.**
Abstract: The question of sufficient sample size in population studies was addressed. Sampling and experimental design, mathematical models, empirical models and indices, and classification of methods were defined and discussed. Methods to estimate sample size for the various techniques and study designs were provided.
Keywords: experimental design/ mathematical models/ population dynamics/ sample size
28. **Eberhardt, L. L. 1978. Transect methods for population studies. *Journal of Wildlife Management* 42:1-31.**
Abstract: Three transect methods (line-intercept, line transect, and strip transect) were described and classified. Suggestions regarding sample design were provided. An appendix included formulas associated with density estimates for line intercepts, variable-distance line transects, and strip transects.
Keywords: formula/ line transect sampling/ line-intercept sampling/ sample design/ strip transect sampling
29. **Magnusson, W. E., Caughley, G., and Grigg, G. C. 1978. A double survey estimate of population size from incomplete counts. *Journal of Wildlife Management* 42:174-176.**
Abstract: This article discusses the use of two separate counts (incomplete) to estimate population size. The technique is contrasted with survey estimates that require many counts. Equations were provided that detail this technique and how the mathematics of the Peterson method can be adapted for use with incomplete counts.
Keywords: population size estimation/ incomplete counts/ double survey

30. **Otis, D. L., Burnham, K. P., White, G. C., and Anderson, D. R. 1978. Statistical inference from capture data on closed animal populations. Wildlife Monographs #62. 135 pp.**
Abstract: Several models incorporating capture-recapture data on closed populations and variability in capture probabilities were analyzed and discussed. Simulations and real data sets complete with computer output (CAPTURE) and statistical theory were included. Appendices were provided that detail the statistics used for each model.
Keywords: closed population/ statistical theory/ capture probabilities/ abundance estimation
31. **Burnham, K. P., and Overton, W. S. 1979. Robust estimation of population size when capture probabilities vary among animals. Ecology 60:927-936.**
Abstract: A model for multiple recapture in closed populations when capture probabilities vary among individuals (but remain constant over time) was presented. A non-parametric estimation procedure was provided for estimating population size that was based on the linear combination of capture frequencies. Using theory and a simulation study, the estimator was shown to be robust to moderate variations in capture probabilities common in live-trapping studies.
Keywords: capture-recapture/ jackknife estimator/ population size estimation/ robust estimation/ simulation/ variable capture probabilities
32. **Burnham, K. P., Anderson, D. R., and Laake, J. L. 1980. Estimation of density from line transect sampling of biological populations. Wildlife Monographs #72. 202 pp.**
Abstract: This work provides both theory and practical advice on line-transect sampling of biological populations and has long been considered the seminal work on this topic. Divided into 5 parts, one section includes a guide for readers depending on the amount of statistical and quantitative training in an individual's background. Some amount of experience with statistics is recommended. The fundamental features of line-transect sampling were reviewed including: angles, truncated data, mobile populations, clustering and more. Various estimators were reviewed including the Fourier series and Hayne (general and modified). The computer program TRANSECT was introduced.
Keywords: line-transect sampling/ TRANSECT (computer software)
33. **Keiper, R. R., and Hunter, N. B. 1982. Population characteristics, habitat utilization, and feeding habits of the feral ponies, sika deer, and white-tailed deer within Assateague Island National Seashore. Research/Resources Management Report, MAR-4. National Park Service, Mid-Atlantic Region. Philadelphia, PA. 44 pp.**
Abstract: White-tailed and Sika deer populations within Assateague Island National Seashore were estimated using pellet-group counts. Plots measuring 10 m² (107.64 ft²) were established at 100 m (328.1 ft) intervals along 10 randomly established transects. Each plot was surveyed three times over a 14 day period in June. Population estimates based on this study were not considered reliable due to small sample sizes and a limited sampling period.
Keywords: Maryland/ Virginia/ pellet-group / Sika deer
34. **Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. Second edition. Macmillian Publishing Co., Inc. New York, NY. 653 pp.**
Abstract: This book addressed all aspects of census methodology. Topics included general discussions, density estimates, single mark-release, multiple mark-releases during and before sampling periods, catch-effort, and change-in-ratio methods. Each of the techniques was subdivided to address specifics of open and closed populations. Assumptions were thoroughly discussed and a comparison of the methods was also provided.
Keywords: census/ closed population/ direct methods/ indirect methods/ open population/ catch-effort/ change-in-ratio

35. **White, G. C., Anderson, D. R., Burnham, K. P., and Otis, D. L. 1982. Capture-recapture and removal methods from sampling closed populations. LA-8787-NERP. Los Alamos National Laboratory. Los Alamos, New Mexico. 235 pp.**
Abstract: Considered a primer and companion document to the more "theoretical" monograph (Otis et al. 1978, see citation #31 in this section), all aspects of sampling closed populations were reviewed, including the inherent assumptions. The intent of this work was to allow biologists to apply capture-recapture methods to real situations. A manual for the program CAPTURE was provided.
Keywords: *closed population/ capture-recapture/ removal/ sampling theory*
36. **Burnham, K. P., and Anderson, D. R. 1984. The need for distance data in transect counts. Journal of Wildlife Management 48:1248-1254.**
Abstract: Strip and line transect sampling methods for estimating density of biological populations were compared. Biases inherent in both methods were discussed. In addition, methods for using incomplete counts and general approaches to the techniques were included. The necessity of recording perpendicular distance data was emphasized and explained.
Keywords: *bias/ incomplete counts/ line transect sampling/ methods/ perpendicular distance/ strip transect sampling*
37. **Rollins, D., Bryant, F. C., and Montandon, R. 1984. Fecal pH and defecation rates of eight ruminants fed known diets. Journal of Wildlife Management 48:807-813.**
Abstract: Fecal pH and defecation rates were examined to determine the viability of using these characteristics to differentiate pellet-groups from sympatric populations of eight species of ruminants. Using fecal pH, pellet groups of blackbuck antelope, fallow and white-tailed deer were distinguishable from sheep, goats, sika deer and aoudad, but identification between the first three species and the latter four species was not possible. Only axis deer exhibited unique fecal pH values. Defecation rates were not unique to individual species. In addition, it was determined that a defecation rate of 17-20 times/day for white-tailed deer was more reasonable than the commonly accepted rate of 12-13 times/day.
Keywords: *defecation rate/ fecal pH/ pellet group/ sympatric species*
38. **Rowland, M. M., White, G. C., and Karlen, E. M. 1984. Use of pellet-group plots to measure trends in deer and elk populations. Wildlife Society Bulletin 12:147-155.**
Abstract: Pellet-group counts were used to examine population trends of mule deer and elk from 1976-1981 near Los Alamos, New Mexico. Attention was given to trends in pellet distribution, habitat use, and potential biases. Deer pellet-groups were clumped in distribution. Weather conditions and fire did not appear to affect pellet-group counts.
Keywords: *elk/ habitat/ New Mexico/ mule deer/ pellet-group / population dynamics*
39. **Stokes, S. L. 1984. The Jolly-Seber method applied to age-stratified populations. Journal of Wildlife Management 48:1053-1059.**
Abstract: Minimum likelihood estimators for population size and survival rates for young and adult age classes and their variances were presented and explained. The estimators allowed for categorizing population size estimates for young and adults if more than one sampling period per year was conducted.
Keywords: *age ratio/ Jolly-Seber/ minimum likelihood estimators*

40. **Burnham, K. P., Anderson, D. R., and Laake, J. L. 1985. Efficiency and bias in strip and line transect data. *Journal of Wildlife Management* 49:1012-1018.**
Abstract: Bias and efficiency were compared for the strip and line transect methods of population estimation. Use of the line transect method resulted in smaller mean square errors. Additional advantages associated with this method included: (1) relaxation of assumptions regarding detection function; (2) lack of positive correlation between bias and transect width; and (3) all objects detected could be used in analyses.
Keywords: assumptions/ bias/ efficiency/ line transect sampling/ mean square error/ strip transect sampling
41. **Gates, C. E., Evans, W., Gober, D. R., Guthery, F. S., and Grant, W. E. 1985. Line transect estimation of animal densities from large data sets. Pages 37-50 in S. L. Beasom and S. F. Roberson, eds. *Game Harvest Management. Caesar Kleberg Wildlife Research Institute. Kingsville, TX.***
Abstract: Statistical properties associated with the line transect estimation of animal abundance were examined using large data sets from 3 regions in Texas. Attention was given to the following properties: (1) problem of heaping of distance observations; (2) effects of grouping right angle distances; (3) use of number of sightings vs. number of animals; and (4) effects of sample size of goodness-of-fit data to parametric distribution.
Keywords: line transect sampling/ statistical properties/ Texas
42. **Tzilkowski, W. M., and Brown, C. L. 1985. Calibration of indices to sika and white-tailed deer abundance on Assateague Island National Seashore. *Research/Resources Management Report, MAR-14. National Park Service, Mid-Atlantic Region. Philadelphia, PA. 45 pp.***
Abstract: The size of sika and white-tailed deer populations on Assateague Island National Seashore (VA & MD) was estimated by species, age, and sex. Spotlight counts were conducted using 1 light, 1 driver, and 1 observer during a 30-day pre-harvest survey (Oct 5-Nov 8, 1984) and during a 30-day post-harvest survey (Dec 13, 1984-Jan 12, 1985). All surveys were conducted approximately 1 hour after sunset. Estimates of abundance were calculated using calibrated change-in-ratio (CIR), index and control, and selective removal. Assumptions were the same for all techniques. Estimates by index and control were invalidated due to violation of assumptions regarding conspicuousness and dispersion. The selective removal technique provided an estimate, but with no measure of precision. Calibration of CIR provided both a reasonable point estimate and an interval of precision. Formulae for performing calculations and the results using each of the 3 techniques were provided.
Keywords: Assateague Island National Seashore/ assumptions/ change-in-ratio/ index/ control/ selective removal/ sika deer/ spotlight census
43. **Harris, R. B. 1986. Reliability of trend lines obtained from variable counts. *Journal of Wildlife Management* 50:165-171.**
Abstract: Population estimates were analyzed in terms of standard error and recommendations were made to improve precision. The investigation was conducted using an analytical procedure that requires assumptions likely to be violated in field situations. The main recommendation made was to perform multiple counts each year to establish population trends within a short time span.
Keywords: trends/ standard error/ precision/ multiple observations
44. **Pollock, K. H., and Kendall, W. H. 1987. Visibility bias in aerial surveys: a review of estimation procedures. *Journal of Wildlife Management* 51:502-510.**
Abstract: Various methods of estimating visibility bias including comparison with ground counts, using marked animals, mapping with multiple observers, line transect sampling, and multiple counts were discussed. Models were presented for each technique as well as the respective assumptions.
Keywords: aerial survey/ visibility/ bias

45. **Chao, A. 1988. Estimating animal abundance with capture frequency data. *Journal of Wildlife Management* 52:295-300.**
Abstract: A method was presented for estimating abundance when animals exhibit different but constant probabilities of capture. The method, a moment estimator, was compared to the jackknife estimator. Generally, the jackknife estimator was superior when many individuals were captured more than 2 times, but the moment estimator was superior when individuals were captured twice or less.
Keywords: mark-recapture/ jackknife estimator/ moment estimator
46. **Kie, J. G. 1988. Performance in wild ungulates: measuring population density and condition of individuals. PSW-106. U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station. Berkeley, CA. 17 pp.**
Abstract: A review of the dominant literature and techniques for assessing population size and condition was provided. Census methods were divided into direct techniques (drive counts, aerial counts, transect counts, spotlight counts, remote sensing) and indirect techniques (mark-recapture methods, change-in-ratio methods, track and trail counts, and pellet counts). Methodology, assumptions, and suggestions were provided for each census method. A flow chart was provided to aid in selection of the most appropriate technique. Information regarding physiological condition was presented in a similar manner.
Keywords: census/ drive census/ aerial survey/ transect/ spotlight census/ remote sensing/ mark-recapture/ infrared/ track count/ trail count/ pellet-group
47. **Otto, M. C., and Pollock, K. H. 1990. Size bias in line transect sampling: a field test. *Biometrics* 46:239-245.**
Abstract: This paper addressed a key bias issue in line transect sampling: size differences in subject objects. Empirical evidence that equal precision of parameter estimates was met when equal numbers of each cluster size were collected was provided. The application of this size bias was most easily described by the impact of habitat features on sighting ability.
Keywords: clustering/ line transect sampling/ bias
48. **Pollock, K. H., Nichols, J. D., Brownie, C., and Hines, J. E. 1990. Statistical inference from capture-recapture experiments. *Wildlife Monographs* #107. 97 pp.**
Abstract: Capture-recapture studies for "open populations" were evaluated, analyzed, and interpreted with a focus on the Jolly-Seber model. Two variations of this model were examined (one where losses [i.e., deaths] but not additions [i.e., births] were allowed, the second with a constant survival rate). The computer programs, JOLLY and JOLLYAGE, were explained in detail.
Keywords: open population/ JOLLY (computer software)/ JOLLYAGE (computer software)/ assumptions/ capture-recapture
49. **Nichols, J. D. 1992. Capture-recapture models. *BioScience* 42:94-102.**
Abstract: A brief, general review of capture-recapture models was provided. Recent advances in the models and the need for ecologists to implement these advances were emphasized. Attention was given to both open and closed models, reproduction, and problems associated with movement and multiple states. Descriptions were included for a variety of computer software packages designed for use in mark-recapture studies.
Keywords: computer software/ mark-recapture

50. **Buckland, S. T., Anderson, D. R., Burnham, K. P., and Laake, J. L. 1993. Distance sampling: estimating abundance of biological populations. Chapman & Hall, Inc. London, England. 446 pp.**
Abstract: This book is the most recent treatise on line and point sampling, and estimating population density or abundance. Chapters included the basic concepts of line and point sampling including statistical theory. The last two chapters examined study design and field techniques along with a plethora of real-world data sets as examples. The computer program DISTANCE was introduced. Some experience with statistics is recommended, including sampling theory and likelihood reference.
Keywords: line transect sampling/ point transect sampling/ distance sampling/ detection/ abundance estimation/ DISTANCE (computer software)
51. **Garner, D. L., Underwood, H. B., and Porter, W. F. 1995. Use of modern infrared thermography for wildlife population surveys. Environmental Management 19:233-238.**
Abstract: The ability of a commercially available thermal-infrared scanning system to: (1) detect species of several different sizes relative to conventional survey methods, (2) differentiate between species in the same habitat, and (3) determine the influence of environmental factors on operation of the system in the field was evaluated. Computer assisted analysis of infrared imagery recorded 52% fewer deer than were estimated from drive counts. Telephoto capabilities enhanced the system in distinguishing different species within the same image. Scanning periods should be limited to times that provide highest thermal contrast and lowest thermal loading.
Keywords: infrared thermography/ population size estimation/ New York
52. **Rivest, L. P., Potvin, F., Crepeau, H., and Daigle, G. 1995. Statistical methods for aerial surveys using the double-count technique to correct visibility bias. Biometrics 51:461-470.**
Abstract: Statistical methods were presented to reduce negative bias associated with aerial surveys. One solution involved classifying animals observed according to variables potentially influencing visibility during the survey. A second potential was to use parcel-specific correction factors based on variance estimators. Both methods were defined and discussed in terms of statistical equations. Each method was tested using data from deer population surveys done on Anticosti Island in the Gulf of St. Lawrence. Results showed a correction of 10-13% for double-count surveys compared with 33% for single-count surveys, and that the double-count survey is an attractive method for correcting the visibility bias associated with aerial surveys.
Keywords: mark-recapture/ multinomial distribution/ Lincoln index/ population size estimation/ stratification

White-tailed Deer

53. **McCain, R. 1939. The development and use of game drives for determining white-tailed deer populations on Allegheny National Forest. Transactions of the North American Wildlife Conference 4:221-230.**
Abstract: The use of drive censuses as a method of population estimation was examined on the Allegheny National Forest in Pennsylvania. Over a 5 year period, 120 drives were conducted in a variety of habitat types. Each drive used >100 men to survey areas up to 121.5 ha (300 acres) in size. A detailed description of the organization and planning of the drives, and considerations to ensure successful censuses were provided. The main obstacle encountered was the variation in walking speed of the drivers. Several figures illustrated the conversions used and represent # of deer/acre in the study areas. The most important factor in drive census analysis was that drive areas must be representative of distinct cover types. Future work comparing drive censuses with pellet-group and aerial surveys was also mentioned.
Keywords: Pennsylvania/ drive census
54. **Bennet, L. J., English, P. F., and McCain, R. 1940. A study of deer populations by use of pellet-group counts. Journal of Wildlife Management 4:398-403.**
Abstract: Random 0.04 ha (0.1acre) quadrats were established in several forest types in Centre County, Pennsylvania. Pellet-groups were counted and removed monthly. A correlation was observed between deer observation and pellet-group frequencies. Results indicated that pellet-groups could be used to estimate deer population size, deer movements, and deer habitat use.
Keywords: pellet-group/ Pennsylvania/ quadrat
55. **Erickson, A. B. 1940. Notes on a method for censusing white-tailed deer in the spring and summer. Journal of Wildlife Management 4:15-18.**
Abstract: Inherent limitations and advantages of censusing by drive-count, deeryard count, and track counts were reviewed. A new method of censusing known as cruising was described. The method involved an observer that records the number of animals encountered, miles of lines cruised, and average flushing distance. The method was modeled after a technique used in a study of ruffed grouse.
Keywords: cruise census
56. **Kelker, G. H. 1940. Estimating deer population size by a differential hunting loss in the sexes. Proceedings of the Utah Academy of Sciences, Arts, and Letters. 17:65-69.**
Abstract: A method of estimating deer population size utilizing wardens and rangers to collect hunter check station data in the form of counts and sex ratios of the previous year. An underlying assumption was that changes in sex ratio due to hunting resulted in buck loss and was proportional to the number of does in a herd. A correction factor was used when does were hunted. An advantage of this method was low cost. Disadvantages included weakness of data with respect to field determination of sex, obtaining an adequate sample, and inaccurate estimates of the previous year herd statistics. The method was recommended for use in conjunction with other census techniques.
Keywords: harvest data/ sex ratio/ total-kill

57. **Halloran, A. F. 1941. A study of deer census methods and deer-cattle relationships on the Aransas National Refuge. M.S. Thesis. Texas A&M University. College Station, TX. 64 pp.**
Abstract: Census methods were described in south Texas that included cruise, drive, and random auto counts. Cost was prohibitive for the drive method, but cruise counts and random auto counts were considered effective for this type of terrain and vegetation. In addition, a comparative index of population size based on correlations between temperature and deer sightings was described. A discussion of sex ratio counts was also included.
Keywords: Aransas National Refuge/ Texas/ auto count/ census/ cruise census/ drive census/ population size estimation/ sex ratio/ temperature
58. **Krefting, L. W., and Fletcher, J. B. 1941. Notes on the cruising method of censusing white-tailed deer in Oklahoma. Journal of Wildlife Management 5:412-415.**
Abstract: The cruising method of censusing deer was examined in a mountainous region of Oklahoma. Biologists stalked deer along specified routes and recorded flushing distances and cover distances. A population estimate was calculated using a modification of the formula that King used in grouse studies.
Keywords: cruise census
59. **Morse, M. A. 1943. Technique for reducing man-power in the deer drive census. Journal of Wildlife Management 7:217-220.**
Abstract: Snow-tracking was included in this modification of the drive census. Drivers tallied the number of deer on drive lines after counting crews had tallied and obliterated tracks on lateral and far boundaries. During the drive, counters retraced their routes along the boundary to eliminate possibility of counting an animal twice. Although applicable in most forest areas, it was suggested that the method was best adapted to deer ranges bounded by roads or trails and/or in long narrow areas.
Keywords: drive census/ man-power/ snow-tracking/ techniques
60. **Schrader, T. A. 1944. Roadside deer counts as an emergency census method. Transactions of the North American Wildlife Conference 9:150-155.**
Abstract: Use of the drive census, pellet-group count, roadside track count, aerial census, and roadside census in Minnesota were described. Roadside censuses conducted by wardens during their regular working regime were considered most appropriate during this time of war when manpower and supplies were limited.
Keywords: aerial survey/ drive census/ Minnesota/ pellet-group/ roadside census/ track count
61. **Steinhoff, H. W. 1947. White-tailed deer census methods. M.S. Thesis. State University of New York, College of Environmental Science and Forestry. Syracuse, NY. 84 pp.**
Abstract: Huntington Wildlife Forest, near Newcomb, New York, was the site for this study with objectives of examining census methods for white-tailed deer, determining distribution effects on accuracy of enumeration, and devising improved deer census methods. Census techniques evaluated in the project included drives, strip census methods (marked deer ratio, Erickson's method, vertical distance method, and Kelker's method), estimates based on previous drives, pellet counts, track counts, and animal sign (scrapes, pawings, and beds). Census accuracy was greatest using the total drive method. Of the strip census techniques, the vertical jumping distance method exhibited the most acceptable accuracy. The marked deer ratio method was too costly to be effective unless used in conjunction with other research. Distribution of deer during monthly censuses indicated that deer preferred spruce-type areas over hardwood areas, with seasonal variation in habitat preference evident. Suggestions for improvement in each of the census methods were discussed.
Keywords: animal sign/ drive census/ estimate/ habitat/ pellet-group/ track count/ New York

62. **Hahn, H. C., Jr. 1949. A method of censusing deer and its application in the Edwards Plateau of Texas. Pittman-Robertson Project, Final Report W-25-R. Texas Game, Fish, and Oyster Commission. Austin, TX. 24 pp.**
Abstract: Dense underbrush and rocky terrain precluded use of pellet counts, drive counts, and aerial counts to census deer in the Edwards Plateau region of Texas. Walking and riding cruise census techniques were therefore evaluated for use in this area. The walking cruise technique was deemed superior to the riding census. The last hour of daylight between October 15-January 15 was considered the optimal period for this method. It was recommended that surveys be conducted when relative humidity is below 70% and sky is less than 50% overcast to avoid weather effects on deer activity. Accuracy may be improved by conducting 2 counts of 3.2 km (2 mi) lines. Optimum location of lines should include appropriate proportions of all terrain features.
Keywords: *cruise census/Texas*
63. **Lauckhart, J. B. 1950. Determining the big-game population from the kill. Transactions of the North American Wildlife Conference 15:644-650.**
Abstract: Harvest kill data were combined with age/sex ratio statistics obtained over a period of years to calculate a life equation for deer herds. The assumption of a 10% winter loss was inherent in the model. In addition to the necessary formula, a figure depicting animals left per buck killed at various ratios was presented. Results were calculated using fawn survival rates of 1 fawn/doe and 0.5 fawn/doe. Assumptions and application of the model to deer herds in other regions were discussed.
Keywords: *fawn/harvest data/sex ratio/age ratio/Washington*
64. **Rognrud, M. J. 1950. White-tailed deer strip census in the Thompson River. Final progress report for surveys and investigations, Project 1-R-9. Montana Department of Fisheries and Wildlife. Bozeman, MT. 6 pp.**
Abstract: Strip censuses were initiated in 1949 and repeated in 1950 in the Thompson River area of Montana. Twenty-two strips, varying in length and width, were surveyed, and basic calculations were performed to estimate acres/deer. Estimates were 1.8 ha (4.5 acres)/deer in 1949 and 2.08 ha (5.2 acres)/deer in 1950. The apparent increase in density was not accepted due to the inability to recensus all strips in 1950. Although strip censuses were cited as being practical for that area, several suggestions for survey improvement were made. The use of pellet-group counts as a check against the strip census method was recommended. Information on sightings of incidental and predator species, forage composition and usage, and occurrence of dead deer was also noted.
Keywords: *Montana/strip census/pellet-group*
65. **Dasmann, R. F. 1952. Methods for estimating deer populations from kill data. California Fish and Game 38:225-233.**
Abstract: The technique of determining deer population abundance using kill data and sex and age ratios was described. The importance of accurate field data was stressed. Sources of error, particularly those encountered with minimal or limited data were discussed. Analysis of kill data alone was purported to provide useful information in situations where exact measurements were less critical. Tables and figures were provided for determining deer herd size based on sex/age ratios that remained in a herd after hunting.
Keywords: *sex ratio/age ratio/error/harvest data*
66. **Gunvalson, V. E, Erickson, A. B., and Burcalow, D. W. 1952. Hunting season statistics as an index to range conditions and population fluctuations in Minnesota. Journal of Wildlife Management 16:121-131.**
Abstract: Hunter kill data were used to ascertain herd composition, age ratios, and sex ratios. Data were obtained by hunter reports during a period when hunting season was open to "any deer". It was assumed that the deer kill figures were representative of the Minnesota deer herd. Results and implications were presented for 5 distinct regions of the state.
Keywords: *age ratio/harvest data/herd composition/Minnesota/range condition/sex ratio*

67. **Tyson, E. L. 1952. Estimating deer populations from tracks: a preliminary report. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 6:3-15.**
Abstract: The potential for converting track counts from an index to a census was explored. Track counts were conducted from a jeep driving sand roads at Eglin Air Force Base, Florida. The study began in July, and a sharp decline in the number of tracks observed occurred during the fawning period. Factors influencing track counts included weather, food abundance, population density, season, and the availability of water. Formulas were provided for calculating density based on numbers of tracks and an estimation of average daily range. This estimation accounted for the greatest source of error. A drive count was also conducted in the same area, and it was found to underestimate deer density. Information was provided for estimation based on kill data.
Keywords: Florida/ track count/ drive census/ harvest data
68. **Kabat, D. N., Collias, E., and Guettinger, R. C. 1953. Some winter food habits of white-tailed deer and the development of census methods in the Flag Yard of northern Wisconsin. Bulletin Number 7. Wisconsin Conservation Department of Wildlife. Madison, WI. 32 pp.**
Abstract: A dense deer population and a series of artificial feeders to support deer during winter characterized the Flag Yard. Three methods were used to census the population.: direct observations, Lincoln index, and feed consumption, Results showed that the Lincoln index, in the form of the Schnabel method, provided the best estimate. Direct observations underestimated the population. Natural markings were used to identify individuals. Observation of crippled deer appeared to be the greatest source of error due to the increased likelihood of repeat trips to the feeding station. Feed consumption, based on food consumption per deer per day, yielded results similar to that of the Lincoln index.
Keywords: Wisconsin/ direct methods/ Lincoln index/ Schnabel method/ feed consumption
69. **Howe, D. L. 1954. A comparison of deer census methods in the Rifle River Game Area. M.S. Thesis. Michigan State University. East Lansing, MI. 46 pp.**
Abstract: The strip count, Delury method (regression of effort and success during open season), shining counts, drive counts, mileage counts, sex and age ratios, track counts, and time area counts were tested and compared in the Rifle River Game Area of Michigan. Efficiency of the Delury regression method was limited to areas where accurate records could be maintained. Deer drives were considered accurate, but labor intensive. Mileage counts were biased due to environmental effects. Difficulty in obtaining accurate sex and age ratios precluded efficacy as a census method. The time area count provided estimates comparable to the strip method, but was more expensive. Track counts were highly variable and not considered reliable. Shining counts of deer were reliable only when angular correction factors were used.
Keywords: Delury regression method/ drive census/ Michigan/ mileage count/ sex ratio/ age ratio/ spotlight census/ strip census/ time area count/ track count
70. **Robinette, W. L., Jones, D. A., Gashwiler, J. S., and Aldous, C. M. 1954. Methods for censusing winter-lost deer. Transactions of the North American Wildlife Conference 19:511-525.**
Abstract: King's (1937) grouse census method, Lincoln index (1930), Kelker's (1945) belt-transect method, Webb's (1942) snowshoe hare method, and Haynes (1949) modification of King's method were tested on dead deer surveys in Utah. Population estimates were compared to known population numbers. Although the Kelker and King methods, and the Lincoln index were reliable, King's method was favored. Advantages and precautions associated with the techniques were discussed. The Webb and Hayne methods resulted in positively biased estimates and were not recommended for censuses of this type.
Keywords: dead deer census/ Lincoln index/ Utah/ grouse census/ snowshoe hare census/ transect

71. **Dasmann, R. F., and Taber, R. D. 1955. A comparison of four deer census methods. California Fish and Game 41:225-228.**
Abstract: The total deer count, Lincoln index, sample area, and pellet-group techniques of estimating deer abundance were evaluated in chaparral covered mountains in California. Visibility was high on the study site as a result of fire, thus tagged deer were easily recognized. Total deer counts, Lincoln index, and sample area methods resulted in comparable estimates. The sample area count was most cost-effective, but application was considered most suitable in open terrain. Variable defecation rates precluded reliable use of pellet-group estimates.
Keywords: chaparral/ California/ Lincoln index/ pellet-group/ sample area count/ total count/ abundance estimation
72. **Eberhardt, L. L. 1955. Information on deer pellet group surveys in Michigan. Report Number 2042. Michigan Department of Conservation. Lansing, MI. 2 pp.**
Abstract: Results of pellet-group surveys conducted in Michigan in 1953 and 1954 were presented. Current research on defecation rates and pellet deterioration was described. The need for replication of surveys was stressed, and the stratified sampling method was recommended for use in future censuses.
Keywords: Michigan/ pellet-group
73. **Eberhardt, L. L. 1955. Aerial dead deer searches. Report Number 2051. Michigan Department of Conservation. Lansing, MI. 3 pp.**
Abstract: The utility of combining air and ground surveys to estimate the numbers of dead deer was examined. The results showed that the two methods were comparable. Due to the limited nature of the research, several recommendations were made for further study and analysis. Statistical formulas for the calculation of variance ratio limits were also presented.
Keywords: Michigan/ aerial survey/ ground survey
74. **Severinghaus, C. W., and Maguire, H. F. 1955. Use of age composition data for determining sex ratios among adult deer. New York Fish and Game Journal 2:242-245.**
Abstract: The percentage of yearlings in separate, random samples of each sex was used to derive sex ratios among adults in a population. A model was produced to provide an example using harvesting as the only source of mortality. The procedure was not valid unless the ratio of the two sexes among yearlings in the population was known before the hunting season. The model showed that sex ratios became stable over time if other factors such as natality and mortality were held constant. Controlling influences were the proportion of yearlings in the population and doe harvest limits on population growth.
Keywords: harvest data/ sex ratio/ age ratio/ population model
75. **Aldous, C. M. 1956. Conducting deer studies with the use of a helicopter. Journal of Wildlife Management 20:327-328.**
Abstract: Census techniques and problems associated with each method were reviewed. Aerial surveys performed with the H-13 Bell reconnaissance type helicopter was recommended as an alternative. The advantage to this method in game counts was that it was more effective than traditional small aircraft over all types of terrain and ground cover. The single propeller helicopter appeared to be best for big-game surveys due to maneuverability. Best survey conditions were after leaf-fall and during the early morning and early evening hours.
Keywords: census/ helicopter survey

76. **Eberhardt, L. L., and Van Etten, R. C. 1956. Evaluation of the pellet-group count as a deer census method. *Journal of Wildlife Management* 20:70-74.**
Abstract: Accuracy of the pellet-group count method of censusing deer was evaluated by comparing results obtained on 2 areas of known density in Michigan. Defecation rate was determined as 12.7 pellet groups/day/deer. Inherent difficulties with the procedure included pellet deterioration, leaf fall, and observer error.
Keywords: defecation rate/ pellet deterioration/ Michigan/ observer error/ pellet-group
77. **Robinette, W. L., Jones, D. A., Gashwiler, J. S., and Aldous, C. M. 1956. Further analysis of methods for censusing winter-lost deer. *Journal of Wildlife Management* 20:75-78.**
Abstract: Updated information on censusing of winter-lost deer was provided. Sight distance adjustments for improving reliability of the methods were presented and explained. Final recommendations were amended to include Kelker's method - covering a strip of predetermined width, and the Lincoln index as being the most appropriate methods for field application (as opposed) to the King method. Merits of the King method were addressed along with measures to minimize biases. Precautionary measures and planning strategies for the revised, recommended methods were included.
Keywords: dead deer census/ observability/ Lincoln index/ Kelker method/ King method
78. **Whitlock, S. C., and Eberhardt, L. L. 1956. Large scale dead deer surveys: methods, results, and management implications. *Transactions of the North American Wildlife Conference* 21:555-566.**
Abstract: Importance and effects of overwinter loss in Michigan deer herds were addressed. A stratified random sampling design was used on sample plots to estimate the number of deer succumbing to illegal harvest and starvation. Losses to illegal hunting were evenly distributed over several age classes whereas starvation losses were concentrated in fawn and older (> 6 yrs) doe classes. Associated problems of survey cost and cause of mortality were discussed.
Keywords: harvest data/ Michigan/ population dynamics/ productivity/ starvation
79. **Duerre, D. C. 1959. Analysis of summer spotlighting for determining deer population indices. M.S. Thesis. South Dakota State University. Brookings, SD. 70 pp.**
Abstract: Equipment, physiological, and ecological factors affecting summer spotlighting of deer were examined in the Black Hills of South Dakota. A 100-volt, 100,000 candlepower spotlight unit was superior to 6-volt and 12-volt units in reducing fatigue, observer error, and survey time. Fawning, antler growth, and feeding activities had measurable effects on census results. Temperature was the most significant ecological factor affecting the spotlight census technique.
Keywords: ecological factors/ equipment/ physiological indices/ South Dakota/ spotlight census
80. **Hart, R. D. 1959. Evaluation of summer spotlighting counts of deer, 1959. Pittman-Robertson Project, W-75-R-2. South Dakota Dept. of Game, Fish, and Parks. Pierre, SD. 10 pp.**
Abstract: Summer spotlighting counts of deer in South Dakota were evaluated as a census technique in South Dakota and to obtain data on deer movement and meadow use. Data over a two year period showed a 20% increase in the deer herd, and that bucks tended to use meadows in August to a greater degree than July. A minimal amount of mark-resight was also done, but no conclusions were made. Several recommendations for future spotlight surveys were given.
Keywords: South Dakota/ spotlight census/ mark-recapture

81. **Jahn, L. R. 1959. Highway mortality as an index of deer population change. *Journal of Wildlife Management* 23:187-197.**
Abstract: Records of deer killed by motor vehicles between 1946-1955 were studied to determine potential use as a population index. Variation in vehicle speed was assumed not to affect the number of deer killed and that state highways constituted a well-distributed set of transects. When compared to harvest and sighting data, road-kills did not accurately reflect population trends. Poor record-keeping was cited as the greatest liability associated with this technique. However, these data were considered useful in determining physical condition of the deer.
Keywords: harvest data/ population dynamics/ road-kills/ sighting data/ Wisconsin
82. **Tyson, T. L. 1959. A deer drive vs. track census. *Transactions of the North American Wildlife Conference* 24:457-464.**
Abstract: The drive count and track count methods of censusing deer in Florida were compared. Results indicated no significant difference in estimates obtained by the 2 methods.
Keywords: drive census/ Florida/ track count
83. **Eberhardt, L. L. 1960. Estimation of vital characteristics of Michigan deer herds. Ph.D. Thesis. Michigan State University. East Lansing, MI. 192 pp.**
Abstract: Methods of estimating deer demographics in Michigan were compared and analyzed. Pellet-group surveys, harvest data, and a combined index were all found to be highly correlated. The pellet-group survey was found to be an unreliable standard, whereas the combined index did not give direct population estimates. Harvest data gave a useful estimate provided that the assumption of low, non-hunting mortality of adult male deer was met; this method, however, underestimated fawns. The best estimates required knowledge of age and sex structure of a population as well as density levels over at least the previous two years. This work also provided productivity information and estimates for Michigan deer.
Keywords: Michigan/ harvest data/ pellet-group/ index
84. **Brunett, L. E., and Lambou, V. W. 1962. A test of track counts as a measurement of deer population size. *Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies*. 16:29-31.**
Abstract: Track counts were conducted in three enclosures with different densities of deer in Louisiana. Results showed that track counts were not proportional to the population size. High variability between counts was cited as a confounding factor in analysis. The authors stated that track counts were not a valid measure of population size. Track counts were able to detect differences in population size, but not differences in the orders of magnitude.
Keywords: track count/ Louisiana/ density
85. **Johnson, F. M., and Downing, R. L. 1962. Preliminary investigations of deer census techniques applicable to the Southeast. *Proceedings of the Society of American Foresters* 16:162-165.**
Abstract: Pellet-group, imprints, and day and night drive census techniques were investigated for use in the Southeast. Treatment of pellet-group plots with insecticides deterred insect degradation of pellets, thus improving reliability of this technique. Climatic factors influenced results from imprint methods precluding accuracy. Nighttime spotlight censuses were considered the most effective method for use in the Southeast.
Keywords: track count/ pellet-group/ Southeastern U.S./ spotlight census

86. **Wallmo, O. C., Jackson, A. W., Hailey, T. L., and Carlisle, R. L. 1962. Influence of rain on the count of deer pellet-groups. *Journal of Wildlife Management* 26:50-55.**
Abstract: Deterioration of deer pellet-groups was examined on 4 ecologically distinct study sites in Texas. Significant negative correlations between pellet-group densities and number of rains were reported for 2 of the study sites. One study site was eliminated from analyses due to limited sample size. The study site exhibiting little correlation was typified by level terrain where washing away was not a significant factor. It was recommended that the pellet-group census method be performed during dry periods because of varying physiography and spatial variability in rainfall intensity.
Keywords: pellet deterioration/ pellet-group/ physiography/ Texas/ weather
87. **Robbins, R. L. 1963. Evaluation of summer spotlighting counts of deer, 1962. Pitman-Robertson Project, W-75-R-5. South Dakota Department of Game, Fish, and Parks. Pierre, SD. 6 pp.**
Abstract: Spotlight censuses were performed in July and August and compared over several seasons to determine the effectiveness of the survey technique. Methodology and study areas were described in detail. Estimates over time showed extreme variability due to changes in land use and forage conditions. Spotlight surveys indicated a decrease in the population whereas pellet-group counts, considered a more reliable estimator, revealed little change. Spotlight counts were not recommended for management purposes.
Keywords: South Dakota/ spotlight census/ pellet-group
88. **Progulske, D. R., and Duerre, D. C. 1964. Factors influencing spotlighting counts of deer. *Journal of Wildlife Management* 28:27-34.**
Abstract: Spotlight surveys of deer were conducted in meadows along a 109.4 km (68 mi) route in the Black Hills of South Dakota to identify factors affecting the technique. Herd composition, availability of preferred foods, size and vegetative type of meadow, time of day, and weather were identified as influencing factors. Temperature was considered the most significant meteorological factor.
Keywords: meadows/ South Dakota/ spotlight census/ temperature/ weather
89. **Downing, R. L., Moore, W. H., and Kight, J. 1965. Comparison of deer census techniques applied to a known population in a Georgia enclosure. *Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies* 19:26-30.**
Abstract: Five methods of censusing deer (pellet-group count, track count, drive census, strip count, hunter observation) were compared using a deer population of known size and composition. The pellet-group count was abandoned because of decimation of pellets by dung beetles, but the other techniques were considered valid in most areas. Specific advantages and disadvantages of each method were discussed.
Keywords: drive census/ Georgia/ hunter data/ pellet-group/ strip census/ track count
90. **Jeter, L. K. 1965. Census Methods. Pages 186-192 in R. F. Harlow and F. K. James, eds. White-tailed deer in Florida. Technical Bulletin, Number 9. Florida Game and Freshwater Fish Commission. Tallahassee, FL.**
Abstract: An overview of census techniques used in Florida was presented. Due to the diversity of habitat within the state, several different methods have been employed, including track counts, pellet-group counts, aerial surveys, and drive censuses. Each methodology is detailed, and the history and extent of usage within Florida was also included. The process of choosing a technique to best cover a particular habitat type in the state and how to maximize the effectiveness of each method was provided.
Keywords: Florida/ track count/ aerial survey/ drive census/ spotlight census/ pellet-group

91. **Sittler, O. D. 1965. Theoretical basis for estimating deer population from automatically collected data. *Journal of Wildlife Management* 29:381-387.**
Abstract: Using automatic detection devices to count deer, a theory for estimating population density based on the behavior patterns of deer was developed. The theory formed the relation between density and counts in terms of frequency of detection. A correction factor was also mentioned, based on the average behavior pattern of the deer in the region around the automatic detectors. The theory was not field-tested.
Keywords: *theory/ estimate/ automatic detection*
92. **Tester, J. R., and Heezen, K. L. 1965. Deer response to a drive census determined by radio tracking. *BioScience* 15:100-104.**
Abstract: Behavioral response of deer to the drive census method was investigated in Cedar Creek Natural History Area, Minnesota. Two does were outfitted with radio transmitters and monitored by an automatic tracking system. Movements were recorded and reported for periods prior to, during, and following the drive. Normal movement patterns were disturbed for both does, but more so for one than the other.
Keywords: *behavior/ drive census/ Minnesota/ movement*
93. **Van Etten, R. C., and Bennett, C. L., Jr. 1965. Some sources of error in using pellet-group counts for censusing deer. *Journal of Wildlife Management* 29:723-729.**
Abstract: Observer error in pellet-group counts to census deer was evaluated in the Upper Peninsula of Michigan. Ability of 2 wildlife biologists to find and age pellet-groups was tested. Data from the 2 observers were significantly different. Censuses were negatively biased as a result of overlooking pellet-groups or incorrectly identifying age of pellet-groups. Modification of plot shape to ease searching, use of 2 observers to check each other, and use of pellet-group position on litter as an age criterion were recommendations to alleviate these errors.
Keywords: *observer error/ pellet-group/ Michigan*
94. **Koivisto, I. 1966. Census of white-tailed deer in Finland in 1966. *Suomen Riista* 19:100-104.**
Abstract: A deer census was undertaken in 1966 as part of a moose census in hunting areas in Finland. Hunting areas were divided into sections where hunters conducted censuses. Methods used were not described, but most likely included track counts, pellet-group counts, and flushing. The estimated number of deer within the census areas (2,442) and observed numbers (2,111) were comparable. Barriers to range expansion included watercourses, extensive tracts of forest, and bogs.
Keywords: *Finland/ census/ hunter data*
95. **Harlow, R. F., and Downing, R. L. 1967. Evaluating the deer track census method used in the southeast. *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 21:39-41.**
Abstract: The track census method commonly used in the Southeastern U.S. was critiqued. Day-to-day variability of track crossings was cited as the greatest weakness in this technique. Formulas were provided to detect differences in deer numbers between years and to determine adequate sample size. The technique, limited in its ability to accurately detect population size, was deemed most valuable as a means to determine population changes and to demonstrate the presence of animals.
Keywords: *population dynamics/ sample size/ track count/ southeastern U.S.*

96. **Lewis, J. C., and Safley, L. E. 1967. A comparison of some deer census methods in Tennessee. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 20:56-63.**
Abstract: Several population estimation methods based on changes-in-ratio were compared in eastern Tennessee. The Lincoln index, sex-age-kill, percent kill, minimum standing crop, and minimum fawn crop all indicated similar population trends, but differed in magnitude. The minimum standing crop and minimum fawn crop tended to underestimate the population, while the Lincoln index and percent kill methods provided the most reliable estimates. The percent kill method was chosen as the most effective due to the high cost of the Lincoln index in terms of time and manpower.
Keywords: Tennessee/ Lincoln index/ percent kill/ sex ratio/ age ratio/ harvest data/ change-in-ratio/ minimum standing crop/ minimum fawn crop
97. **Croon, G. W., McCullough, D. R., Olson, C. E., Jr., and Queal, L. M. 1968. Infrared scanning techniques for big game censusing. Journal of Wildlife Management 32:751-759.**
Abstract: Basic operating principles of imaging infrared sensors and the associated principal components (mechanical scanning system, detector, and signal processing and display system) were described. An operational test of the technique was conducted on the George Reserve white-tailed deer herd. Under ideal conditions, population estimates using infrared scanning were close to estimates obtained using other methods. Problems encountered with the technique included limited infrared penetration of canopy, difficulty in distinguishing between animals of similar size, weather conditions affecting animal and background, temperature, and high initial cost.
Keywords: big game/ equipment/ infrared/ techniques/ Michigan
98. **Klataske, R. D. 1968. An evaluation of deer census techniques and the physical condition of deer on Isle au Haut. M.S. Thesis. University of Maine. Orono, ME. 159 pp.**
Abstract: Census techniques used in this study included strip census methods, deer drives, marked deer counts, roadside counts, track counts, and aerial surveys. Special attention was given to the strip census. Advantages, disadvantages, and recommendations associated with each of the census techniques were discussed.
Keywords: aerial survey/ drive census/ island/ Maine/ mark-recapture/ roadside census/ strip census/ track count
99. **Kufield, R. C. 1968. Use of paint for marking deer pellet groups. Journal of Wildlife Management 32:592-596.**
Abstract: The feasibility of marking pellet groups to facilitate aging pellet groups during surveys was examined. Three paints (alkyd-type yellow traffic striping paint, Kem Lustral enamel, orange farm implement enamel) were tested by painting pellet groups. In addition, painted limestone fragments were placed within pellet groups to determine if this type of marking would last longer than marked pellets alone. Yellow traffic striping paint applied to limestone fragments provided the greatest durability.
Keywords: paint/ marking/ pellet group
100. **Lewis, J. C., and Farrar, J. W. 1968. An attempt to use the Leslie census method on deer. Journal of Wildlife Management 32:760-764.**
Abstract: Examination of the Leslie census method was conducted on an enclosed area of 1012.5 ha (2,500 acres) in Tennessee during 1958-1965. Population estimates for 14 trapping periods were highly variable. Herd size was negatively biased because vulnerability of herd size changed during the census period.
Keywords: herd size vulnerability/ Leslie census/ Tennessee

101. **Smith, R. H. 1968. A comparison of several sizes of circular plots for estimating deer pellet-group density. *Journal of Wildlife Management* 32:585-591.**
Abstract: Efficiency and biases associated with estimating deer pellet-group density were examined in Arizona using 4.5 m² (50 ft²), 9.09 m² (100 ft²), and 0.004 ha (0.01 acre) circular plots. A variety of habitat types were sampled. Net sampling efficiency increased as plot size decreased.
Keywords: Arizona/ bias/ efficiency/ circular plot/ pellet-group
102. **Hawn, L. J., and Ryel, L. A. 1969. Michigan deer harvest estimates: sample surveys versus a complete count. *Journal of Wildlife Management* 33:871-880.**
Abstract: Sample surveys and complete enumeration (by traffic surveys) were compared to determine the most reliable estimate of the Michigan deer harvest. Surveys were cheaper, faster, and more accurate than complete enumeration. Cost estimates of both methods, and problems associated with effective design of sample surveys were included.
Keywords: harvest data/ Michigan/ sample design/ traffic survey
103. **Jenkins, J. H. and Marchinton, R. L. 1969. Problems in censusing white-tailed deer. Pages 115-118 in L. K. Halls, ed. *White-tailed deer in the southern forest habitat: a symposium*. U. S. Forest Service, Southern Forest Experiment Station. Nacogdoches, TX.**
Abstract: Many types of census methods including drives, strip-flushing, pellet-group counts, track counts, aerial photography, Lincoln index, kill data, and infrared scanning were tested. The advantages and disadvantages were discussed for each method. Deer movement, size of census areas, and deer home ranges were cited as potential problems. Use of radio telemetry was advocated to assist in refining census techniques.
Keywords: drive census/ strip census/ pellet-group/ track count/ aerial photography/ Lincoln index/ harvest data/ infrared/ radio telemetry
104. **Smith, R. H., Neff, D. J., and McCullough, C. Y. 1969. A model for the installation and use of a deer pellet group survey. Special Report Number 1. Research Division, Arizona Game and Fish Department. Phoenix, AZ. 30 pp.**
Abstract: The authors presented a clear and detailed description of 2 models for designing and analyzing pellet group surveys to estimate deer numbers. The importance of planning a survey relative to objectives and geographical area of concern was emphasized. Topics regarding design included description of survey area, determination of area required for effective survey, use of aerial-photos, allocation of lines and plots, selection of random versus non-random transects, establishment and marking of transect end-points, required equipment, and methods for reading plots and recording data. Defecation rate and period of herd occupancy were described as constants in data analyses and estimation of deer numbers. Computation of group density and variance, confidence limits, and comparison between estimates were thoroughly described. An appendix provided details regarding acquisition of photos, maps, recommended compass use, and construction of aerial mosaics.
Keywords: analysis/ equipment/ pellet-group/ survey design
105. **Behrend, D. F., Mattfield, G. F., Tierson, W. C., and Wiley, J. E., III. 1970. Deer density control for comprehensive management. *Journal of Forestry* 68:695-700.**
Abstract: A study to determine the intensity of deer control to obtain a herd density compatible with silvicultural practices was undertaken in northern New York. Historical density information from drive counts was supplemented with additional drive counts of 101.3-121.5 ha (250-300 acres) by up to 150 people per drive. Only areas of hardwoods were surveyed by this method, and track counts were used in mixed and coniferous areas. Track count data were converted to an index using a formula given in the text to allow for comparison with drive count data. A controlled harvest was undertaken based on herd density estimates. Although post-harvest surveys indicated a higher deer density than expected, results showed that the effects of immigration post-harvest did not completely replenish the herd.
Keywords: New York/ drive census/ track count/ harvest data

106. **Daniel, W. S., and Frels, D. B. 1971. A track-count method for censusing white-tailed deer. Pittman-Robertson Projects W-74-R and W-82-R. Texas Parks and Wildlife. Austin, TX.**
Abstract: A standardized deer track census was developed for conditions on the East Texas Timberland Resource Area. A drag assembly was designed and used to prepare count lines and to obliterate old track imprints. Twelve 0.805 km (1/2 mile) line segments, 91.44 cm (36 in) wide, were established on the Engeling Wildlife Management Area and on several private ranches. Optimum inventory period was determined to be during the first 2 weeks of July. Counts were conducted from a vehicle and by walking. Adult and fawn tracks were recorded separately and only deer tracks exiting from the count strip were included in the tally. The technique was more effective in areas of moderate to high population levels (>27.94 tracks/km [45 tracks/mile]). In areas of lower deer density, precision was improved by counting only adult tracks and correcting with later, additional counts.
Keywords: Texas/ techniques/ track count
107. **Darr, G. W. 1971. White-tailed deer habitat in the Texas rolling plains. M.S. Thesis. Texas Tech University. Lubbock, TX. 73 pp.**
Abstract: Spotlight surveys were used to determine habitat usage in six habitat types in Texas. Surveys were conducted two times per field season along four transects, each approximately 32.2 km (20 mi) in length. Cruise censuses were utilized in five habitats to evaluate the accuracy of spotlight surveys. Spotlight surveys were favored over cruise censuses for the purpose of habitat use analysis. Recommendations for spotlight surveys included restriction of survey time to four hours after sunset and avoiding nights with precipitation or bright moonlight.
Keywords: Texas/ spotlight survey/ cruise census
108. **Ryel, L. A. 1971. Evaluation of pellet group surveys for estimating deer populations in Michigan. Ph.D. Dissertation. Michigan State University. East Lansing, MI. 237 pp.**
Abstract: Pellet-group surveys were used to estimate deer population abundance in Michigan. Surveys were conducted on 2 study areas with penned deer of known herd composition. In addition to population estimates, defecation rate and pellet deterioration were examined. It was determined that pellet-group surveys yielded a poor fit to known populations. Mean defecation rates were 15.61 for adult bucks, 12.89 for adult does, 14.74 for buck fawns and 11.89 for doe fawns. Pellet-groups were extant for long periods of time, and correctly aging groups, particularly in areas with no leaf litter, proved problematic. Observer error was cited as the most important factor in the method.
Keywords: defecation rate/ pellet deterioration/ observer error/ pellet-group
109. **Graves, H. B., Bellis, E. D., and Knuth, W. M. 1972. Censusing white-tailed deer by airborne thermal infrared imagery. Journal of Wildlife Management 36:875-884.**
Abstract: Two types of infrared detectors were evaluated to census white-tailed deer during different seasons and at different altitudes in Pennsylvania. Estimates were compared to those obtained using ground census techniques. Factors affecting detectability included time of day, season, altitude, and wavelength sensitivity of the infrared detectors. The Indium Antimonide (InSb) detector, most sensitive in the 3-5 μm (0.12-0.2 mils) region, provided better images during winter. The Mercury Cadmium Telluride (MCT) detector, most sensitive in the 3-14 μm (0.12- 0.56 mils) region provided better images during summer. Nocturnal surveys were more successful than diurnal surveys except during overcast conditions. Animals in shrublands were detected at 30.5 m (100 ft), 76.25 m (250 ft), and 152.5 m (500 ft). Overall, more deer were located along highway rights-of-way by ground survey than by infrared survey.
Keywords: detection/ equipment/ infrared/ Pennsylvania

110. **McKenzie, J. V. 1972 . Evaluation of the winter aerial white-tailed deer census technique with special reference to snow cover, five-year summary. Pittman-Robertson Project, W-67-R-11. North Dakota State Game and Fish Department Report, Number 173. Bismarck, ND. 8 pp.**
Abstract: Two permanent study sites were established and maintained for a 5-year evaluation of winter aerial deer census methods, particularly with respect to effects of snow. In general, observations and group size increased with snow cover whereas flight time was inversely proportional to snow cover. The most effective census results were obtained at altitudes between 76.3 and 106.8 m (250 and 350 ft) and at air speeds < 28.7 kmh (80 mph). Snow cover and search intensity were the most significant factors affecting winter deer surveys.
Keywords: aerial survey/ census/ snow/ winter
111. **Parker, H. D., Jr., and Driscoll, R. S. 1972. An experiment in deer detection by thermal scanning. Journal of Range Management 25:480-481.**
Abstract: The ability to detect deer by aerial thermal scanning was evaluated using penned deer near Fort Collins, Colorado. The scanner was able to detect animals at altitudes of 91.5 and 152.5 m (300 and 500 ft), but not at 305 m (1000 ft). In addition, the inability to differentiate between antelope and deer increased the error rate of species enumeration.
Keywords: equipment/ detection/ radiant temperature/ thermal imagery
112. **Poux, R. J., Jr. 1972. Deer behavior and its effects on sex and age ratio counts. M.S. Thesis. Virginia Polytechnic Institute. Blacksburg, VA. 44 pp.**
Abstract: Biases in sex- and age-ratio counts of white-tailed deer were evaluated in southwestern Virginia. Weather patterns were not significantly correlated with counts, but behavior affected observability. It was recommended that counts be made during periods of lowest observability bias when using change-in-ratio population estimators. In southwestern Virginia, November was the optimal period for obtaining sex-ratio data and December was the optimal period for obtaining fawn/doe ratios.
Keywords: behavior/ change-in-ratio/ weather/ Virginia
113. **McCaffery, K. R. 1973. Road-kills show trends in Wisconsin deer populations. Journal of Wildlife Management 37:212-216.**
Abstract: The relationship between road-killed and harvested deer was compared using correlation and regression techniques. Information on road-kills were obtained from records kept by conservation officers responsible for their disposal. Harvest data were acquired from official examination and tagging records maintained by the Department of Natural Resources personnel. Results indicated a strong correlation between road-killed trends and buck harvest trends, thus providing a useful index to deer population changes in Wisconsin. Accurately reported road-kills and an estimate of percent change in annual traffic volume were cited as prerequisites to the successful use of this type of index.
Keywords: harvest data/ index/ population dynamics/ road-kills/ Wisconsin

114. **Woolf, A. 1973. Population dynamics and remote sensing of a large captive white-tailed deer herd. Ph.D Dissertation. Cornell University. Ithaca, NY. 168 pp.**
Abstract: Census methods and population dynamics of a high density, captive white-tailed deer herd in Pennsylvania were investigated. In addition to remote sensing, traditional census methods including aerial counts, roadside counts, pellet-group counts, and feeding counts by stationary investigators were also examined. The most precise technique involved a helicopter census using tagged animals and a Lincoln estimate. Feeding counts, also using a Lincoln estimate, were more varied due to decreased observability. Roadside counts were least effective due to animal behavior patterns and lack of distinctive marking systems. Pellet counts were problematic as a result of observer error. The 2 remote sensing techniques of censusing deer, thermal scanning and low altitude photography, were not recommended under conditions in which they were tested. Current (i.e., 1973) technological development, inadequate photographic coverage of the area, deer behavior, distribution characteristics, and weather conditions were cited as limitations of the remote sensing technique.
Keywords: aircraft/ direct methods/ equipment/ Pennsylvania/ remote sensing
115. **Kranz, J. J. 1974. Spotlight counts as an index to deer numbers and reproduction in the Black Hills of South Dakota, 1970-72. Pittman-Robertson, W-75-R-16. South Dakota Department of Game, Fish, and Parks. Pierre, SD. 69 pp.**
Abstract: The objectives of this study were to test the reliability of spotlight surveys as an index to the total deer population and as an estimate of reproduction, sex- and age-ratios, and species composition of deer herds in the Black Hills of South Dakota. Eight 48.28 km (30 mi) routes were spotlighted several times during mid-summer and early autumn over each of three field seasons. Data collected were broken into 12.8 km (10 mi) segments and corrected for variations in date and temperature. Results showed that a significantly greater number of replications per route were necessary to achieve the minimum acceptable accuracy for each comparison. Several recommendations were given including discontinuation of summer spotlight surveys and correlation of spotlight data with pellet count data, harvest data, and herd age structure data.
Keywords: South Dakota/ spotlight census/ sex ratio/ age ratio/ mule deer
116. **Pastuck, R. D., and Shoesmith, M. W. 1974. Aerial census of white-tailed deer (*Odocoileus virginianus*) in game hunting areas 27 and 31A. Research Branch, MS. Report Number 74-15. Manitoba Department of Mines, Resources, and Environmental Management. 24 pp.**
Abstract: A pilot study was conducted to provide a more precise method of estimating deer populations within certain blocks of land in southwestern Manitoba. Aerial surveys were conducted over 2.59 km² (1 mi²) quadrats that were designed using the stratified sampling method. Results showed that larger sample sizes reduced variance and gave more reliable estimates. High variability occurred in one sample area due to errors in placing quadrats within appropriate strata. This method was compared with trend surveys, and although no statistically significant difference was found, trend surveys gave consistently lower estimates.
Keywords: Manitoba/ aerial survey/ stratified sampling/ quadrat/ trend survey
117. **Zagata, M. D., and Haugen, A. O. 1974. Influence of light and weather on observability of Iowa deer. Journal of Wildlife Management 38:220-228.**
Abstract: A study was conducted in Iowa to determine if light intensity and selected weather parameters were related to the number of deer sighted during crepuscular periods. Deer were observed by the investigators and approximately 20 bowhunters. Track counts were performed prior to and after all observation periods. Deer were found to move most often before sunrise and after sunset, and males tended to move after it was too dark to observe them. Wind direction affected movements in the mornings, and track counts showed that the majority of movements occurred during periods when it was too dark for observation. Implications and suggestions for management through manipulating harvest regulations were provided.
Keywords: Iowa/ track count/ observability

118. **Atkinson, D. E. 1975. Population dynamics and predator-prey relationships of the Carmen Mountains white-tailed deer. M.S. Thesis. Texas A&M University. College Station, TX. 106 pp.**
Abstract: Pellet plot transects were established throughout the Chisos mountains of Texas to estimate the numbers of a sub-species known as the Carmen mountains white-tailed deer. Transects consisted of 20 pellet-group plots, for a total of 0.2 acres, on parallel lines located about 100m apart. Pellets were removed after sampling. Transects were sampled four times a year. Wide confidence intervals around estimates led the author to believe that the number of transects was too low for adequate precision.
Keywords: pellet-group/ predators / Texas/ transect
119. **Batchelor, C. L. 1975. Development of a distance method for deer census from pellet groups. Journal of Wildlife Management 39:641-652.**
Abstract: A plotless method of the pellet-group census technique was described. The method was tested on a population of red deer in New Zealand. The model, which alleviated the inversely proportional relationship between pellet count and plot size, incorporated pellet-group density, disappearance, and defecation rate. A running line used to measure intervals between plot centers was also described and illustrated.
Keywords: bounded count/ pellet-group/ plotless method/ New Zealand/ red deer
120. **Evans, W. 1975. Methods of estimating densities of white-tailed deer. Ph.D. Dissertation. Texas A&M University. College Station, TX. 185 pp.**
Abstract: Twelve transect methods of estimating deer density were evaluated on the Welder Wildlife Refuge in south Texas. Nine methods (King, Hayne, Hahn, Webb, Gates I, Gates II, Dasmann and Mossman, White, and Kelker) were selected from the literature and 3 (normal, stake, and P[Y]) were developed during this study. The unbiased estimators, ranked by statistical efficiency were Hayne, P(Y), stake, normal, and White. The Hahn, Webb, Gates I and II, and Dasmann and Mossman were positively biased, whereas the King method was negatively biased. A discussion detailing advantages and disadvantages was included for each of the estimators. During this study, it was determined that sun position, wind direction, human and helicopter disturbance, time of day, visibility, and age composition could affect census results. Although surveys conducted from fixed-wing aircraft were cheaper than surveys conducted from helicopters, the latter were more efficient.
Keywords: bias/ transect/ Texas
121. **Jacobson, D., Goulden, H., and Milliken, I. 1975. Application of quadrat and strip plot sampling techniques to an aerial census of white-tailed deer in southwestern Manitoba. MS. Report 75. Manitoba Department of Mines, Resources and Environmental Management, Research Branch. 51 pp.**
Abstract: The use of square mile quadrats were tested on aerial censuses for white-tailed deer in southwestern Manitoba. Fixed-wing aircraft, two observers, and overlapping strip plots to increase accuracy were used. Results showed estimate variances in the 14-26% range, but that was an acceptable level of precision for management purposes. Little advantage was found in using larger numbers of smaller quadrats, and the importance of accurate identification and correction of visibility bias factors were stressed. The double observer modification lowered the visibility bias, but the stratified random estimates produced by this technique should be treated as conservative.
Keywords: Manitoba/ bias/ double count/ aerial survey/ strip census/ quadrat

122. **Lautenschlager, R. A., and Hennessey, G. J. 1975. Some advantages of a track-pellet-group technique for estimating deer numbers. Transactions of the Northeastern Fish and Wildlife Conference 32:13-24.**
Abstract: A track-pellet-group technique incorporating freshly fallen snow was compared to the circular plot pellet-group count for estimating deer abundance. The study was conducted on 2 Connecticut sites including mixed, conifer, hardwood, and swamp habitat types. Results were comparable using both methods, but the track-pellet-group method was cheaper and reduced errors associated with pellet visibility, group distinction, pellet age, and pellet decimation. Recommendations for optimal results and snow conditions were discussed.
Keywords: circular plot/ Connecticut/ pellet group/ snow/ track count
123. **Hardin, J. W., and Roseberry, J. L. 1976. Estimates of unreported loss resulting from a special deer hunt on Crab Orchard National Wildlife Refuge. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 29:460-466.**
Abstract: Amount and composition of unretrieved losses of deer were evaluated to aid in population assessment and management practices on 2 study areas of the Crab Orchard National Wildlife Refuge. A total of 67 hunt-related mortalities (20% of the legal harvest) was discovered. The estimate of unretrieved losses established by hunter surveys and interviews was positively biased (32.3% of the legal harvest). Retrieval rates were lower for does than bucks. No significant difference was evident for retrieval rates of yearling males, yearling females, and fawns.
Keywords: harvest data/ population dynamics/ unretrieved loss/ Crab Orchard National Wildlife Refuge
124. **King, D. R. 1976. Estimates of the white-tailed deer population and mortality in central Ontario, 1970-1972. Canadian Field Naturalist 29:29-36.**
Abstract: Pellet-group and dead deer surveys were conducted to estimate deer populations and winter mortality in central Ontario. A stratified random sampling technique based upon expected deer use of forested habitat during winter was used. Triangular plots were measured and pellet groups were counted along each side. Dead deer were counted in 1-3 chain wide transects around the entire length of the triangular transect. The dead deer survey underestimated winter mortality, as it was confounded by predators and scavengers. The pellet-group survey was recommended as an effective measure of population density, while dead deer surveys should be used only as an index.
Keywords: Ontario/ pellet-group/ dead deer census/ population estimation
125. **Kucera, E. 1976. Deer flushing distance as related to observer's mode of travel. Wildlife Society Bulletin 4:128-129.**
Abstract: Reactions of deer to 3 modes of approach were examined in Manitoba during 1970-1972. Mode of approach (walking, riding horseback, or driving) and the distance flushed were recorded for observation of 1,034 animals. Mean flushing distances were 122 m, 97 m, and 82 m, for walking, riding, and driving, respectively. Walking was the most successful mode of approach at distances < 25 m, but at distances > 25 m, riding and driving were more successful modes of approach.
Keywords: flushing distance/ Manitoba/ mode of approach/ observer
126. **McCaffery, K. R. 1976. Deer trail counts as an index to populations and habitat use. Journal of Wildlife Management 40:308-316.**
Abstract: Deer trails were counted in 23 deer management units in Wisconsin and compared to other indices of deer population abundance. Specifics with regard to the different management units were provided, but generally a positive correlation was apparent for trail counts and other indices.
Keywords: population estimation/ trail count/ Wisconsin

127. **Downing, R. L., Michael, E. D., and Poux, R. J., Jr. 1977. Accuracy of sex and age-ratio counts of white-tailed deer. Journal of Wildlife Management 41:709-714.**
Abstract: Counts of deer in Texas and Virginia were conducted over 2 and 3 year periods, respectively, to quantify changes in observability of bucks, does, and fawns. Feeding and bedding patterns were reported to affect visibility more than cover use or group size. Observability bias was apparent during most months, but least apparent during August and November. Effects of these biases on change-in-ratio estimates and Lincoln index estimates were discussed.
Keywords: age ratio/ change-in-ratio/ Lincoln index/ observability/ Texas/ Virginia/ sex ratio/ Texas/ Virginia
128. **Guynn, D. C., Jr., Jacobson, H. A., and Mitchell, W. A. 1977. Deer data collection systems used by state wildlife management agencies. Proceedings of the Joint Northeast-Southeast Deer Study Group Meeting. 6 pp.**
Abstract: A mail survey of all 50 state wildlife management agencies was conducted to determine systems used for collecting data for deer management. All results were based on the 1976-77 season. The majority of the paper dealt with hunter and harvest data, as that was the focus of the questionnaire. Eleven states flew aerial surveys, 9 performed sign counts, and 11 did browse surveys. Only 4 states did field counts. Virginia was the lone state to respond with biologist estimates.
Keywords: mail survey/ harvest data/ data collection
129. **Johnson, R. E. 1977. Road and aerial surveys for deer in the North Dakota coteau region. M.S. Thesis. North Dakota State University. Fargo, ND. 47 pp.**
Abstract: Road and aerial surveys were conducted to evaluate their potential for use in deer management. Road surveys were conducted at three different times of day, and spotlight surveys at night were found to yield the best precision. Two types of aerial surveys, systematic transect and stratified random quadrat, were used, and the stratified random quadrat method appeared to be the more effective. Increases in sightings and precision were correlated with small grain harvest and the reduction of escape cover. Methods of reducing variance in aerial quadrat surveys were also discussed.
Keywords: North Dakota/ aerial survey/ roadside census/ spotlight census/ quadrat
130. **Rice, W. R., and Harder, J. D. 1977. Application of multiple aerial sampling to a mark-recapture census of white-tailed deer. Journal of Wildlife Management 41:197-206.**
Abstract: A white-tailed deer population was censused in Ohio using a helicopter assisted mark-recapture technique. Bias as a result of animal behavior was reportedly alleviated using the described, 3-phase technique. Modifications and procedures for selecting optimum marking and sampling efforts were discussed.
Keywords: aerial survey/ behavior/ bias/ mark-recapture/ techniques
131. **Braden, R. G. 1978. Factors affecting summer activity of white-tailed deer with consideration of track and spotlight counts. M.S. Thesis. Stephen F. Austin University. Nacogdoches, TX. 56 pp.**
Abstract: Track counts and spotlight counts were used and compared to estimate deer density in Texas. Results indicated that spotlighting was more economical, more efficient, and provided more demographic data than track counts. Humidity, time of sunrise, and time of sunset significantly affected summer deer activity patterns.
Keywords: abundance estimation/ activity/ demographics/ spotlight survey/ Texas/ track count

132. **Burst, T. L., and Pelton, M. R. 1978. Some population parameters of the Cades Cove deer herd, Great Smokey Mountains National Park. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 32:339-347.**
Abstract: A study of the deer herd in Cades Cove, Smoky Mountains National Park was conducted to determine population density, herd behavior, and habitat utilization. Three roadside counts were conducted per week from June through September at different periods of the day (morning, dusk, evening). The minimum number of deer in the study area was estimated using bounded counts. Morning counts were found to be least productive, and variability of counts was high due to weather factors. Counts yielded lower sightings in August and September than June and July. The paper also discussed the dynamics of the herd, management options, and future research needs for Cades Cove.
Keywords: Smoky Mountains National Park/ Cades Cove/ spotlight census/ bounded count
133. **Rybarczyk, W. B. 1978. Evaluation of a spotlight survey technique as an index to Iowa white-tailed deer (*Odocoileus virginianus*) and raccoon (*Procyon lotor*) populations. M.S. Thesis. Iowa State University. Ames, IA.**
Abstract: Spotlight surveys were conducted in Iowa during six different months to determine the best time of year to survey deer with the least amount of variability. No significant difference was found between months, and the lowest variability occurred in April. There was a significant positive correlation between number of deer seen, temperature, and relative humidity during August and April. Habitat differences and the degree of deer visibility were factors contributing to variation between counts.
Keywords: Iowa/ spotlight census
134. **Beasom, S. L. 1979. Precision in helicopter censusing of white-tailed deer. Journal of Wildlife Management 43:777-780.**
Abstract: A study was conducted in LaSalle County, Texas to evaluate precision in multiple helicopter censusing of a deer herd. Results indicate that censusing of white-tailed deer during spring in low, dense, brush yielded more precise population estimates than those conducted in fall or winter.
Keywords: brushland/ helicopter survey/ Texas
135. **Fisher, A. R. 1979. Ambiguities in distance method for censusing deer by pellet groups. Journal of Wildlife Management 43:969-970.**
Abstract: Correction of typographical errors and an interpretation of Batcheler's (1975) distance method formulas were provided. The technique was not otherwise criticized.
Keywords: distance method/ formula/ pellet-group
136. **Floyd, T. J., Mech, L. D., and Nelson, M. E. 1979. An improved method of censusing deer in deciduous-coniferous forests. Journal of Wildlife Management 43:258-261.**
Abstract: Deer were enumerated using an aerial census using a two step technique. Observability of deer was calculated in test plots using radio-tagged deer. Census results were then multiplied by the reciprocal of observability figures to increase accuracy of the population estimate.
Keywords: aerial survey/ coniferous-deciduous forest/ observability
137. **Gunson, J. R. 1979. Use of night-lighted census in management of deer in Alberta and Saskatchewan. Wildlife Society Bulletin 7:259-267.**
Abstract: Night-lighted census techniques on paired transects was used to study deer in Alberta and Saskatchewan. Results indicated that the method may be more appropriate in some areas than traditional aerial censusing. Data obtained by night-lighting were useful in examining harvest and management strategies.
Keywords: Saskatchewan/ harvest data/ Alberta/ spotlight census

138. **Knight, K. B., Michael, E. D., and Woolf, A. 1979. A study of factors affecting dead deer surveys. Transactions of the Northeastern Fish and Wildlife Conference 36:120-125.**
Abstract: Effects of transect slope, carcass decomposition, and observer variation on surveys of dead deer were examined at Rachelwood Wildlife Research Preserve in Pennsylvania. Sighting success was highest on level terrain and lowest on uphill terrain. Whole carcasses were more easily observed than partially decomposed carcasses. Observer bias was the most significant factor affecting surveys, but also the most controllable factor. Reported results were considered preliminary.
Keywords: bias/ dead deer census/ decomposition/ observer error/ Pennsylvania/ slope
139. **Woolf, A. and Harder, J. D. 1979. Population dynamics of a captive deer herd with emphasis on reproduction and mortality. Wildlife Monographs #67. 53 pp.**
Abstract: The objectives of this study were to (1) document the population dynamics of a captive deer population in Pennsylvania, and (2) to evaluate census techniques, perform mortality surveys, and determine sex-age ratios within the herd. Sixteen censuses, using a variety of techniques, were made of the herd and combined with known harvest and mortality data to estimate the population size. Deer were marked for use with the Lincoln index, and sex and age ratios were obtained using spotlight counts and harvest data. Mark-recapture estimates incurred major sampling biases and violations of the random sampling assumption. Aerial censuses were better, but also biased due to the higher visibility of marked deer. All census methods provided comparable results, with the aerial survey being most precise. Harvest data, spotlight surveys, and dead deer surveys all produced sex ratios of 1:1. The monograph also went into great detail on reproductive performance and physiology, disease, and an overall evaluation of herd mortality.
Keywords: spotlight census/ aerial survey/ observability/ pellet-group/ Lincoln index/ bias/ harvest data/ mark-recapture
140. **Coe, R. J., Downing, R. L., and McGinnes, B. S. 1980. Sex and age bias in hunter-killed white-tailed deer. Journal of Wildlife Management 44:245-249.**
Abstract: Behavior of deer in Virginia and behavior of hunters and deer in Georgia and South Carolina were examined to clarify bias in hunter harvest. Factors attributing to bias in sex and age of harvested deer were discussed but not empirically studied and analyzed.
Keywords: bias/ age ratio/ behavior/ Georgia/ sex ratio/ South Carolina/ vulnerability/ Virginia
141. **Gladfelter, L. 1980. Deer population estimates in midwest farmland. Pages 5-11 in R. L. Hine and S. Nehls, eds. White-tailed deer population management in the north central states. Proceedings of the 1979 Symposium, North Central Section, The Wildlife Society.**
Abstract: Population estimates used in the midwest farmland include deer-vehicle accident reports, sex-age-kill estimates, roadside observations, aerial surveys, registered buck-kill, hunter kill-effort, landowner surveys, track-counts, conservation officer estimates, crop degradation reports, and population models. Advantages, disadvantages, and biases of individual techniques, as well as the statistical procedures associated with each were discussed. Highlights and recommendations included: most estimators could not detect changes of less than 20% in deer populations, use of multiple techniques necessary to allow comparison and reliability, new techniques should facilitate data collection and analysis, and define assumptions. Deer behavioral aspects warranted consideration in any census method, and all techniques should be field-tested.
Keywords: assumptions/ farmland/ mid-West U.S./ census

142. **Kinningham, M. J., Pelton, M. R., and Flynn, D. C. 1980. Use of the deer pellet count technique for determining densities of deer in the southeastern Appalachians. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies. 34:508-514.**
Abstract: Objectives of this study were to evaluate the feasibility of pellet-group censuses of deer in the Southeast and to determine the most effective sampling intensity. Permanent transects were established at 3 study sites and density estimates from pellet counts were compared to density estimates obtained by mark-recapture, plot sampling, and line transect methods. Estimates obtained by pellet counts were comparable to those obtained by other techniques. Sampling intervals of 3 weeks-1 month were deemed most appropriate for use in the Southeast.
Keywords: line transect sampling/ mark-recapture/ pellet-group/ plot sampling/ Southeastern U.S.
143. **Mooty, J. J. 1980. Monitoring deer populations in the northern forested sites of the midwest. Pages 13-22 in S.L. Hine and S. Nehls, eds. White-tailed deer population management in the north central states. Proceedings of the 1979 Symposium, North Central Section, The Wildlife Society.**
Abstract: Deer drives, strip counts, various mark-recapture techniques, and aerial counts were of "limited use" in forested areas of the mid-West. Advantages, disadvantages, and situations where these techniques would be best suited were discussed. More commonly used techniques for this particular area included trail counts, track counts, sex-age-kill estimates, population modeling, and pellet-group counts. Despite the expense, the pellet-group method was deemed most effective because of unbiased random sampling effort and appropriate statistical analyses associated with the method. String-counts and bed-counts, lesser known methods, were critiqued. Incorporating a collection of other biological data during the census was stressed.
Keywords: drive census/ forest/ mark-recapture/ mid-West U.S. / population model/ sex ratio/ age ratio/ harvest data/ strip census/ track count/ trail count
144. **Rowe, D. J. 1980. Spotlighting deer for determination of population trends in Oklahoma. M.S. Thesis. Oklahoma State University. Stillwater, OK. 27 pp.**
Abstract: Spotlight counts were evaluated for use in determining population trends and sex-age ratios of deer in Oklahoma. Hahn transects and drive counts were also conducted for comparison. The study was conducted over two habitat types (Cross Timbers and Oak-Hickory), and significantly more deer were observed in Oak-Hickory habitat. May and August through September were the optimum periods for maximizing counts, while late summer was best for sex-age determination. Spotlight surveys provided better estimates than either Hahn transects or drive counts. Weather and traffic did not significantly affect the number of deer observed during spotlight surveys.
Keywords: Oklahoma/ spotlight census/ Hahn survey/ drive census/ sex ratio/ age ratio
145. **Ryel, L. A. 1980. The legal deer kill--how its measured. Pages 37-45 in R.L. Hine and S. Nehls, eds. White-tailed deer population management in the north central states. Proceedings of the 1979 Symposium, North Central Section, The Wildlife Society.**
Abstract: Three deer harvest techniques used in the midwest states---compulsory deer registration, compulsory hunter report cards, and mail-back questionnaires were discussed. Registrations were considered expensive, but yielded a variety of data (sex, age, physical condition) in addition to harvest data. Mail-back surveys were considered the most economical method, but inherent problems included non-response and inaccuracy of data. Hunter report cards, similar to the mail-back survey, but required at time of license purchase, saved postal costs and insured receipt. Hunters were aware of the requirement prior to hunting so chance of errors was minimized. Biases of each method were also discussed. Less attention was given to deer traffic surveys, license stub surveys, and telephone surveys. No one method was recommended over the others and problems associated with each were detailed.
Keywords: harvest data/ mid-West U.S./ survey design

146. **White, G. C., and Eberhardt, L. L. 1980. Statistical analysis of deer and elk pellet-group data. *Journal of Wildlife Management* 44:121-131.**
Abstract: A method of testing for differences in means of pellet-group data for two or more populations without a common k value was evaluated statistically. "The parameter " k " is a positive exponent and a measure of contagion." To test the hypotheses, data were collected from 100 pellet-group plots in two habitat types. A series of four models with five associated tests were used to determine which model was appropriate for a particular data set. Factors such as sample sizes and confidence intervals were recommended as considerations in survey design. Appendices were also provided with formulas for maximum likelihood estimators and likelihood ratio tests.
Keywords: *pellet-group/ statistical properties/ population model*
147. **Wyatt, C. L., Trivedi, M., and Anderson, D. R. 1980. Statistical evaluation of remotely sensed thermal data for deer census. *Journal of Wildlife Management* 44:397-402.**
Abstract: This study assessed the feasibility of the application of thermal infrared scanners for the census of deer under conditions of snow and no direct sunlight. The authors created analyses that used the effective radiant temperature of any natural object as opposed to using the physical properties of deer and the background. Results showed that the system was more effective when there was no direct sunlight. They also found that the thermal scanner could detect deer against snow covered backgrounds, but would exhibit large errors when the probability of snow-free objects being present was greater than the probability of deer being present.
Keywords: *thermal imagery/ infrared*
148. **Beasom, S. L., Hood, J. C., and Cain, J. R. 1981. The effect of strip width on helicopter censusing of deer. *Journal of Range Management* 34:36-37.**
Abstract: Effects of strip width in aerial line transect censusing in south Texas brushlands is examined. A Bell 4-A model helicopter was used to census deer in transects estimated at 100 m on either side of the midline. Each 100 m strip was divided into 50 m strips and observers record number of deer and whether deer were sighted in the near or far 50 m strip. Thirty-four (73%) fewer animals were reported in the outer 50 m strips. It was recommended that a correction factor, derived from individual study sites, be used to alleviate negative bias associated with this type of survey.
Keywords: *bias/ helicopter survey/ line transect sampling/ Texas/ strip census*
149. **Downing, R. L. 1981. Deer harvest sex ratios: a symptom, a prescription, or what? *Wildlife Society Bulletin* 9:8-13.**
Abstract: Population simulations were used to analyze biological information obtained from harvest sex ratios. The application of these data in management strategies was criticized. It was reported that numbers of deer of each sex in the harvest, recruitment, vulnerability, and non-hunting mortality were given inadequate consideration in sex ratio data. These factors conveyed more usable information regarding herd status than harvest sex ratios used alone.
Keywords: *harvest data/ sex ratio/ population model*
150. **Krausman, P. R., and Ables, E. D. 1981. Ecology of the Carmen Mountains white-tailed deer. NPS Scientific Monograph #15. U.S. Department of the Interior, National Park Service. Washington, DC. 114 pp.**
Abstract: As part of a wide range study of an unexploited deer herd in Big Bend National Park, Texas, pellet plots were established and monitored over a three year period to estimate the population. Plots were paired at 88 m intervals along two parallel transects. White-tailed deer pellet groups were distinguished from mule deer pellet groups by pH analysis. Population estimates ranged from 790 to 1244 individuals, but the plots were biased and the estimate was high. Sex and age classification and reproductive activity of the herd were also examined.
Keywords: *Texas/ pellet-group/ pH analysis/ sex ratio/ age ratio*

151. **Wigley, T. B., and Johnson, M. K. 1981. Disappearance rates for deer pellets in the southeast. *Journal of Wildlife Management* 45:251-253.**
Abstract: Effects of temperature, precipitation, evaporation, and wind speed on disappearance rates of deer pellets were examined in Mississippi. Data were collected in areas of bare soil and in areas covered with litter. Results indicated that surveys conducted during dry seasons would provide optimal data.
Keywords: Mississippi/ pellet-group/ pellet deterioration/ weather
152. **Floyd, T. J., Mech, L. D., and Nelson, M. E. 1982. Deer in forested areas. Pages 254-256 in D. E. Davis, ed. *CRC Handbook of Census Methods for Terrestrial Vertebrates*. CRC Press, Inc. Boca Raton, FL.**
Abstract: Observability biases often cause aerial censuses to be inaccurate. The authors propose that stratified random sampling and correcting visibility bias can improve efficiency of the technique. The three major steps involved in this method, design, actual counts and data analysis, and a test of observability, were discussed. It was recommended that flight lines should be in concentric circles rather than transects, and that marked deer are the best method of gaining information on visibility and observer ability. The statistical procedure for allocating plots within a strata was also given.
Keywords: aerial survey/ stratified sampling/ observability/ observer/ bias/ random
153. **Lautenschlager, R. A. 1982. Deer (Track-Pellet). Pages 249-250 in D. E. Davis, ed. *CRC Handbook of Census Methods for Terrestrial Vertebrates*. CRC Press, Inc. Boca Raton, FL.**
Abstract: A census technique combining pellet-group and track counts was described. An overview of the pellet-group survey was given, and the problems with implementing it in the Southeastern U.S. were detailed. The importance of the determination of daily defecation rates, and the preference of large numbers of small plots were mentioned. The track-pellet-group count method was described, and the combination took less time and was as reliable as the pellet-group method alone. However, the track-pellet-group count was applicable only in areas with periodic snowfall.
Keywords: pellet-group/ track count/ defecation rate
154. **Longhurst, W. M. and Connolly, G. E. 1982. Deer (Pellet Count). Pages 247-248 in D. E. Davis, ed. *CRC Handbook of Census Methods for Terrestrial Vertebrates*. CRC Press, Inc. Boca Raton, FL.**
Abstract: An overview of the pellet-group survey method was provided. A great deal of emphasis on the assumptions associated with this technique was discussed. Five assumptions was examined in detail, with several illustrative examples for each. They stressed that the cover types within a plot must be representative of those within the overall sample areas. Pellet-group surveys show similar precision and efficacy relative to other estimation methods.
Keywords: pellet-group/ assumptions
155. **McCullough, D. R. 1982. Evaluation of night spotlighting as a deer study technique. *Journal of Wildlife Management* 46:963-973.**
Abstract: Objectives of this study on a population of known size and composition on the George Reserve in Michigan were to evaluate the spotlight method as a census technique, as a means of monitoring population trends, as method of ascertaining population composition, and as a method of studying social behavior. Counts were not affected by deer activity, group dynamics, or most weather conditions (excluding snow). Impenetrability of the spotlight in dense brush habitat was the greatest discernible liability of this technique. Seasonal effects were detected with regard to sex and age ratios.
Keywords: Michigan/ seasonal effects/ spotlight census

156. **Teer, J. G. 1982. White-tailed Deer (Texas). Pages 251-253 in D. E. Davis, ed. CRC Handbook of Census Methods for Terrestrial Vertebrates. CRC Press, Inc. Boca Raton, FL.**
Abstract: Two types of censuses (visual and sign) were described. The walking cruise or Hahn method is a two mile long transect that is walked by one person east to west, and deer are counted as they are flushed. The emphasis on this method was replication. The second method, aerial census, discussed the optimal time to fly the transect routes - just after dawn until mid-morning. Care should be given to avoid duplicate counts of individuals.
Keywords: aerial survey/ Hahn survey/ direct methods
157. **Trivedi, M., Wyatt, C. L., and Anderson, D. R. 1982. A multispectral approach to remote detection of deer. Photogrammetric Engineering and Remote Sensing. 48:1879-1889.**
Abstract: Theoretical and experimental methods were used to evaluate a system using spectral reflectance to detect deer. A specially designed circular variable filter spectrometer was used to collect data. Field experimentation was conducted during winter due to favorability of snow covered background and observations that deer concentrated in open south facing slopes to browse during this period. Generally, 2 spectral bands were sufficient for error-free detection of deer in snow covered and/or evergreen habitats. Four spectral bands provided 60% deer detection capability in more complex or five-class typical scenes. Accuracy using 4 bands increased to 90% when dry brush was not present.
Keywords: detection/ remote sensing/ spectral reflectance
158. **Shult, M. J., and Armstrong, B. 1983. Deer census techniques. Texas Parks and Wildlife Department. Austin, TX. 6 pp.**
Abstract: Census techniques employed in Texas were reviewed. Reasons for monitoring of deer were given in the introduction, and the strip census was cited as the method that was used most often. Detailed descriptions were given for the Hahn (walking) method, spotlight surveys, and the mobile line method. Basic assumptions and guidelines were discussed for each method, and the mobile line technique was rated as the least effective. Only one year of census information was not considered adequate to make management decisions (i.e., multiple years are required to document trends).
Keywords: Hahn survey/ Texas/ spotlight census/ mobile line survey
159. **Strider, P. V. 1983. Aerial deer census of Catoctin Mountain Park. National Park Service, Catoctin Mountain Park. Thurmont, MD. 8 pp.**
Abstract: An aerial deer survey was conducted at Catoctin Mountain National Park in Maryland to determine whether the current population was above carrying capacity. A flight pattern consisting of concentric circles was adopted over the traditional grid type pattern due to terrain restraints. The results of the survey were related to a carrying capacity estimate based on aerial photo interpretation. High overcast skies and >4 inches of snow cover were favored for optimum observability. Human and environmental factors that affected aerial surveys were discussed.
Keywords: aerial survey/ carrying capacity/ Maryland
160. **Creed, W. A., Haberland, F., Krohn, B. E., and McCaffery, K. R. 1984. Harvest management: the Wisconsin experience. Pages 243-260 in L.K. Halls, ed. White-tailed deer: ecology and management. Stackpole Books. Harrisburg, PA.**
Abstract: Methods of monitoring white-tailed deer populations in Wisconsin included deer registration data, sex-age-kill population estimates, pellet-group surveys, and deer trail counts. The sex-age-kill technique for estimating density was used extensively. A 20% non-harvest adjustment had been adopted for estimating adult buck population. Annual expansion factors, converted to buck-kill-to-total-population factors, were incorporated into the calculations in some management regions. Dead deer surveys and hunter pressure polls have been used to supplement the more traditional surveys.
Keywords: abundance estimation/ Wisconsin/ harvest data/ pellet-group/ sex ratio/ age ratio/ track count

161. **Gavin, T. A., Suring, L. H., Vohs, P. A., Jr., and Meslow, E. C. 1984. Population characteristics, spatial organization, and natural mortality in the Columbian white-tailed deer. *Wildlife Monographs* #91. 41 pp.**
Abstract: Population ecology of Columbian subspecies of white-tailed deer was studied in southwestern Washington. Population size was estimated using a mark-recapture (visual resighting) technique known as the Schnabel method. Observers traveled different routes simultaneously to count marked and unmarked deer. Population estimates were calculated for each month. The z-statistic was used to compare estimates between years. This population was unharmed and densities were considered high (21-30 deer/km²); however, the population was considered stable, largely due to a mild climate and "constancy of the habitat".
Keywords: Washington/ population estimation/ Schnabel method/ mark-recapture
162. **Guynn, D. E. 1984. Interpreting deer harvest records. Report B-1486. Texas Agricultural Extension Service. Texas A&M University, College Station, TX. 7 pp.**
Abstract: The role of harvest records was examined in accurately estimating population demographics. Topics covered include types of information to collect from harvested deer and methods of arranging data and performing calculations. Although the importance of harvest data in recognizing trends within deer populations was addressed, harvest management strategies were favored as opposed to population monitoring.
Keywords: harvest data/ Texas
163. **Mooty, J. J., Karns, P. D., and Heisley, D. M. 1984. The relationship between white-tailed deer track counts and pellet group surveys. *Journal of Wildlife Management* 48:275-279.**
Abstract: The relationship between deer track counts and pellet-group counts was evaluated in Minnesota. A significant linear correlation was detected between mid-summer track counts of adult deer and spring pellet-group surveys. Results from track counts exhibited high variability and were less sensitive to changes in population trends than pellet surveys. Precision was not significantly affected by route length, but was improved by increasing the number of replications.
Keywords: Minnesota/ pellet-group/ population dynamics/ replications/ track count
164. **Cypher, B. L., Yahner, R. H., and Cypher, E. A. 1985. Ecology and management of white-tailed deer at Valley Forge National Historical Park. Research/Resources Management Report MAR-15. National Park Service, Mid-Atlantic Region. Philadelphia, PA. 245 pp.**
Abstract: A general study of an "island" population at Valley Forge National Historical Park in Pennsylvania. Baseline information was collected to establish a monitoring/management plan for the herd. The population was estimated at 165-185 individuals based on 63 spotlight surveys that covered a 42 km (26.08 mi) route. Two aerial surveys and several pellet-group counts were conducted to provide additional population censuses. All survey techniques utilized in this study were based on established methodology.
Keywords: Pennsylvania/ spotlight survey/ pellet-group / aerial survey/ Valley Forge National Historical Park
165. **DeYoung, C. A. 1985. Accuracy of helicopter surveys of deer in south Texas. *Wildlife Society Bulletin* 13:146-148.**
Abstract: Population estimation of deer on 2 areas in south Texas was obtained and compared using mark-recapture and helicopter surveys. Helicopter surveys resulted in an under-representation of population size on both study sites. Possible sources of bias were discussed.
Keywords: accuracy/ bias/ helicopter survey/ mark-recapture/ Texas

166. **Euler, D. and Smith, H. 1985. Evaluating kill quotas for deer using minimal data. Pages 57-65 in S.L. Beasom and S.F. Roberson, eds. Game Harvest Management. Caesar Kleberg Wildlife Research Institute. Kingsville, TX.**
Abstract: Computer simulations were employed to examine the practice of using harvest data to establish antlerless harvest quotas in Ontario. Estimated rates of non-hunting mortality under 3 levels of winter severity were incorporated into the model. Harvest sex ratios, although limited in the ability to indicate rates of population increase or decline, were determined to be useful in evaluation where more adequate data is unavailable.
Keywords: sex ratio/ harvest data/ population model/ Ontario
167. **Hess, M. 1985. Nevada's use of change-in-ratio estimates to establish deer hunting quotas. Pages 67-78 in S. L. Beasom and S. F. Roberson, eds. Game Harvest Management. Caesar Kleberg Wildlife Research Institute. Kingsville, TX.**
Abstract: A summary of surveys, inventories, and use of change-in-ratio (CIR) models in Nevada was presented. Descriptions of development of the model, establishment of quotas, statistical assessment of the CIR model, and sampling and estimate improvements were provided.
Keywords: Assumptions/ change-in-ratio/ mule deer/ Nevada
168. **Teer, J. G., Drawe, D. L., and Urubek, R. L. 1985. Sampling patterns and intensities for helicopter censuses. Pages 15-24 in S.L. Beasom and S.F. Roberson, eds. Big Game Management. Caesar Kleberg Wildlife Research Institute. Kingsville, TX.**
Abstract: Transect and quadrat sampling schemes using helicopters were compared at varying intensities on the Welder Wildlife Refuge in Texas. Transect sampling resulted in a higher number of deer with lower variances than quadrat sampling. Variances increased as sample intensity decreased, but results were similar at levels of 33%-100% using both transects and quadrats.
Keywords: helicopter survey/ quadrat/ Texas/ transect
169. **Underwood, H. B. and Porter, W. F. 1985. Sex ratios and harvest management: a computer simulation and analysis for white-tailed deer. Pages 83-94 in S.L. Beasom and S.F. Roberson, eds. Game Harvest Management. Caesar Kleberg Wildlife Research Institute. Kingsville, TX.**
Abstract: Computer simulations and sensitivity analyses were used to examine the efficacy of sex-ratio management regimes. Assumptions and applications of various models were specifically discussed. Harvest sex ratios were determined to be most useful when combined with other data including recruitment and population size statistics.
Keywords: harvest data/ sex ratio/ simulation
170. **Wood, G. W., Davis, J. R., and Askew, G. R. 1985. An evaluation of 7 years of spotlight-count data on a coastal South Carolina plantation. Pages 25-35 in S.L. Beasom and S.F. Roberson, eds. Game Harvest Management. Caesar Kleberg Wildlife Research Institute. Kingsville, TX.**
Abstract: Five methods of calculating an index of white-tailed deer population density were used and compared in Hobcaw Barony, South Carolina. The Hanson method, using 1-km plots, was the most amenable to incorporation of all data from a number of surveys. Its use provided an estimate with a variance for all data combined. In addition to this method, descriptions were provided for the Gates index using the sighting method and the perpendicular distance method, the Hanson method using 2-km plots, and the Eberhart-Cross index.
Keywords: population estimation/ South Carolina/ spotlight census

171. **Beasom, S. L., Leon, F. G., III, and Synatzke, D. R. 1986. Accuracy and precision of counting white-tailed deer with helicopters at different sampling intensities. *Wildlife Society Bulletin* 14:364-368.**
Abstract: Four sampling intensities (100%, 50%, 25%, and 10% coverage) of helicopter surveys of deer in south Texas were compared. Accuracy is affected by intensity. However, precision (CV) at 100% and 50% sampling intensities was lower than that obtained at 25% and 10% intensity. Increasing the number of replicates decreased the level of error, thereby making use of 10% sampling intensity more reliable and cost effective.
Keywords: accuracy/ helicopter survey/ precision/ sampling intensity/ Texas
172. **Conner, M. C. 1986. Refinement of the change-in-ratio technique for estimating abundance of white-tailed deer. Ph.D. Dissertation. North Carolina State University. Raleigh, NC. 91 pp.**
Abstract: Application of and biases associated with the change-in-ratio method of estimating deer population abundance were investigated at Remington Farms, Maryland. Observability of deer was positively related to group size and was predicted by a non-linear regression model. The ratio of probability of observing does to the probability of observing bucks was estimated in 4 ways: (1) using observed group-sized frequency distributions, (2) averaging number of observations/ marked deer/road count, (3) using the CAPTURE computer software package, and (4) using unbiased Change-In-Ratio and Peterson estimates. Population estimates based on the latter method were most consistent with predictions. Recommendations for adjusting estimated sex ratios were included.
Keywords: bias/ change-in-ratio/ Maryland/ observability
173. **Conner, M. C., Lancia, R. A., and Pollock, K. H. 1986. Precision of the change-in-ratio technique for deer population management. *Journal of Wildlife Management* 50:125-129.**
Abstract: Precision of estimator, sample size requirement, and assumptions of the change-in-ratio technique for estimating populations of white-tailed deer were examined and the technique was applied to the deer population at Remington Farms, Maryland. Inherent biases were discussed.
Keywords: assumptions/ bias/ change-in-ratio/ Maryland/ precision
174. **Fafarman, K. R., and DeYoung, C. A. 1986. Evaluation of spotlight counts of deer in south Texas. *Wildlife Society Bulletin* 14:180-185.**
Abstract: Spotlight counts and helicopter counts of deer were conducted and compared in south Texas. Effects of temporal and environmental variables, relationships between density estimates, precision of density estimates, buck/doe ratios, and fawn/doe ratios were evaluated using both techniques. Time affected density estimates more than month or weather conditions. Buck/doe and fawn/doe ratios were variable and biased. Spotlight counts conducted after 33% of the nocturnal period had elapsed were considered less biased than counts obtained by helicopter survey.
Keywords: age ratio/ density/ helicopter survey/ sex ratio/ Texas/ spotlight census
175. **Franklin, W. L. 1986. A roadside technique using scent lures for measuring relative white-tailed deer abundance. *Proceedings of the Iowa Academy of Sciences* 93:44-47.**
Abstract: In this 2-phase study, 5 different scents were first evaluated for deer behavioral response. Scent stations were then used in the field to determine viability of using visitation to the sites as a census technique. There was no significant difference in response to any of the 5 scents or in visitation by free-ranging deer to scented and unscented stations. Abundance estimates of deer obtained using the scent station technique were comparable to estimates obtained using aerial surveys. Advantages of the technique included its simplicity, minimal need for equipment and tools, and the identifiability of tracks. The technique was recommended for areas where aerial surveys were cost prohibitive or precluded by topography and where vegetation obscured visibility.
Keywords: abundance estimation/ behavior/ index/ scent lure/ scent station/ Iowa

176. **Leon, F. G., III. 1986. Evaluation of white-tailed deer survey methods. M.S. Thesis. Texas A&I University. Kingsville, TX. 70 pp.**
Abstract: Three census methods (spotlight survey, fixed-wing aircraft survey, helicopter survey) were evaluated at varying sampling intensities in south Texas. Accuracy, precision, and cost were presented for each year and for each of 3 study sites. Accuracy (during the first year) of helicopter surveys was consistent, but not as accurate as spotlighting and fixed-wing aircraft surveys. The latter 2 methods exhibited between year variability for both precision and accuracy. Cost/405 ha was highest for helicopter surveys and lowest for spotlight surveys.
Keywords: accuracy/ cost/ helicopter survey/ fixed-wing survey/ precision/ Texas/ spotlight census
177. **Ford, C. R. 1987. Spotlight survey for white-tailed deer population trends on Cumberland Island National Seashore. Research/Resources Management Report Number 42. National Park Service, Southeast Region. Atlanta, Georgia. 12 pp.**
Abstract: A night-time spotlight technique was described for censusing deer on Cumberland Island National Seashore, Georgia. One driver and 2 observers using spotlights from a pick-up truck bed recorded deer seen and recorded age and sex when possible. Optimal time for surveys was approximately 30-45 minutes after sunset to coincide with peak deer activity. Late August or early September was considered the appropriate season for surveys in this particular area. It was recommended that surveys be conducted on at least 4-6 consecutive nights of similar weather conditions, but not during a full moon. Data obtained during March 1986 and sample data sheets were included in the report.
Keywords: spotlight census/ census/ Georgia
178. **Herriges, J. D., Jr. 1987. Population ecology and habitat relationships of white-tailed deer in eastern Montana. BG-2. Montana Department of Fish, Wildlife and Parks. Helena, MT. 131 pp.**
Abstract: Distribution, movements, activity and habitat use by white-tailed deer in eastern Montana were studied from 1982 to 1984. The majority of data collection was completed through the radio-marking and relocation of 51 individuals. Additional density and habitat use information were obtained through spotlight surveys of agricultural land. Complete coverage of the Elk Island study area was also conducted by aerial survey. Census data collected was supplemental to the telemetry data and not considered an integral part of the overall study.
Keywords: Montana/ spotlight survey/ radio telemetry
179. **Leon, F. G., III, DeYoung, C. A., and Beasom, S. L. 1987. Bias in age and sex composition of white-tailed deer observed from helicopters. Wildlife Society Bulletin 15:426-429.**
Abstract: Helicopter resightings of marked deer were evaluated in south Texas to determine the possibility of obtaining unbiased sex ratios. Data were pooled from 6-8 flights for statistical analyses. Sex and age bias in herd composition was not evident, although the possibility of overlooking antlers of small bucks and incorrectly classifying them as females was addressed.
Keywords: age ratio/ bias/ helicopter survey/ sex ratio/ Texas
180. **Prachar, R. E., Sage, R. W., Jr., and Underwood, H. B. 1987. Pellet group and track counts as indicators of white-tailed deer abundance and habitat use on Huntington Wildlife Forest. Adirondack Ecological Center Special Project, Number 16 Syracuse, NY. 40 pp.**
Abstract: Pellet-group counts and track counts were used to ascertain population abundance and habitat use by white-tailed deer on Huntington Wildlife Forest, New York. Sample sizes for pellet counts were inadequate for all years of the study. Generally, track counts provided more information and were deemed more reliable than pellet-group counts. Methodology employed for both techniques was described within the paper, and a more detailed description of pellet-group counts was included in an appendix. Examples of data sheets were also included in the appendix.
Keywords: abundance estimation/ habitat/ pellet-group/ track count

181. **Rogers, L. L. 1987. Seasonal changes in defecation rates of free-ranging white-tailed deer. *Journal of Wildlife Management* 51:330-333.**
Abstract: Defecation rates were calculated seasonally for 7 female white-tailed deer in a coniferous-deciduous forest in Minnesota. Significant seasonal differences were apparent except between winter and spring green-up. Defecation rates were lower for penned deer than for free-ranging deer.
Keywords: coniferous-deciduous forest/ defecation rate/ free-ranging deer/ penned deer/ seasonal effects/ Minnesota
182. **Shupe, T. E., and Beasom, S. L. 1987. Speed and altitude influences on helicopter surveys of mammals in brushland. *Wildlife Society Bulletin* 15:552-555.**
Abstract: Effects of speed and altitude on precision, age and sex ratios, and cost effectiveness of helicopter surveys of white-tailed deer, collared peccaries, coyotes, and feral hogs were determined in south Texas brushlands. No discernible loss of precision of counts or sex ratios of deer was evident at air speeds from 48-72 km/h; however, flying at 72 km/h reduced flying time, thus minimizing cost. Age ratios of deer were affected by decreased ability to observe spikes at altitudes of 55 m or higher.
Keywords: age ratio/ altitude/ brushland/ helicopter survey/ Texas/ speed
183. **Tilton, D. A., Teer, J. G., and Silvy, N. J. 1987. Accuracy and precision of line transect procedures for white-tailed deer. *Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies* 41:424-431.**
Abstract: The accuracy and precision of line transect estimates of deer density were tested by comparing results to those obtained by drive census. Accuracy of sex ratio data obtained from line transects was also evaluated. The Hayne Constant Radius estimator was most comparable to the drive count during fall censusing. Estimates obtained during summer indicated the Exponential estimator was most accurate. Accuracy was greatest for the Generalized Exponential method when considering both fall and summer estimates. Polynomial, triangular, and exponential procedures were most precise for summer, fall, and combined surveys, respectively. Drive counts resulted in lower buck-to-doe ratios than the estimates obtained from line transects.
Keywords: accuracy/ drive census/ estimate/ line transect sampling/ precision/ sex ratio
184. **McCullough, D. R., and Hirth, D. H. 1988. Evaluation of the Petersen-Lincoln estimator for a white-tailed deer population. *Journal of Wildlife Management* 52:534-544.**
Abstract: Accuracy of the Peterson-Lincoln estimate was tested for a period of 32 months on a penned population of white-tailed deer on the George Reserve in Michigan. Results indicated an error rate of -30 to 138% with positive biases being most prevalent. Problems associated with the assumption of equal observability and catchability were cited as the greatest liability to the estimator. Sample size of marked animals observed was the second most important variable contributing to the error rate. Viability of the Peterson-Lincoln estimator and suggestions for diminishing errors were discussed.
Keywords: bias/ mark-recapture/ Lincoln index

185. **Roseberry, J. L., and Woolf, A. 1988. Evidence for and consequences of deer harvest data biases. Proceedings of the Annual Conference of Southeast Association of Fish and Wildlife Agencies. 42:306-314.**
Abstract: While not a techniques or methods paper, this manuscript raised some important considerations for managers who estimate deer populations based on harvest data. Daily harvest records for 165,000 deer over 7 hunting seasons in Illinois were examined for evidence of bias. Factors studied were availability, differential vulnerability, and hunter selectivity. Results focused on a representation of sex-age groups over each day of the six day hunting season. Biases involving various sex-age classes can affect calculation of certain population parameters from harvest data. Overrepresentation of yearlings, fawn/doe harvest ratios, and the overall impact of the female harvest could all have serious implications in population estimation.
Keywords: Illinois/ bias/ harvest data/ sex ratio/ age ratio/ population estimation
186. **DeYoung, C. A., Guthery, F. S., Beasom, S. L., Caughlin, S. P., and Heffelfinger, J. R. 1989. Improving estimates of white-tailed deer abundance from helicopter surveys. Wildlife Society Bulletin 17:275-279.**
Abstract: Two methods of alleviating negative bias in estimates of deer abundance obtained by helicopter survey were evaluated in brush dominated habitats in Texas. Base counts for assessment of improvements were estimated using the Bailey mark-recapture technique. A correction factor, based on frequency distributions of groups observed in belts paralleling the flight line, was more effective in reducing bias than reduction of counting strip width. However, the correction factor was developed on 2 sites and samples lacked independence.
Keywords: helicopter survey/ bias/ Texas
187. **DeYoung, C. A., Heffelfinger, J. R., Beasom, S. L., and Coughlin, S. P. 1989. Classifying male white-tailed deer from a helicopter. Proceedings of the Annual Conference of Southeastern Association Fish and Wildlife Agencies 43:292-296.**
Abstract: The ability of observers to classify male deer into two age classes (≤ 3.5 years and ≥ 4.5 years) from a helicopter was evaluated in south Texas. The criteria for classifying males from a helicopter, antler size and body musculature, are highly subjective. On average, greater than 90% of marked males were correctly classified, however, some flights gave inaccurate estimates where $>10\%$ were classified incorrectly. Avoidance of using male composition data from individual flights in calculation of harvest rates for a particular age class is recommended. Instead, this data would be more useful to indicate trends through time.
Keywords: Texas/ helicopter survey/ age ratio
188. **Dusek, G. L., Mackie, R. J., Herriges, J. D., Jr., and Compton, B. B. 1989. Population Ecology of White-tailed Deer along the lower Yellowstone River. Wildlife Monographs #104. 68 pp.**
Abstract: Population size, structure, and trends along with relationships to habitat were studied in a deer population along the lower Yellowstone River in eastern Montana. Historical abundance was reviewed and recent population trends were estimated using "aerial surveys designed for census". Fixed wing aircraft were used using the same pilot and observer; complete coverage of the entire area or "intensive study units" were employed. One section of the study area was censused with a helicopter for a two year period. Marked deer (12-16% of the population was marked) were used to produce population estimates using a Lincoln index. Deer numbers increased since the 1940s. Although accurate census data were lacking prior to the study, trends in harvest and recruitment were considered the best indicators of population size. Increase in abundance and widespread distribution of deer was considered a reflection of changing habitat due to current land use practices and elimination of other ungulates.
Keywords: population dynamics/ Montana/ Lincoln index/ census/ mark-recapture

189. **Storm, G. L., Yahner, R. H., Cottam, D. P., and Vecellio, G. M. 1989. Population status, movements, habitat use, and impact of white-tailed deer at Gettysburg National Military Park and Eisenhower National Historic Site, Pennsylvania. Technical Report NPS/MAR/NRTR-89/043. National Park Service, Mid-Atlantic Region. Philadelphia, PA. 390 pp. + Appendices and Tables (123 pp.) .**
Abstract: The study examined several aspects of deer ecology on National Park Service lands in Pennsylvania including seasonal abundance. Deer were counted using multiple techniques: counts from vehicles along designated survey routes at dawn and dusk, spotlight surveys, and morning counts from a helicopter. Randomly placed deer targets (life-sized photographs of deer mounted on styrofoam) were used throughout the study area to enhance the quality of counts. Marked deer were used to determine population estimates.
Keywords: Pennsylvania/ Gettysburg National Military Park/ Eisenhower National Historic Site/ spotlight survey/ helicopter survey/ direct methods/ mark-recapture
190. **Wathen, W. G., and New, J. C., Jr. 1989. The white-tailed deer of Cades Cove: population status, movements and survey of infectious diseases. Research/Resources Management Report SER-89/01. National Park Service, Southeast Region. Atlanta, Georgia. 139 pp.**
Abstract: A study was conducted on the population dynamics, movement ecology and diseases of white-tailed deer in Cades Cove, Smokey Mountain National Forest in Tennessee. The population was surveyed using spotlight surveys. Counts were conducted bi-weekly, and additional dawn and dusk counts were used to obtain data on sex ratios, productivity and ratios of marked to unmarked individuals. The authors suggest that the use of mark-recapture techniques yield more precise population estimates than spotlight surveys due to seasonal variations in spotlight surveys and differences in seasonal habitat utilization patterns.
Keywords: Tennessee/ spotlight survey/ mark-recapture
191. **deCalesta, D. S., and Witmer, G. W. 1990. Drive line census for deer within fenced enclosures . Research Paper, NE-643 . U.S. Forest Service, Northeast Forest Experimental Station. Radnor, PA. 4 pp.**
Abstract: A detailed description of methodology for the line drive census was provided. Essentials of proper spacing and proper alignment of drivers were included. Results using this technique were comparable to results obtained using the pellet count technique in the same enclosure. Organization and communication were stressed as essential to successful line drive censuses.
Keywords: drive census/ enclosure/ Pennsylvania/ techniques
192. **Sawyer, T. G., Marchinton, R. L., and Lentz, W. M. 1990. Defecation rates of female white-tailed deer in Georgia. Wildlife Society Bulletin 18:16-18.**
Abstract: Four does (1 adult and 3 yearlings) were outfitted with radio collars and released on the Whitehall Experimental Forest study area to evaluate defecation rates. An overall mean of 26.9 defecations/deer/day was reported with an increase in defecation rate during autumn. A defecation rate of 25 or more was deemed appropriate for use in population estimation, particularly during autumn.
Keywords: defecation rate/ Georgia/ pellet-group

193. **Sullivan, J. B., DeYoung, C. A., Beasom, S. L., Heffelfinger, J. R., Coughlin, S. P., and Hellickson, M. W. 1990. Evaluation of bias in the proportion of white-tailed deer fawns sighted from helicopters. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 44:202-205.**
Abstract: This study compared frequency of sightings of marked fawns versus older deer from helicopters on two south Texas study areas. Fawns were marked with color-coded radio-transmitter collars for individual recognition. Results found that the proportion of marked fawns sighted on helicopter surveys was generally lower than the overall proportion of fawns in the marked population. Two potential reasons for this underestimation were that not all fawns were marked with ear tags, thus decreasing visibility, and the basic size difference between fawns and older deer. Although pooled data was analyzed for this analysis, the authors stated data was best evaluated on an individual flight basis.
Keywords: fawn/ Texas/ helicopter survey
194. **Cypher, B. L. 1991. A technique to improve spotlight observations of deer. Wildlife Society Bulletin 19:391-393.**
Abstract: Attention eliciting techniques to improve eye tapetum reflection during spotlight surveys were tested. Increases in the number of deer per observation were apparent using a whistle or a predator call. Predator calls resulted in a flight response from some deer whereas flight responses were not evident using the whistle.
Keywords: attention eliciting devices/ eye tapetum/ spotlight census
195. **Fuller, T. K. 1991. Do pellet counts index white-tailed deer numbers and population change? Journal of Wildlife Management 55:393-396.**
Abstract: Deer densities in north-central Minnesota, calculated from pellet counts were compared to estimates derived from aerial surveys. Effects of pellet degradation were incorporated into the pellet count based estimate using regression analysis, and observability bias was incorporated into the aerial survey estimates. No significant correlation was evident between pellet counts or estimated deer density and estimates from aerial surveys. Variability of defecation rate was cited as the probable cause limiting use of pellet groups as a reliable indicator of deer density.
Keywords: aerial survey/ defecation rate/ density/ pellet-group/ Minnesota
196. **Novak, J. M., Scribner, K. T., DuPont, W. D., and Smith, M. H. 1991. Catch-effort estimation of white-tailed deer population size. Journal of Wildlife Management 55:31-38.**
Abstract: A stochastic catch-effort competing risks model of natural and hunter-induced mortality was described and used to estimate population size of the Savannah River Site deer herd. Inherent assumptions of the model include: (1) hunting and natural mortality are additive and are correctly modeled by the hazard regression equations; and (2) compared to probability of a single capture or death, probability of the death of >1 individual in a given short time interval is small. Required data include cohort specific hunter kills for consecutive intervals, hunter effort required for the kills, and life history data. Results using this model represented realistic estimation of Savannah River Site deer herd, but its value in other areas is dependent on strength and integrity of data set. Relaxed assumptions, inclusion of confidence limits on estimates, and ability to incorporate area-specific variables constitute some advantages of this model. Necessary formulas, assumptions and availability of associated software problems were discussed.
Keywords: assumptions/ catch-effort/ Savannah River/ stochastic model

197. **Stoll, R. J., Jr., McClain, M. W., Clem, J. C., and Plageman, T. 1991. Accuracy of helicopter counts of white-tailed deer in western Ohio farmland. *Wildlife Society Bulletin* 19:309-314.**
Abstract: Ground counts were used to determine accuracy of helicopter counts of white-tailed deer during winter between 1982-1987. Helicopter counts were conducted using 2 observers and the pilot. A combined ground count and helicopter search was performed immediately after the initial helicopter count using 18-20 drives. Counts obtained by ground survey and by helicopter survey were similar. Sparsely wooded habitat, uniform background of snow cover, and readily detectable tracts were factors contributing to a high degree of similarity.
Keywords: *helicopter survey*
198. **Potvin, F., Breton, L., and Gingras, A. 1992. Application of a double-count aerial survey technique for white-tailed deer, *Odocoileus virginianus*, on Anticosti Island, Quebec. *Canadian Field Naturalist* 106:435-442.**
Abstract: A double-count survey (2 observers, front and rear on same side of aircraft) was used to census deer on Anticosti Island. The technique, uncorrected, increased the density estimate by 35%. When corrected using the Peterson model (also known as the Lincoln index), the estimate was increased 58%. Use of separate corrected estimates for single deer and for groups of deer was recommended.
Keywords: *aerial survey/ double-count/ Lincoln index/ Quebec/ visibility bias*
199. **Shea, S. M., Breault, T. A., and Richardson, M. L. 1992. Herd density and physical condition of white-tailed deer in Florida flatwoods. *Journal of Wildlife Management* 56:262-267.**
Abstract: Spotlight surveys were used to estimate relative deer density during 1980-1989. Herd condition was evaluated during the same period using physiological indices of yearling bucks. Despite density decreases of 75%, improvement in physiological condition was not observed. Results indicated that inverse relationships between herd density and physiological indices were less apparent in habitats of abundant, low quality forage. It was recommended that deer management strategies in relatively low quality habitat should therefore be determined using multiple, or more site-specific criteria.
Keywords: *habitat/ physiological indices/ relative abundance*
200. **Storm, G. L., Cottam, D. F., Yahner, R. H., and Nichols, J. D. 1992. A comparison of 2 techniques for estimating deer density. *Wildlife Society Bulletin* 20:197-203.**
Abstract: Mark-resight and area conversion estimates of deer abundance were calculated and compared near Gettysburg, Pennsylvania. Sighting probability was similar for marked and unmarked deer because of abundant open areas and extensive roadways. However, the assumption of equal distribution inherent in the area-conversion method could not be met in this study area. Additionally, deer marked for estimation using the mark-resight method diminished the possibility of double-counting deer during surveys conducted at dusk. The mark-resight method was deemed more appropriate for this particular area.
Keywords: *area conversion/ assumptions/ mark-recapture/ Pennsylvania*
201. **White, G. C. 1992. Do pellet counts index white-tailed deer numbers and population change? a comment. *Journal of Wildlife Management* 56:611-612.**
Abstract: White criticized Fuller's (1991) contention that pellet counts were of limited use as an index to deer density. He stressed the weak power of statistical analyses and denounced comparison of pellet-group counts to aerial censuses because the aerial census was not a true count.
Keywords: *aerial survey/ pellet-group*

202. **Whipple, J. D., Rollins, D., and Schacht, W. H. 1994. A field simulation for assessing accuracy of spotlight deer surveys. *Wildlife Society Bulletin* 22:667-673.**
Abstract: Variability associated with spotlight surveys was assessed in west Texas. Populations of simulated deer were constructed using reflective thumbtacks in dense (juniper) and defoliated (mesquite) habitats. Three independent teams estimated strip width, deer density, and sex of individuals within each habitat. Width of dense habitat was overestimated while width of defoliated habitat was underestimated. Deer density was overestimated in dense habitat and underestimated in defoliated habitat. Accuracy for both deer detection and sex identification was high. The authors suggested that spotlight survey data would be more useful for indices of abundance rather than deer density estimates.
Keywords: census/ spotlight census/ Texas
203. **Fritzen, D. E., Labisky, R. F., Easton, D. E., and Kilgo, J. C. 1995. Nocturnal movements of white-tailed deer: implications for refinement of track-count surveys. *Wildlife Society Bulletin* 23:187-193.**
Abstract: Radio telemetry was used to compare activity among age-sex groups within and between low and high density populations in northern Florida. Nocturnal rate of travel, distance between locations, and frequency of road crossings were examined on both sites. Deer were significantly more active at night on the high density site, suggesting that population density alone may affect behavior regardless of quantity and quality of forage. The results falsified 2 major assumptions of Tyson's (1952) track-count survey method. Authors modified the track-count technique by reducing estimated nocturnal range and increasing number of tracks observed along transect line to compensate for deer that cross roads only once.
Keywords: Florida/ nocturnal movements/ population estimation/ track-count
204. **Mandujano, S., and Gallina, S. 1995. Comparison of deer censusing methods in tropical dry forest. *Wildlife Society Bulletin* 23:180-186.**
Abstract: Three different methods of censusing deer, track counts, pellet group counts, and direct counts from line transects, were compared in tropical dry forest habitats in Mexico. The main hypothesis was that all methods would yield similar density results, but actual density estimations varied 17 fold between methods (1.6-27.6 deer/km²). Pellet group counts were conducted only during dry seasons due to site accessibility problems. Basic biological factors such as defecation rate/day and daily movement patterns in a particular area were unknown, potentially leading to inaccurate conversion factors for the pellet group and track count methods. Direct counts were cited as the overall preferred method, as no conversion factor was needed.
Keywords: census/ density/ tropical deciduous forest
205. **Rivest, L. P., Potvin, F., Crepeau, H., and Daigle, G. 1995. Statistical methods for aerial surveys using the double-count technique to correct visibility bias. *Biometrics* 51:461-470.**
Abstract: Statistical methods were presented to reduce negative bias associated with aerial surveys. One solution involved classifying animals seen according to variables potentially influencing visibility during the survey. A second potential was to use parcel-specific correction factors based on variance estimators. Both methods were defined and discussed in terms of statistical equations within the paper. Each method was tested using data from deer population surveys done on Anticosti Island in the St. Lawrence Gulf. Results showed a correction of 10-13% for double-count surveys compared with 33% for single-count surveys, and that the double-count survey is an attractive method for correcting the visibility bias associated with aerial surveys.
Keywords: mark-recapture/ multinomial distribution/ Lincoln index/ population estimation/ stratified sampling

206. **Naugle, D. E., Jenks, J. A., and Kernohan, B. J. 1996. Use of thermal infrared sensing to estimate density of white-tailed deer. *Wildlife Society Bulletin* 24:37-43.**
Abstract: Deer density was estimated using both spotlight surveys and an infrared sensing system at Sand Lake National Wildlife Refuge in South Dakota. Over three field seasons, deer density was estimated at 16.5 deer / km² with infrared sensing and 8.9 deer / km² using spotlight surveys. Infrared detected 88.2% of deer counted from the ground, while the spotlight surveys underestimated density by 38%. Although infrared was deemed to be more reliable than spotlight surveys, infrared was about four times more expensive.
Keywords: *density/ infrared/ spotlight census/ transect*
207. **Romin, L. A., and Bissonette, J. A. 1996. Deer-vehicle collisions: status of state monitoring activities and mitigation efforts. *Wildlife Society Bulletin* 24:276-283.**
Abstract: Questionnaires were sent to 50 state natural resource agencies in 1992. Inquiries were made into estimates of deer killed per year on highways, sources of those estimates, and methods used to reduce collisions. Total 1991 road kill of deer was in excess of 500,000. Twenty-six of 29 states with trend data over the previous 10 years showed a steady increase in collisions per year. Twenty-four states keep annual counts of deer mortality from highway collisions. Management efforts were reviewed and alternatives provided for reducing highway collisions.
Keywords: *mortality/ highways / auto-deer collisions/ road-kills*
208. **Seagle, S. W., and Close, J. D. 1996. Modeling white-tailed deer *Odocoileus virginianus* population control by contraception. *Biological Conservation* 76:87-91.**
Abstract: The Generalized Animal Population Projection System (GAPPS II) was used to simulate temporal effects of contraception on deer population control and immigration rates. Results from the model showed that a minimum contraception rate of 50% of does was necessary to reduce the population, and this took 5-10 years to be detectable in a closed population. Variability in trials was high, leading to difficulty in detecting population changes in the field. This approach was deemed to be an inviable option for control and estimation of open populations.
Keywords: *contraception/ population dynamics/ immigration/ simulation/ landscape*
209. **Jacobson, H. A., Kroll, J. C., Browning, R. W., Koerth, B. H., and Conway, M. H. 1997. Infrared-triggered cameras for censusing white-tailed deer. *Wildlife Society Bulletin* 25:547-556.**
Abstract: This study evaluated use of cameras triggered by infrared sensors to estimate population size of free-ranging deer in a forested environment in Mississippi. Population size was determined using photographs of previously marked deer to establish Lincoln-Petersen (LP) index estimates and the total number of sex and age groupings subsequently applied to demographic ratios, the number of spike bucks, does, and fawns. The latter technique was termed the "camera estimate". At various densities, sex ratios and LP estimates differed significantly and there was an inverse relationship between deer density from documented with cameras and LP population estimates. The authors considered cameras a useful technique and costs (over a 5 year equipment expectancy) were reasonable.
Keywords: *census/ infrared-triggered camera/ Lincoln index/ mark-recapture*

210. **Koerth, B. H., McKown, C. D., and Kroll, J. C. 1997. Infrared-triggered camera versus helicopter counts for white-tailed deer. *Wildlife Society Bulletin* 25:557-562.**
Abstract: Counts of a white-tailed deer population in south Texas were compared using infrared-triggered cameras and replicate helicopter counts. Number of spike and antlered bucks estimated by the two techniques were similar but the camera technique estimated fewer fawns and does. Use of bait sites by other large animal species precluded use by deer. The exact size of this population was unknown but the authors felt that both techniques gave reasonable population estimates. The utility and cost-effectiveness of the camera technique versus helicopters at different times of the year and at varying deer densities were discussed.
Keywords: *aerial survey/ census/ helicopter survey/ infrared-triggered camera/ Texas*
211. **McShea, W. J., Underwood, H. B., and Rappole, J. H. 1997. The science of overabundance: deer ecology and population management. Smithsonian Institution Press. Washington, DC. 402 pp.**
Abstract: A variety of research on different deer populations was compiled into one volume along with various perspectives on philosophy and management. Effects of high density herds on ecosystems were explored using a variety of case studies. Several chapters included estimating deer population size as a component of a larger project. Techniques like drive counts, distance line-transect sampling, pellet group counts, and reconstruction modeling were used in areas where deer populations were typically considered overabundant. Density dependence was also reviewed.
Keywords: *overabundance / population dynamics*
212. **Underwood, H. B., Verret, F. D., and Fischer, J. P. 1998. Density and herd composition of white-tailed deer populations on Fire Island National Seashore. NPS/NESO-RNR/NRTR/98-4. National Park Service, New England System Support Office. Boston, MA. 42 pp.**
Abstract: A study was conducted using distance sampling to estimate deer populations on Fire Island, New York. Results were compared to estimates obtained from aerial surveys of the same area. Distance technique was evaluated in terms of statistics, biology of local deer populations (i.e., density). Distance sampling was relatively easy to use (minimal effort in time) but several months of work were necessary to achieve "high technical proficiency".
Keywords: *distance sampling/ aerial survey/ transect/ density/ Fire Island*

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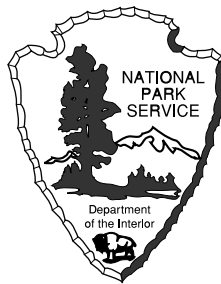
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As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and MUM, preserving the environmental and cultural values of our national parks and historical places, and providing for enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility of the public lands and promoting citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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