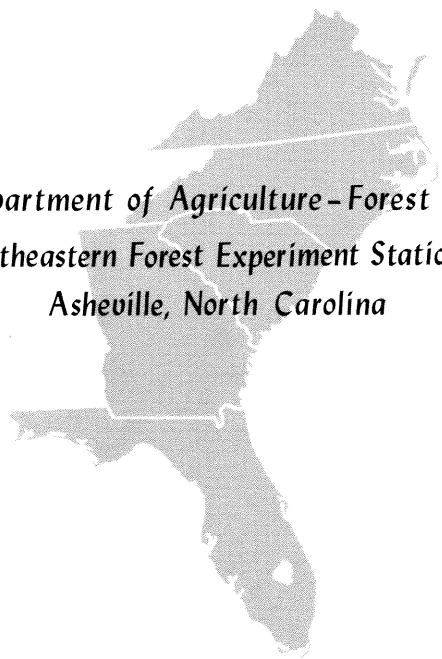
U. S. Forest Service Research Paper SE- 30 December 1967

Forests, Wildlife, and Habitat Management--
A critical examination of practice and need

by

Joseph S. Larson



U.S. Department of Agriculture-Forest Service
Southeastern Forest Experiment Station
Asheville, North Carolina

TABLE OF CONTENTS

Forests, Wildlife, and Habitat Management--
A critical examination of practice and need

by

Joseph S. Larson,[1] *Assistant Leader*

Massachusetts Cooperative Wildlife Research Unit
University of Massachusetts
Amherst, Massachusetts

INTRODUCTION

The history of the relationship between man and wildlife in the United States includes several stages, starting with the American Indian tribes, running through the conquest of the land by white man, and ending with man's attempt to protect, husband, and finally manage wildlife populations.

When it was realized around the beginning of the 20th century that many species of wildlife would be exterminated if action were not taken, a variety of efforts were made to "do something for wildlife." Legal protection, creation of refuges, and stocking of native and exotic species were typical action programs which characterized this period. Subsequent critical examination of a number of these efforts has shown that, although they were effective at the time, they were mainly stopgap measures which were not of long-term value to wildlife. As a result, and often accompanied by public protest, wildlife agencies have shifted from programs directly involving the animals to programs centered on habitat management. Thus, habitat management has largely replaced husbandry in the modern wildlife management program. Refuges, hatcheries, game farms, and buck laws have been shown to be of less lasting value than manipulation and restoration of the environment which wild species call home.

---

[1]The author presented a more detailed version of this study as a dissertation to the graduate faculty of the Virginia Polytechnic Institute in partial fulfillment of the degree Doctor of Philosophy.

Financial support was supplied through the Virginia Cooperative Wildlife Research Unit (U. S. Bureau of Sport Fisheries and Wildlife, Virginia Commission of Game and Inland Fisheries, Virginia Polytechnic Institute, Wildlife Management Institute) and Virginia Agricultural Experiment Station by the U. S. Forest Service, Southeastern Forest Experiment Station, Project FS-SE-1801-5.

Acknowledgments. --Many key personnel from state wildlife agencies and National Forests provided data for this study, and the author gratefully acknowledges the key role they generously played. Dr. Thomas H. Ripley, U. S. Forest Service, Southeastern Forest Experiment Station, initially recognized the need for a study of this type, arranged material support, and gave professional encouragement throughout. Professor Thomas C. Evans, formerly Department of Forestry and Wildlife, Virginia Polytechnic Institute, provided continuing guidance and critical review of a very valuable nature. The University of Maryland, Natural Resources Institute, provided support during preparation of the final report.

However, the pressure for action programs which leave some visible mark on the land has continued. Public demand, channeled through public-sensitive administrators, has resulted in land management programs vast in scope and high in cost. Among these is the very extensive and often intensive creation of agricultural clearings in forested areas for wildlife habitat improvement. The following report is a critical review of this practice.

Study Objectives

1. To determine the nature and extent of the forage clearing practice in forests of the Eastern United States for game animal management.

2. To evaluate critically the present body of knowledge concerning the contribution of this practice as a basis for:

   a. Programing effective research

   b. Providing guides for interim management policies and procedures pending expanded knowledge.

Definitions

By definition, this study is concerned only with one type of clearing practice; namely, clearings in forest habitat, natural or manmade, which are maintained in natural or artificially planted agricultural forage crop species. These forest clearings may be simply natural grassy openings, or clearings which have been planted and maintained in an agricultural crop for wildlife. Maintenance may be as simple as periodic mowing to retain a certain botanical composition, or may entail annual plowing, disking, liming, fertilization, and seeding.

It is recognized that sprout clearings, seeded utility rights-of-way, trails, skidroads, and fire lanes are associated types of forest-wildlife management. Each of these have values under a wildlife management program but will be only incidentally mentioned in this study.

The writer has found confusion in the literature concerning the use of the term forage. For the purpose of this discussion, forage species are defined as herbaceous agricultural or native plants. Where used, the term browse means woody vine, shrub, or tree species.

Organization of the U. S. Forest Service Regions mentioned herein is in accordance with the organization which was in effect on May 31, 1965.

SOME BACKGROUND MATERIAL

In the course of the original study the writer made an extensive review of the literature pertaining to clearings (119 North American and European references cited), conducted field inspection trips in 11 states, obtained data by personal interview with key personnel from 10 additional states, and received data from 3 states through correspondence alone. These data are presented in considerable detail elsewhere, and the reader is referred to it for more specific information (Larson 1966a). For present purposes, a summary of this material follows.

Organized programs of clearing installation started in 1935 and have involved 22 eastern and southeastern states. Over 30,000 acres of forest land have been cleared. The present status of the programs in each state is varied (table 1). One-third to one-half of the total acreage in forage clearings occurs on National Forest land, and clearings in general occupy sites which are less desirable for other land-management

Table 1.--Acreage in clearings, initial year of installation, and status of clearing program by states

State	Clearing size	Initial installation	Status of programs
	Acres	Year	
Virginia	4,255	1936	Cutting back since 1959
Pennsylvania	4,000	1935	Cutting back since 1950
Illinois	3,600	1950 - 1954	Continuing
Tennessee	3,244	1950	Leveling out since 1957
West Virginia	2,108	1945	Cutting back since 1950
Maryland	2,090	1936	Cutting back since 1945-50
Mississippi	2,000	1935 - 1939	Cutting back since 1959-60
Kentucky	1,220	1946	State stopped in 1950-55; U. S. Forest Service is continuing
Florida	1,181	1947	Cutting back since 1960
South Carolina	1,000	1948	Cutting back since 1950-55
New Jersey	1,000	1946	Continuing
Indiana	882	1953	Continuing
Alabama	875	1945 - 1946	Continuing
Georgia	640	1945 - 1949	Cutting back since 1962
Ohio	500	1935	Ceased in 1962
Louisiana	453	1954	Continuing
Missouri	425	1959	Ceased in 1963
North Carolina	350	1949	Leveling out since 1964
Texas	200	1940's	Stable
Massachusetts	108	1964	Experimental
Oklahoma	60	1950	Ceased in 1960-64
New Hampshire	15	1951	Ceased in 1953
Total acres	30,206		

programs. With some notable exceptions, most states continue to maintain clearings already established; but trends indicate that new clearings will be established at a reduced rate.

The U. S. Forest Service's Region 8 distinguishes between forest openings and agricultural forage clearings and does not encourage creating the latter. Regions 7 and 9 do not make a distinction; and in the Shawnee National Forest, the State of Illinois pays the Forest from $70,000 to $90,000 annually to install forage clearings.

Agricultural clearings are created in the same manner, with some exceptions, in all states. Trees are removed, a seedbed is prepared and sown, and lime and fertilizer are applied. A great variety of crops have been tried by managers, mostly on a trial-and-error basis, though recommendations of state agronomists and the U. S. Soil Conservation Service have been important influences. Few records of success or failure have been kept on crops (a detailed list of crops tried in the various states appears in Larson 1966a).

Mowing, ranging in frequency from twice a year to once every 2 years, is the most common crop-maintenance procedure (outside of soil amendments) for perennial species. Complete renewal of clearings ranges from once a year to once every 5 to 10 years. Some states renew their clearings each year as a matter of practice. One state reported that this was done to justify having the men and equipment on hand, despite the fact that a permanent forage planting could be maintained with less frequent treatment. Soil tests are used sparingly, often only at the creation of a clearing, with all future soil amendments based on it alone. One clearing in a group may be deemed representative of the whole, or "standard" applications of lime and fertilizer may be used, based on the practices of the nearest farmers growing the crop in question.

Clearing sizes range from 1/10 to 60 acres. The most common lower limit is between 1/4 to 1 acre, and the most common upper limit is between 10 and 20 acres. Average sizes of clearings run from between 1/2 to 3/4 acre to 5 and 7 acres, most commonly 1 to 3 acres. Size and shape of clearings are usually dictated by the available site; and selection of sites is usually dictated by location of public land, forest-management policies, and existing openings. Percent of area goals and patterns of clearing installation varied widely, but the writer failed to find any objective evidence or investigations to support these. In fact, the tendency has been to accept various percent goals which have a basis in common sense, aimed to meet an immediate administrative need, and then to settle for whatever percent or pattern the topography of an area permits.

When biologists were questioned about the major role clearings play in their forest-game management programs, provision of supplemental food was by far the most frequently cited role. Fourteen of the states gave this as the major contribution and four others ranked it in second place. Second cited among the major roles of clearings was the addition of "edge effect." Nine states reported this as the primary role and three

placed it second. Three states felt that influencing harvest of game animals was the prime role of clearings, three placed this factor second, two placed it third, and one placed it fourth. Three states felt that public relations value was the first role of clearings, three put this item second, and one third. Three states put influence on animal distribution first, one ranked this second, and one third in order of importance. A number of states expressed opinions indicating that alternative methods could or were being employed to achieve the same objectives originally ascribed to clearings.

There is almost a complete lack of studies to measure wildlife utilization of vegetation planted on clearings or to measure the effects of clearings on animal numbers or distribution. There is a similar lack of information on the effect clearings have on hunter success, distribution, and use of management areas.

In conjunction with this study, the writer tested a statistical sampling approach for measuring forage production and utilization on ladino clover clearings and reported on this in another paper (Larson 1966b).

DISCUSSION

The Rationale for Clearings

Wildlife management, based on habitat manipulation, is closely tied to ecological changes, both natural and manmade. Deer, turkeys, and ruffed grouse are referred to as forest game species; and it was earlier believed that the preservation of large tracts of forest land automatically meant preservation of good habitat for these species. This was a leading reason, among others, for establishment of National, State, and local forests which would be free from unregulated timber operations. Much of the land so dedicated had been cut or burned several times before it was abandoned to poor agriculture and later dedicated to growing trees again. These lands were of a broken and diverse cover at the outset. Following protection and reintroduction, forest game species started to increase in number, thus lending support to the contention that forest protection was the major tool in forest game management.

As time passed and the forests developed into pole-stage stands with rapidly closing canopies, game populations and food supply became unbalanced. In general, it became evident that large, mature forest tracts were not the utopia for forest game as was once generally believed. It was soon realized that optimum forest game habitat existed at a point somewhere in the middle of the sere between bare land and climax forest. This realization, and related factors observed among farm game, led to the concept of wildlife habitat management.

Apparently forest game populations are, and probably were before the 1600's in North America, most numerous under conditions which provide at least in part some open canopy, some thick brush, some

grassy open areas, in short, some diversity of vegetative types. In nature this condition is most frequently caused by accidental natural events. The term "disruptive ecology" is applied by some to this condition. Following elimination of forest game habitat (logging, related fires, etc.), man had to turn full cycle to the return of mature stands before the significance of partial disruption or diversity was realized. Having learned this lesson, game managers made an effort to create situations in which forest game could not only survive but provide a surplus for recreational harvest. Agricultural clearings were, and still are, in many areas a major tool used to create the diversity needed.

Just because a tool will do the job in some situations is not sufficient basis for its selection in all cases. The correct selection of the tools may involve all of Wilm's (1952) steps of logic, exploration, experience, and experiment. This study provides the basis for deciding to what extent wildlife management as a profession has utilized these steps in choosing the agricultural clearing as a major tool, and to what extent it has tended "to dive into the physical part of the work without adequate advance planning" (Longwood 1962).

The Need for Knowledge

Present knowledge of the food and cover requirements of forest game indicates that some diversity in vegetative cover is necessary to sustain huntable populations. The basic observations of Leopold (1930, 1933) and Stoddard (1936) regarding needs for openings in the forest are logical and their validity has been fully demonstrated. The description of the prime turkey range in Virginia by Mosby and Handley (1943) included observations of an apparent relationship between turkey abundance and forest openings at that time; but they avoided specific recommendations of how much and where, leaving this to the discretion of the area manager. However, it is the lack of a means for determining these answers, for various locations, which is the basic underlying problem today. These are not new questions. Gabrielson (1936) was quick to ask them; Hosley (1942) asked for research 10 years after the need for diversity was first advocated; Graham (1947), during the big push for habitat management following World War II, stated that creation of openings solely for deer could not be justified; and more recently Bailey et al. (1951), McGinnes (1962), Krefting (1962), and the Northeastern Forest Wildlife Research Committee (1964) have voiced general and specific needs for research to determine how much, what kind, and where.

The persistent call for a factual basis for the use of clearings and repeated expression of reservations from active workers in the field are in themselves strong indicators of an untenable situation. On the other hand, the use of clearings has been widespread and intensive in many areas. The magnitude of the practice amounts to an irresistible force which few agencies and fewer individuals publicly discuss. The public has been almost universally pleased with the appearance of clearings, administrators and managers use them as highlights on show-me trips,

and there has been generated an inherent feeling of goodness and justification towards any activity which feeds wildlife. Despite this, careful inspection of the means of providing a disruptive ecology leads the writer to suggest that it is, in the main, impulsive disruption.

A Critical Appraisal

A broad look at the use of clearings among the eastern states fails to show any consistent pattern of practice which can be associated with an ecological fact base. In fact, the design of the pattern seems most closely associated with political exigencies. States sharing similar biotic communities differ radically in the use of agricultural clearings, leading to the suspicion that the governing factor is not biological. This suspicion is further encouraged by the fact that U. S. Forest Service, although consistent in its policy within one Region (which includes states holding differing views), has differing policies between Regions; and Regional boundaries are mainly political in nature. The only significant trend discernible from a broad inspection is that which includes time as a factor. In the main, those states which have had the longest experience with agricultural clearings are showing a tendency to quietly withdraw or deemphasize the program.

The very nature of agricultural clearings is dominated by commercial agricultural techniques. The physical characteristics of a new clearing are those of an improved pasture for domestic stock. In some cases this condition is carefully maintained each year, whereas in others a period of senescence is reluctantly permitted before intensive renewal is imposed. That such clearings are supposed to supply an essential "natural" requirement in the environment of forest cannot be accepted by "naturalists." This is not objective criticism, however. What is more to the point is the observation that expensive techniques, such as seeding, plowing, liming, fertilization, and mowing, should at least be demonstrably superior to or more practical than less expensive measures. Here again, practices which logically should be comparable differ widely. Some states simply create an opening and conduct only enough maintenance to insure that it remains fairly open and somewhat more attractive to wildlife than the adjacent forest. Many states maintain their clearings through an intensive program resembling farming. On the other hand, they neglect periodic soil tests and make no serious effort to match soil amendments to soil conditions. Selection of crops favors those which are high in vegetative production and low in maintenance requirements rather than those which will supplement a demonstratedly deficient diet.

Many biologists discussed at length with the writer the most desirable shape and size for a clearing. Few topics called forth as detailed discussion as did these. It was a distinct disappointment to discover in practice that these considerations were largely theoretical and that the shape and size of the available site were the final deciding factors. The same can be said, in general, about dispersion of clearings on a management unit. If the funds were on hand, every accessible and available site was usually developed. Using a very conservative estimate ($100/acre for

cost of installation; 1/4 mile of access road per clearing at $100/mile), these agricultural clearings have a minimum replacement value of at least $3.7 million. Conservative estimates for annual maintenance ($25/acre for an average of 5 years per clearing) indicate that nearly $4 million has been invested in maintaining clearings.

Although provision of food and "edge effect" were the prime reasons offered as the major roles of agricultural clearings, no state had conducted reliable studies of actual food production on agricultural clearings; and no edge effect studies applicable to a program of clearings had been made. Evaluations of clearings by key personnel were varied in emphasis and several indicated that the programs were valued more for their expedient nature than for their contribution to the ecology of the game habitat.

Open Questions

Our deficiencies of knowledge can be illustrated, in part, by a sampling of questions raised and left unanswered during the course of the study:

1. What are the effects of brushpiling around the edge of clearings on animal use?

2. What form of seedbed preparation, if any, is optimum under a given set of circumstances?

3. Should topsoil be turned under or not on sites where soil is shallow and dry?

4. Are silvicides a suitable tool in opening up new sites for agricultural clearings?

5. How does one determine which is the best vegetative composition for a clearing?

6. What are the guidelines for use of soil amendments?

7. Should a maintenance program include annual renewal, renewal every few years, or simply mowing the brush and adding cheap fertilizer as needed?

8. What is the optimum size and shape of a clearing for a given game species?

9. What pattern of distribution or density of clearings is optimal?

10. Do game animals use the center of clearings regardless of size and shape?

11. How can one decide whether agricultural clearings are desirable or not?

These are not important questions in every case, in light of the total problem, but they illustrate the dilemma which wildlife managers still face, despite a long history of the use of agricultural clearings. Perhaps the last listed question demands priority over all others.

CONCLUSIONS AND RECOMMENDATIONS

The general goal of this study, in addition to a critical review of the state of knowledge regarding agricultural clearings, was to create some order out of the confusion which has characterized this practice. To achieve this goal, it is necessary to offer some evaluations based on the critical review. The formation of these evaluations avoids the temptation to judge specific clearing practices found under field conditions in favor of a more meaningful evaluation of the bases of the practice.

At the outset of the study it was evident that professional wildlife managers had developed an array of conclusions about clearings. These conclusions have directly influenced the course of the use of agricultural clearings. To say the least, the practice has been characterized by heterogeneity; and it is evident that this has occurred because of a basic divergence of conclusions among the wildlife managers themselves. The degree of divergence can be partly attributed to a lack of communication among workers responsible for making land management decisions. Professional conferences have traditionally based technical sessions on animal topics, and the managers whose duties are concerned mainly with manipulation of vegetation for several species have not always found a readily available podium to present their problems for review.

This study evaluates the host of conclusions arrived at by managers and, in the light of existing knowledge, appraises these conclusions as: (1) Valid; (2) Invalid; and (3) Tentative or meaningless, pending more information. The last category (conclusions drawn in areas of insufficient information) gives rise to research needs. Identification of these research needs and assignment of priorities for research constitute the recommendations offered by this study.

EVALUATION OF CONCLUSIONS DRAWN BY GAME MANAGERS

Although not all managers may subscribe to any one of them, nor any single manager accept all of them, the critical review suggests that these general conclusions prevail among wildlife managers:

1. Forest game abundance is largely correlated with diversity of vegetative cover
2. Vegetative diversity should include openings in the canopy
3. Openings should be created where lacking
4. Agricultural treatment of openings will supplement the food base for forest game
5. Supplemental agricultural food plantings are essential for forest game species.

The following more specific conclusions also prevail:

1. If openings are to be created, it is only logical to complete the effort by planting a desirable agricultural crop

2. Standard agronomic practices or local farming experience provide the best guidelines for treatment of agricultural clearings

3. Size and shape of clearings are important considerations influencing animal use, food production, and general management

4. Location of clearings on proper soil sites is an important factor in new field installations

5. Percent of a management unit devoted to clearings and pattern of distribution of clearings are important factors affecting animal use and general management

6. Agricultural clearings as such provide supplemental food and necessary "edge" for forest wildlife species

7. Public relations are aided by the use of agricultural clearings

8. The observations that game species are seen on agricultural clearings and eat the planted crops are sound evidence in support of this practice.

9. Human use and distribution over a managed area are influenced by clearings

10. Economic studies of game management are not practical or necessary.

Evaluation of General Conclusions

Because the game species considered in this study evolved under conditions of vegetative diversity, the first general conclusion, that diversity is needed for optimum game production, is valid. Fire, disease, and other natural agents of forest destruction, along with man, have long created openings in the forest. It is reasonable to conclude, therefore, that diversity has a necessary role in managing forest wildlife habitat; and it suggests that where diversity does not exist it should be deliberately created by game managers.

The conclusion that agricultural clearings supplement the food base of forest game is valid only with respect to the addition of plant species which otherwise would not be found on the natural range. It is true that to some degree they change the food base, but in general usage among

managers the term supplement implies beneficial change or addition. Insofar as this conclusion makes this implication, it falls in the area where meaningful conclusions cannot be drawn. To evaluate reasonably the supplemental role of agricultural clearings in terms of the food base, it is necessary that a food resource base line be established for any given management area. Although it is fairly easy to make an estimate of the quantity and to some extent the quality (in terms of value to game species) of food to be produced by a given acreage of agricultural clearings, this is of no value unless accompanied by base line information on what is already available. The writer has been unable to discover any instance where such information has been prepared in conjunction with use of agricultural clearings.

In addition, it must be made clear that base line information on the existing food resources has no value unless reliable estimates of the kinds and numbers of animals to be served are also available. Davis (1963) reports that present-day methods for estimating animal numbers can detect only large changes of populations and that detection of much less than 25 to 50 percent of a population is unlikely. From a practical viewpoint, Taber (1961) says of black-tailed deer: "Another impediment to efficient herd control is the fact that populations of deer cannot be counted accurately and easily. The trial-and-error method of balancing herds to their habitats looks to some citizens like incompetent thinking. Game biologists are often distrusted." Unless these deficiencies are corrected, many of the generally accepted conclusions regarding the use of agricultural clearings in forest game management will continue to be valueless as management guidelines.

The foregoing provides sufficient evidence that it is invalid to conclude that supplemental food plantings are essential for forest game species.

Evaluation of the Specific Conclusions

To a large degree, the specific conclusions just outlined have evolved concurrent with the use of clearings and following the acceptance of most or all of the general conclusions. Insofar as some of these stem from general conclusions found invalid or without substance, it may seem to belabor the point to evaluate them further. However, the writer has been party to earnest discussions among managers on all of these points and believes that a retrospective evaluation of each will add pertinent thoughts or perspective to the total problem.

Planting crops.--Apparently, many agencies and managers have decided that once the effort to create an opening in the forest has been made, it is logical to plant the area to a desirable crop which will supplement the food supply and maintain the open character of the clearing in opposition to natural succession. Sometimes this has been done with the explanation that once all the funds for gaining access and creating the opening have been invested it costs little more to plant it. The problem here is that, though the initial planting is inexpensive in comparison to the outlay which preceded it, the maintenance required over the years ahead may exceed

all other costs if the plan is to retain the botanical composition of the planting. The value of planting the opening depends on the expected cost of maintenance and on the purpose of the planting. Presently, planting to supplement the food supply cannot be justified one way or the other, but planting or treating an opening to insure its open character with as little cost as possible is in keeping with the valid objective of supplying openings in the forest.

Treatment guidelines.--Many wildlife managers have received their training within the agricultural complex of a public university and are rightfully impressed with advances in agronomy with regard to improved forage crop production. As a result they have often turned to agronomists for information on treatment of clearings or have transferred a practice from a successful local farmer to their forage clearings. Even assuming that supplemental food planting is a valid practice, the standard agronomic approach to species selection and soil amendments is not valid unless the manager can give the agronomist an accurate estimate of the grazing pressure the area will receive. In addition the agronomist needs accurate information on what other food supplies are available to the animals which will use the clearing. These factors are necessary in deciding which species and related soil treatments to recommend. Wildlife managers have frequently been surprised to find agronomic recommendations are expensive, and the writer suggests that this is often true because agronomists work with cash crops and little experience has been accumulated on such transient feeders as deer and turkeys. Until the manager can provide the necessary estimate of animal users (grazing pressure) and an inventory of other foodstuffs, there is no basis for evaluating agronomic recommendations for agricultural clearings.

Size and shape of clearings.--The question of optimum size and shape of clearings is one which requires more information than is presently available. Lewis' (1964) study in Tennessee, which showed that turkey use was higher in clearings 10 to 20 acres in size, is the only experimental evidence that clearing size may influence animal use. His findings are yet to be tested elsewhere and on other species, such as deer. Close examination of the experience of the various states fails to indicate any trend in size or shape of clearings which can be associated with any clear benefit to game or harvest. Such factors as available funds and personal preferences of managers frequently influence size and shape as much as anything else. Many managers find that rectangular clearings are easier to cultivate by machine and that several 1- to 3-acre clearings can be more efficiently treated than can the same acreage broken up into $\frac{1}{4}$-acre openings. Outside of this latter consideration, the value of which is dependent on future evidence that cultivated crops are desirable, meaningful conclusions cannot be presently made about shape and size of clearings. There is evidence, through Lewis' (1964) study, that the means exist for obtaining the information.

Soil-site factors.--Regardless of the ultimate decisions about what vegetation should be encouraged on clearings, soil condition will always be a valid consideration. There is little evidence, except in early attempts to establish clearings on purely geometric grids or exact linear distances, that managers deny the importance of soils on the clearing site. On the other hand, in the two states where detailed soil information was available on large forested tracts (Cumberland and Monongahela National Forests), only one was making use of it with regard to clearing installation. Few managers made regular use of soil tests. The conclusion that soil condition deserves consideration is unquestioned, but detailed maps are lacking and managers regularly fail to make use of even the little information and routine tests which are available.

Percent of area and patterns.--Conclusions on percent of a management unit to be devoted to clearings and pattern of clearings have been drawn since the use of clearings began (Jackson et al. 1935), but the question remains uppermost in the minds of most managers and administrators today. Despite the persistence of the question, the evidence is that there is still no reasonable basis upon which to draw meaningful conclusions. The concept of different patterns and densities of clearings within a forested area implies measurable effects on game or game harvest. As has been discussed previously, the means to detect adequately the changes in animal numbers have not been developed. Adequate information on animal behavior for the forest game species considered here is not available. Experience among the states fails to indicate any trends attributable to improved management or harvest. Until adequate means of estimating animal numbers are developed, and until more attention is paid to game ethology, reasonable bases for drawing conclusions on density and distribution of clearings will continue to be lacking.

Role of clearings.--The fact that over 30 years of experience with installation of agricultural clearings has produced such a variety of concepts concerning application is additional evidence that there is probably not a commonly agreed upon role for clearings. It may even indicate that there is not universal agreement on the goal of game management itself. In addition, the assumption that animal production is an index to the success of game management underlies much of the discussion in this study, but it too is subject to critical examination.

Edge effect.--"Edge" is, in a sense, the boundary of the elements which determine diversity; and it may be the most important component of diversity as far as forest game is concerned. As such, edge is combined with the valid need for diversity and is an important consideration in creation of clearings. Unanswered still, however, are the questions of how much, where, and what kind of edge is necessary. Answers to these details depend on determination of animal needs, and this in turn depends on better information on animal behavior and range food inventory. In short, "edge," a basic component of diversity, is needed, but the quantitative and qualitative aspects of this need remain open to question.

Public response.--There is abundant evidence that the public is enthusiastic about agricultural clearings. Such approval is not surprising, for the conservation-minded layman is easily impressed by a conservation effort as obvious as artificial feeding, and particularly so if the effort may be readily observed. Indeed, because most managers are under constant public pressure, public approval is an important, although not an objective, criterion for evaluating a practice. It may often be necessary, in fact, to conduct certain practices which appeal to the public if only to perpetuate other, more valuable aspects of the game management program. But the scientist and the manager cannot, or at least should not, permit the subjectivity of mere approval to dominate objective decisions and their proper criteria for making decisions. Both must maintain a clear professional differentiation between public relations efforts and the biological aspects of habitat management.

Observational evidence.--The evidence of concentrated tracks, droppings, animal observations, and animal removal of planted crops on clearings can be highly persuasive evidence that there is a need for agricultural clearings. It is extremely satisfying to a manager to find his efforts so well received by the game and the public. Unfortunately, this reaction is misleading because the expression of need and preference is not synonymous. Opponents of agricultural clearings ask whether they represent "ice cream or meat" in the dietary needs of game, and proponents challenge them to show that game make as much use of alternative practices. This argument has more life to it because definitive, or even practical, answers are not forthcoming until we are able to assess the effects of clearings, and their alternatives, on game and harvest. It must be remembered that game managers are not in the business to produce tracks, droppings, or bales of vegetation. This is another important area where meaningful conclusions cannot be made until improved methods of animal estimation are developed and more is known of forest game behavior.

Influence on human use.--Human use and distribution over a tract of land has always been influenced by access and access ways. Insofar as a system of clearings provides access, it has a profound influence on human use of an area. The attractiveness of clearings will have some effects on some hunters and other users of management areas. Special demands, such as those made by bow hunters, may be directly and positively served by openings. To this extent, agricultural clearings play a valid role in the hunter-management program. Access is possible, however, without clearings simply through construction of roads and trails. And, clearings need not be planted to agricultural crops to permit unimpeded flight of an arrow. The ultimate question to be answered is, to what extent do agricultural clearings and their alternatives increase man-animal contacts? Close inspection of the experience of the states uncovers no objective information on which to base an answer, and more information on not only animal but also hunter behavior is still required.

Economic study needs.--Few economists are found among wildlife managers, and input and output evaluation of game management practices has not been customary. However, this is not sufficient justification to deny the values of this area of inquiry and its applicability to wildlife management. Management practices are becoming more expensive, and the area of land available for management is on the decline. Costs per unit of area are sharply rising, and the writer suggests that if pressures to inspect the economics of management do not soon originate from within the management group they are sure to arise from the outside. Already competitors for land areas are effectively using economics as a persuasive tool to compete with wildlife resource interests. Although wildlife represents a resource which does not lend itself easily to classical economics studies, the possibilities have not been exhausted. It is not valid to conclude that such studies are impractical or unnecessary.

It should be recognized, however, that at the current state of knowledge it is not pertinent to propose such studies at the level of direct management. The pertinent level for economic inquiry is presently more basic than simple cost accounting related to isolated habitat manipulation techniques. Even assuming that animal production is an index to the success of wildlife management, the definition of the actual commodity produced is still largely unresolved. Are animals bagged by hunters always the end product, or are animals seen by unsuccessful hunters also legitimate products? Is an animal photographed by a naturalist a product as well as one taken as a trophy? Does economic success of management always rest on increased numbers of animals, or can increased man-animal contacts with no increase in animals constitute a desirable product of management?

Following definition of the product of game management is the task of identifying the pertinent inputs of the production process and determining how they act as independent and related variables. These inputs comprise not only biological factors but include such socio-economic factors which express themselves through changes in broad land use and demand for public recreation. And finally, there is the unresolved question of the economic value of the game management product.

Improved information in these three areas is a prerequisite to attacking the economics of management decisions which are related to: Reduction of cost per unit produced; choice of management practices to achieve the desired level of output; desired intensity of management to achieve the greatest private or general social return from game management.

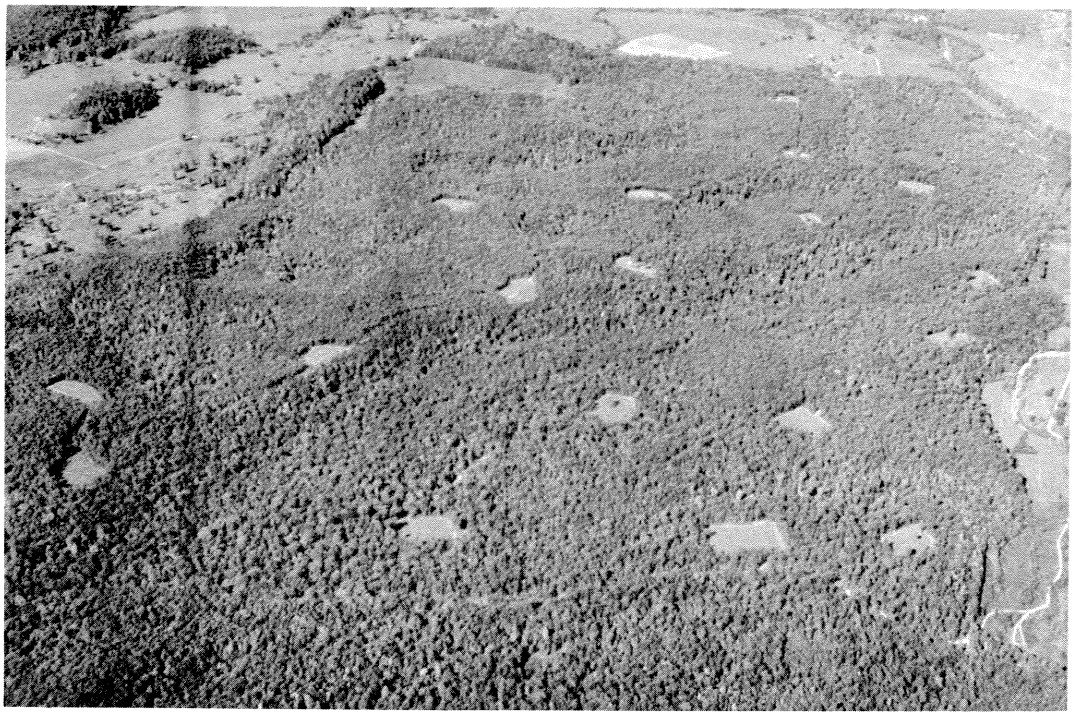


Photo courtesy of Virginia Commission of Game and Inland Fisheries

A series of clearings on a forest in Virginia.

Photo courtesy of Virginia Commission of Game and Inland Fisheries

A completed clearing in Virginia.

CONCLUSIONS IN SUMMARY

In summary, it has been possible through a broad critical review to evaluate the array of conclusions which have directly influenced the use of agricultural clearings in forest game management. The evidence indicates that the following are valid conclusions:

1. Diversity of vegetative cover is correlated with forest game abundance

2. Openings are a necessary component of forest-wildlife habitat

3. Where openings do not exist, they should be created

4. Based on the current state of knowledge, agricultural clearings supplement the food base of forest game only through introduction of additional plant species

5. Planting or encouraging growth which will tend to maintain the open character of a clearing is a valid effort as long as least expense guides the selection of the technique

6. Soil condition on prospective clearing sites is an important consideration frequently given only lip service in practice

7. Edge as a basic component of diversity is a needed factor contributed by clearings

8. Agricultural clearings have value as a public relations tool, but with decided reservations

9. Human use of an area is directly influenced by the access pattern afforded by an existing system of clearings but, except for special requirements such as bow hunting, the clearings themselves contribute little to the actual use.

The following conclusions appear at this time to be invalid:

1. Supplemental food plantings are essential for forest game species

2. Economic studies of game management are not necessary.

The following are features of agricultural clearings for which meaningful conclusions cannot be drawn because information is lacking:

1. The qualitative and quantitative means by which agricultural clearings may supplement the food base

2. The role agricultural clearings play in game production

3. The value of planting clearings to crops which involve expensive maintenance

4. The applicability of standard agronomic recommendations as guidelines in clearing management

5. Optimum size and shape of clearings

6. Optimum percent of a management unit to devote to clearings and pattern of distribution of clearings

7. Determination of how much, where, and what kind of "edge" should be contributed by clearings

8. The degree to which animal use of agricultural clearings is an expression of need or preference

9. The extent to which agricultural clearings increase man-animal contacts.

RESEARCH NEEDS

The fact that significant decision-making areas concerning agricultural clearings in forest game management lie within the realm of inadequate information is a substantial demonstration of the need for research. These research needs, designed to meet specific problem areas regarding use of clearings, constitute the recommendations of this study. In addition, some of the findings of the study have implications for current game management programs. These are discussed in the Appendix.

Information is inadequate in four basic problem areas:

1. The need for base line information on existing range food resources (quantitative and qualitative) is pertinent to understanding: the possible supplemental food role clearings may play; the need for maintenance of expensive crops; the value of agronomic recommendations; the optimum size, shape, density, and distribution of clearings; and the need for added edge.

2. The need for reliable estimates of animal numbers is pertinent to all but the last of the areas listed in "1" and is also needed to better understand the role agricultural clearings play in game production, and the degree to which signs of animal use are indicators of preference or need.

3. The need for better animal behavior information is essential to understanding optimum size, shape, percent of area devoted to clearings, and distribution of clearings; what needs there may be for added edge; the degree to which animal use of clearings expresses need or preference; and to what extent agricultural clearings increase man-animal contacts.

4. Studies of hunter behavior are also needed to assess the role clearings play in man-animal contacts.

It is obvious that results from this research would not only provide needed information for evaluating agricultural clearings, but would at the same time provide the means for examining alternative management techniques. Up to this point, none but passing mention has been made of alternatives to the use of agricultural clearings, because they cannot be profitably evaluated either. To do so requires the same supporting research as is required to evaluate agricultural clearings.

Food Resource Information

The need for qualitative and quantitative base line information for food resources is a problem in wild animal nutrition. This study clearly establishes the link between provision of supplemental forage and agricultural clearings. Alternative management techniques may also include supplementing the food base. This is a problem area because information on animal needs and on the ability of native and domestic plants to meet these needs is very incomplete. Such information would provide the opportunity to manipulate the food base knowledgeably as a major game management tool.

Progress toward improved knowledge of game animal nutrition is being made, as illustrated by the nutrition papers in the Proceedings of the First National White-Tailed Deer Disease Symposium (1962). In addition, a great deal of data has been collected through food preference observations and stomach analyses. For example, Martin et al. (1951) have compiled such data and have assigned wildlife value ratings for many plant species. However, the decision to use an intensive habitat management tool such as agricultural clearings, with their associated crops and soil amendments, calls for nutritional data of a much more sophisticated nature than that now available. To make proper decisions about which crops, if any, should be grown and to what degree soil amendments should be added, will require information similar to that available to pasture farmers. The nutritional capacity of the range to support a given species or combination of species must be estimated before reasonable decisions can be made on what kind of, and to what extent, nutritional

supplements are needed. Dietz (1965), for example, has recently discussed the problems of shrinking range and the need to relate nutrition research to deer-range management in the Western United States. Current information on game animal nutritional requirements is sparse, and each species has not been studied equally. Current means of estimating the animal carrying capacity of forested areas emphasize quantity and almost omit consideration of quality and availability of nutrients to the consumer.

From the viewpoint of animal requirements, the following are aspects in which significant contributions could be made:

1. Establishment and maintenance, through controlled breeding, of stocks of game as sources of experimental animals for pen nutrition studies

2. A critical review of the state of knowledge in this area aimed at delineating the significant gaps in information and suggesting means of improved coordination and contact among investigators in this relatively new field

3. Extension of pen nutrition studies to include additional game species plus the major subspecies of those animals now under study

4. Trials contrasting nutrient value of domestic plants to game animals as opposed to their established value to domestic animals (upon which we base current assumptions).

Regarding the problem of determining nutritional quality of a given range, the following study areas are worthy of consideration:

1. Studies of nutrient content and nutrient availability of native plants high on existing preference lists:

   a. Through the life of the plants or that fraction thereof during which they are available as game food

   b. In major ecological segments of the plant range

   c. Through annual seasonal changes within the plants.

2. Refinement of techniques used to measure carrying capacity by including consideration of nutrient availability as well as quantity.

An ultimate use of nutritional data will be the establishment of guidelines for conscious manipulations of the food base. Such control will consider such factors as:

1. Species composition

2. Age classes of food plants

3. Forage supplements

4. Soil amendments

5. Consequences of conscious and accidental disruption of the vegetative complex.

Population Estimates and Animal Behavior

In practice, animal behavior and estimation of animal numbers are interrelated. Behavior studies similar to that of Darling (1964) should be conducted in conjunction with studies on improved methods for estimating animal populations. Sampling designs suggested by the latter would be affected by the quality of behavioral information available. Davis (1963) points out several specific needs in this area:

1. The need to check current population estimating techniques against known numbers of animals

2. The need for additional basic methods

3. The need to express animal density in terms of the limiting factor rather than animal-per-acre.

New research tools, such as infrared photography, telemetry, isotope tracers, and automatic recording devices, should be fully tested and evaluated. Research of this nature is not suited to state game management agencies because by their very nature they are primarily concerned with short-term problems. University research centers or research institutes cooperatively financed by several state agencies may offer the best sponsorship.

Improved information on both nutritional requirements of animals and their behavior should open the way to significant studies of the effect of the interaction of these broad factors, and should give greater insight into relationships between free-living wild animals and their habitat.

Man-Animal Contacts

Availability of game depends upon the frequency of man-animal encounters. Habitat management can be regarded as having a potential for either bringing man to the game or the game to man. Clearings may have a baiting effect on game; and it is almost self-evident that roadways, trails, and clearings affect hunter distribution. If these are important factors,

present techniques can be used to measure relative attractiveness rather easily. Such studies could measure and compare the attractiveness of areas under differing management to man and to game animals. Direct observation or mechanical recording techniques could be employed in appropriate sampling designs to contrast attractiveness of clearings and alternative management techniques under differing:

1. Cultural practices
   a. Crops
   b. Soil amendments
   c. Mechanical treatment of crops and soils
2. Weather conditions
3. Game seasons
4. Degree of accessibility
5. Location and dispersion of managed areas
6. Time durations of hunting.

Frequently, game managers have expressed the opinion that hunter distribution is important. This is an area open to fairly easy, short-duration studies. The public is now accustomed to cooperating with field research efforts, and it should not be difficult to establish experimental areas where users would record their preferences (an index to attractiveness) between management areas. They might record and hand in accounts of their activities among the areas under contrast. Museums have sampled visitor preference and interest among exhibits through use of automatic voting machines borrowed from local officials. Adaptations of these techniques could sample user preference and differential use of management units. Certainly, techniques used in recreation research could be adapted to this use.

An ultimate goal is to study possible relationships between user activity and game distribution, as influenced by management techniques, when much improved measures of animal numbers and movements are available.

Additional Needs

In addition to the research recommendations, there are two aspects where effective contributions could be made. Soil mapping of forest land with the same intensity as that applied to agricultural land has potential value for forest-wildlife management programs which should be fully explored. Pilot areas on a few National Forests have been mapped and provide an opportunity for studies to determine how this new information may be applied in wildlife habitat management.

Steps should be taken to provide increased opportunities for habitat managers from the various states to meet frequently and to discuss and evaluate progress and problems. Many of the diverse opinions and practices concerning use of agricultural clearings appear to have evolved in the absence of opportunity to share ideas and problems among the states and federal agencies. Because established regional meetings usually have full programs oriented toward animal management, perhaps the various colleges and university departments of wildlife instruction could act as host for annual regional meetings of habitat managers and develop a series of summer short courses similar to those offered to workers in agricultural fields. Such meetings could improve communications and promote frequent evaluation of habitat management practices.

A cursory review of these conclusions and recommendations indicates that no strikingly new suggestions have been presented. Many of these ideas were discussed at the outset of this study; and it has been shown that the major needs for research, especially improved techniques for estimating animal numbers, have been pointed out as major research needs by others.

During the initiation of this study, the writer was presented with a host of suggestions and possible directions to follow in establishing a better understanding of the use of agricultural clearings in forest game management. With few exceptions these were varied concepts originating with persons well trained in the wildlife management field or with persons who had many years of practical management experience, or both. To these were added concepts from persons in more than 20 states. Some had been published, many were found in unpublished files, and a significant number were suggested by persons who had considerable personal experience with agricultural clearings and had taken time to think about various problems they had encountered.

At the outset, any set of conclusions could be well advanced and all had equal weight--as far as the writer could determine. At the same time, few professional people felt able to make recommendations which would have broad application wherever agricultural clearings were used. Drawing on the strength of the first critical review of the clearing practice, this study has evaluated the array of independent conclusions and offers a series of documented and coordinated conclusions applicable to the use of clearings regardless of location. It has documented the need for behavior, nutrition, and population estimation research for this specific problem area, and has shown through a series of recommendations the pertinence of each with respect to answering current management needs. In a broad sense, this study fills a gap in knowledge by selecting the appropriate set of research needs from a broad repository of recognized needs for knowledge and identifies them with, and applies them to, a critical management problem area.

APPENDIX

Guides for Interim Management Procedures Pending Improved Knowledge

The hypothetical game manager who is given 10,000 acres of eastern forest land to manage for maximum production and availability of game must make many decisions in designing his management plan. He must weigh many management techniques currently in vogue in the light of the ecological condition of his area and the ability of various techniques to meet the problems which impede local production and availability of wildlife. Ideally, he should make initial inventories of animal and plant populations, determine limiting factors, and plan for management accordingly. In reality, he will most likely be given the management area and one year's inadequate budget and told to make the best of it and to show definite improvement in 12 months. It is within this context of practicality that management guidelines must be offered. The average manager or state game agency cannot wait for sophisticated research, but must provide a service today and modify decisions in the light of more knowledge later. It is to minimize the inevitable unhappy consequences of this condition that the following guidelines for management are rather closely restricted in scope.

Agricultural clearings, and the related system of roads and access ways necessary for their construction, make a positive contribution toward game management in two well-founded ways:

A. As a means of providing access in areas not already open
   1. Management access
   2. User access
   3. Protection access
      a. Law enforcement
      b. Fire protection
   4. Access for multiple use
      a. Forest management
      b. Nongame-related recreation

B. As a means of adding diversity to the vegetative habitat
   1. Openings in the forest for roads and access ways
   2. Openings and changes for multiple use
      a. Timber removal and stand improvement
      b. Trails and campsites
   3. Actual creation and management of the agricultural clearings themselves.

Pending further research on supplemental food values, influence on animal numbers and distribution, and improved means of estimating numbers of animals, attempts to provide guidelines outside of the topics of access and increased vegetative diversity lack sufficient foundation. Likewise, programs which are based on assumptions beyond the factors of access and simple manipulation of vegetative diversity can be challenged.

If the hypothetical management area is essentially roadless, the question of access is one which may have no relation to agricultural clearings. On the other hand, if the area is deemed lacking in diversity to the extent that herbaceous openings are needed in number, roads may be required first. Under most circumstances, long-range multiple-use management plans will absorb most of the cost of roads and road maintenance in a variety of desirable activities, and thus the portion of these costs to wildlife will be proportionally small. The fact still remains that there have been areas where wildlife funds, as such, have paid for all initial costs of roads plus clearings; and multiple use followed in later years. At any rate, the opportunity is available to use multiple justification for road building and maintenance.

The creation of a road system alone meets all of the access requirements of "A," plus the diversity in habitat under "B-1." With the addition of multiple-use activity, all access and all aspects of vegetative diversity are met except the diversity created by clearings themselves. Because all costs of creating and maintaining agricultural clearings themselves, plus any spur roads added to the road system, must be wholly borne by wildlife interests, this is the crucial point of decision for the manager. The decision at this point must currently be based on the necessity for added diversity, or for adding an essential element necessary for successful game management of the area.

Two special elements other than increased diversity warrant consideration. Management units designed to serve primarily as suppliers of game for live-trapping and restocking in other areas may be the backbone of a wildlife restoration program of a state. As such their cost should be prorated over an indefinite period of time. The units themselves are usually phased out of this activity when the game restocking program is completed. Use of agricultural clearings to supplement the basic food supply and to attract animals to suitable baited trapping locations is probably justified in such cases, assuming that they have a definite life span as a special purpose area. The other element to consider is the demand for suitable areas for bow hunting. This specialized sport requires opportunities to harvest game on open areas free of interference to the arrow. In every state which permitted bow hunting, and on the Patterson Creek Study Area in Virginia, the writer was impressed by the dependence bow hunters had for sod clearings on which to hunt. How far any management plan can justify catering to this group of hunters is impossible to judge except under local conditions.

Aside from these special considerations, the writer believes that few cases will justify creation of new agricultural clearings for added diversity alone; given forest management as a related activity on the area, diversity itself can be created over larger areas at less expense in other ways. Exceptions are possible and the extensive plantings of conifers in areas such as occur on the Piedmont in South Carolina may be one example. Such a manmade or man-maintained environment may so limit diversity that any opportunity to support a huntable population of turkeys, for example, without periodic breaks in a solid conifer canopy to allow vegetation to grow which will support an insect food supply is precluded. Such examples will be the exception and at the present state of knowledge the concept that more diversity means more game cannot be extended beyond the most general terms, as far as forest game is concerned.

The foregoing discussion pertains mostly to the manager facing a previously unmanaged tract of land. For the many circumstances where clearings are an established fact, the writer recommends the following approaches. These are based on recognition of the fact that existing clearings represent an investment to be respected and that in some areas practical public relations factors may be more influential than biological facts.

1. Present clearings should be maintained as openings insofar as practical and consistent with other land-use demands. These clearings represent substantial expenditures and, as areas of open land, offer better opportunities for future habitat manipulation than do forested sites.

2. Limit maintenance to as little periodic rotary mowing as is necessary to keep woody succession out--probably once every 2 or 3 years.

3. Limit soil amendments to a level of topdressing which will cause the clearings to become somewhat more attractive than an untreated site. This will vary from area to area, but probably should not be more often than once every 2 years. A minimum of fertilizer and lime should be applied. This recommendation should be eliminated if the mowing alone keeps the site more attractive than otherwise.

In summary, pending improved information, the game manager should exercise extreme caution regarding commitment to an expensive program of agricultural clearings. Too little is known about many of the assumptions which have evolved with the use of agricultural clearings to make further specific recommendations to the land manager.

REFERENCES

Bailey, R. W., Uhlig, H. G., Breiding, G., and Strunk, W. F.
1951. Wild turkey management in West Virginia. Conserv. Comm. W. Va. Bull. 2, 50 pp.

Darling, F. F.
1964. A herd of red deer. 226 pp. Garden City, N. Y.: Doubleday and Co.

Davis, D. E.
1963. Estimating the numbers of game populations. In Mosby, H. S., (ed.), Wildlife investigational techniques, 2nd ed. Wildlife Soc., Blacksburg, Va., pp. 89-118.

Dietz, D. R.
1965. Deer nutrition research in range management. N. Amer. Wildlife and Nat. Resources Conf. Trans. 30: 274-285.

Gabrielson, I. N.
1936. The correlation of forestry and wildlife management. J. Forest. 34(2): 98-103.

Graham, E. H.
1947. The land and wildlife. 232 pp. New York: Oxford Univ. Press.

Hosley, N. W.
1942. The effects of forest harvest on game production. J. Forest. 40(8): 639-641.

Jackson, H. H. T., Nelson, A. L., and Bailey, V.
1935. Considerations for the improvement of game resources on the Big Levels game refuge, Augusta County, Virginia. (Unpublished typewritten report.) U. S. Biol. Surv., Washington, D. C., 36 pp.

Krefting, L. W.
1962. Use of silvicultural techniques for improving deer habitat in the lake states. J. Forest. 60(1): 40-42.

Larson, J. S.
1966a. Wildlife forage clearings on forest lands--a critical appraisal and research needs. Ph.D. Diss., Va. Polytech. Inst., Blacksburg, 143 pp.

_____
1966b. Problems in measuring food production on forest wildlife clearings. 20th Annu. Conf. Southeast. Assoc. Game and Fish Commrs. Proc., Asheville, N. C., pp. 33-37.

Leopold, A.
1930. Environmental controls for game through modified silviculture. J. Forest. 28(3): 321-326.

_____
1933. Game management. 481 pp. New York: Scribners.

Lewis, J. C.
1964. Populations of wild turkeys in relation to fields. 18th Annu. Conf. Southeast. Assoc. Game and Fish Commrs. Proc., Clearwater, Fla., 15 pp.

Longwood, F. R.
1962. The selection, design and analysis of wildlife habitat studies. U. S. Forest Serv. Northeast. Forest Exp. Sta., 11 pp.

McGinnes, B. S.
1962. Habitat management considerations for white-tailed deer, pp. 3-6. In U. S. Forest Service. Background information for inter-regional timber-wildlife workshop, Regions 7, 8, 9 and Washington office. Blacksburg, Va. 27 pp.

Martin, A. C., Zim, H. S., and Nelson, A. L.
1951. American wildlife and plants. 500 pp. New York: McGraw-Hill Book Co., Inc.

Mosby, H. S., and Handley, C. O.
1943. The wild turkey in Virginia: its status, life history and management. Va. Comm. Game and Inland Fish., Richmond, Va., 281 pp.

Northeastern Forest Wildlife Research Committee
1964. Series of deer problem statements. Maine Dep. Inland Fish. and Game, Univ. Maine, Orono, Maine. n. p.

Proceedings of the First National White-Tailed Deer Disease Symposium
1962. Univ. Ga. Center for Continuing Educ., Athens, 202 pp.

Stoddard, H. L.
1936. Management of wild turkey. N. Amer. Wildlife Conf. Trans. 1: 352-356.

Taber, R. D.
1961. Ecology of the black-tailed deer. Terre et la Vie 108(2/3): 211-245.

Wilm, H. G.
1952. A pattern of scientific inquiry for applied research. J. Forest 50(2): 120-125.